

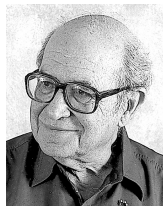
Review of Jacob Cohen's The Earth is Round ($p < .05$)

Will Quinlan

October 7, 2024

An Introduction to Cohen's Paper

- ▶ Scientific advancement has been hindered by null hypothesis testing (NHST)
- ▶ Researchers often misinterpret p-values resulting in mistakes in what can be concluded
- ▶ Critique the "ritualization" of NHST
- ▶ Focus on real-world relevance



- ▶ Argues for better scientific practices

On Null Hypothesis Significance Testing

- ▶ Definition: Method of statistical inference by which an experimental factor is tested against a hypothesis of no effect or no relationship based on a given observation
 - ▶ In other words: Null vs Alternate
- ▶ Decisions are determined by the significance threshold
- ▶ NHST dominates science
- ▶ If one presents a significant result of a known fact like "The Earth is round," nothing is gained

A Ritualization of Reasoning ($p < .05$)

- ▶ Cohen argues against the rigid reliance on p-values
- ▶ Standard p-value of .05
- ▶ Dichotomous reject-accept decision
- ▶ "The primary aim of a scientific experiment is not to precipitate decisions, but to make an appropriate adjustment in the degree to which one . . . believes the hypothesis . . . being tested" - Bill Rozeboom (1960)

Misinterpretation of p-values

- ▶ Consider a Scenario
 - ▶ A scientist believes a certain rare disease does not exist in a population
 - ▶ $H_0: P = 0$
 - ▶ He draws a random sample of 30 cases and finds that 1 person has the disease
 - ▶ $P_S = 1/30 = .033$
- ▶ How should H_0 be tested? Chi-square? How about a Fischer exact test? Is there enough power?
- ▶ Cohen among many other scientists believe that academia would complain unless this result had a p-value attached to it

So, what is wrong?

- ▶ We want NHST to tell us, "Given these data, what is the probability that H_0 is true?"
- ▶ What NHST actually tells us, "Given that H_0 is true, what is the probability of these (or more extreme) data?" before asking your question
- ▶ Academics have pointed out the failures of NHST for many years, even before Cohen's paper
 - ▶ NHST was described "a potent but sterile intellectual rake who leaves in his merry path a long train of ravished maidens but no viable scientific offspring" - Meehl in 1967
 - ▶ Joseph Berkson attacked NHST in 1938
 - ▶ Lancelot Hogben's book-length critique appeared in 1957

The Permanent Illusion

- ▶ Many believe the level of significance at which H_0 is rejected is the probability that it is correct
- ▶ Lets dive into why this thinking is wrong
- ▶ Syllogistic Reasoning according to Aristotle
 - ▶ If the null hypothesis is correct, then this datum (D) can not occur
 - ▶ D has, however, occurred
 - ▶ Therefore, the null hypothesis is false
- ▶ This is an example of a modus tollens syllogism, denying the antecedent by denying the consequent
 - ▶ If P, then Q
 - ▶ Not Q (Q is false)
 - ▶ Therefore, not P (P is false)

Probabilistic Syllogism

- ▶ NHST makes the modus tollens syllogism probabilistic as follows:
 - ▶ If the null hypothesis is correct, then these data are highly unlikely
 - ▶ These data have occurred
 - ▶ Therefore, the null hypothesis is highly unlikely
- ▶ This makes what was a valid modus tollens syllogism formally invalid
 - ▶ If P, then Q is likely
 - ▶ Not Q
 - ▶ Therefore, P is unlikely

Examples of Syllogisms

- ▶ Some Examples:
 - ▶ If a person is a Martian, then he is not a member of Congress
 - ▶ This person is a member of Congress
 - ▶ Therefore, he is not a Martian
- ▶ How about this one?
 - ▶ If a person is an American, then he is not a member of Congress
 - ▶ This person is a member of Congress
 - ▶ Therefore, he is not an American

Examples of Syllogisms cont.

- ▶ What about now?
 - ▶ If a person is an American, then he is probably not a member of Congress
 - ▶ This person is a member of Congress
 - ▶ Therefore, he is probably not an American
- ▶ Notice how these two syllogisms are formally the same
 - ▶ If H_0 is true, then this result (statistical significance) would probably not occur
 - ▶ This result has occurred
 - ▶ Therefore, H_0 is probably not true

$$P(D|H_0) \neq P(H_0|D)$$

- ▶ When testing H_0 , one is finding the probability data (D) could have arisen if H_0 were true, $P(D|H_0)$
- ▶ If this probability is small, one can conclude that H_0 is true and D is unlikely
- ▶ What about the reverse probability $P(H_0|D)$?
 - ▶ When rejecting H_0 , one wants to conclude H_0 is unlikely
 - ▶ This probability is only available through Bayes theorem where we need to know $P(H_0)$
 - ▶ Bayesian statisticians use a prior probability or distribution of probabilities to deal with this problem, but does it hold up?

A Look at Psychiatric Diagnoses

- ▶ Incidence of schizophrenia in adults is 2%
- ▶ A proposed screening test is estimated to have 95% accuracy ($P(\text{normality}|H_0) \approx 0.95$)
- ▶ The screening test is supposed to have 97% accuracy in declaring normality ($P(\text{schizophrenia}|H_1) > 0.97$)
- ▶ Thus, we have a test that is highly sensitive and highly specific
 - ▶ H_0 = The case is normal
 - ▶ H_1 = The case is schizophrenic
 - ▶ D = The test result (the data) is positive for schizophrenia

A Look at Psychiatric Diagnoses cont.

- ▶ $P(D|H_0) < .05$ seems like what we want, but it is not
- ▶ We want $P(H_0|D)$ which equals .60, not the .05 we may have believed

$$P(H_0|D) = \frac{P(H_0) \cdot P(\text{test wrong}|H_0)}{P(H_0) \cdot P(\text{test wrong}|H_0) + P(H_1) \cdot P(\text{test correct}|H_1)}$$

- ▶ Schizophrenic

| Result | Normal | Schiz | Total |
|------------------------|--------|-------|-------|
| Negative Test (Normal) | 949 | 1 | 950 |
| Positive Test (Schiz) | 30 | 20 | 50 |
| Total | 979 | 21 | 1,000 |

Replication

- ▶ The error previously demonstrated can also be applied to replication of tests
- ▶ If there was a successful rejection of H_0 many believe replications will also result in the rejection of H_0
- ▶ Many believe that a p of .99 means 99% of the time a result will replicate
- ▶ Typical level of power for medium effect sizes of .50
 - ▶ The chances are in three replications only one in eight would result in significant results

More Syllogisms

- ▶ We have just seen many failures in logic by researchers such as if H_0 is rejected, then the theory is established. Invalid syllogism and example below:
 - ▶ If it rains (A), then the ground will be wet (B).
 - ▶ The ground is wet (B).
 - ▶ Therefore, it rained (A).
- ▶ However, even if a valid modus tollens syllogism is used, misinterpretations are still made
 - ▶ When H_0 is rejected, it can be because of a variety of auxiliary theories, and not what precipitated the research
 - ▶ Although it is convenient, accept-reject decisions; although convenient, are not how science is done

The Nil Hypothesis

- ▶ Some propositions consider what is occurring within a population (i.e. the proportion of males in this population is .75)
- ▶ Cohen refers to the H_0 when the effect size = 0 as the nil hypothesis
- ▶ Effect size is effectively the practical significance of a test
- ▶ However, universally H_0 is taken to mean nil (zero), Ex:
 - ▶ H_0 is the proportion of males in a population is .50
 - ▶ H_0 is the raters reliability is 0
- ▶ These are cases when H_0 is almost universally rejected
- ▶ Tukey wrote, "It is foolish to ask 'Are the effects of A and B different?' They are always different—for some decimal place"

The Nil Hypothesis cont.

- ▶ Even if a test is statistically significant with $p < .000001$, there is ambient correlation noise among often arbitrarily paired variables
- ▶ Given the fact that the nil hypothesis is always false, the rate of Type I errors is 0%, not 5%, and that only Type II errors can be made, which run typically at about 50%
- ▶ The sample effect size necessary for significance is notably larger than the actual population effect size
- ▶ The use of a Bonferroni adjustment is then adjusting for non-existent alpha error which in turn overestimates the population effect size
- ▶ Again, typically little is learned from A is larger than B ($p < .01$)

Quantifying Effects

- ▶ Confidence intervals and effect sizes are necessary for scientific advancement.
- ▶ Scientists cannot only record pulling a rubberband makes it longer, how much longer is necessary
- ▶ Correlation Coefficients depend on the selection of the population, regression coefficients do not
- ▶ Correlations do not provide insight to causal strength, within group variation can change a correlations strength
- ▶ Cohen's d and f - like correlations, these values are impacted by the variability across the population
- ▶ The context of a regression matters greatly as seen in Cohen's height and IQ
 - ▶ Cohen had a statistically significant correlation between height and IQ
 - ▶ This translated to a regression coefficient that meant a 30 point iq increase required 14 feet of additional height

What to do?

- ▶ There is no magic test to replace NHST
- ▶ Cohen calls for a shift toward understanding and improving data rather than making mechanical accept-reject decisions
- ▶ More emphasis on confidence intervals and effect sizes
- ▶ Confidence intervals aren't frequently used because they expose large variability
- ▶ Move away from the point "nil hypothesis" to "good-enough" range null hypotheses which will make NHST and power more useful

Thank you all for listening!