Reporting and Defending Results

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Discussion Time

Do you think that all statistically significant predictors are scientifically relevant? Provide examples for your opinion.

Discuss as a group before we share as a class.

Reporting Results

The results of a data analysis is typically what most people are interested in. They usually read your title and/or abstract of your paper to get an idea of what the paper is about, then focus on the results to see how it applies to their research.

It is important to remember that you have been working on your analysis for months. The reader only has a small number of pages to become familiar with your project. What may seem obvious to you may not be clear to them.

For both reasons, clear and concise reporting of the results is imperative.

Common Statistical Misconceptions

In order to report your results accurately, you must understand the results of the model. There are some common misconceptions that should be addressed to ensure that your results are interpreted accurately.

Confidence Interval

Common Misconceptions: “There is a 95% chance that the confidence interval contains the true parameter value.”

Confidence Interval

In frequentist statistics, a population parameter has a fixed value, i.e. the parameter is not a random variable. Therefore, it either falls within the confidence interval or it does not.

The significance level of a confidence interval indicates how frequently we can expect a confidence interval to contain the true parameter value.

Confidence Interval

Actual Interpretation:

1. "We can expect the confidence interval to contain the true parameter value 95% of the time."
2. "If we calculated 100 confidence intervals from re-sampling the data, we would expect 95 of them to contain the true parameter value."

P-Values

Common Misconception:

1. "A p-value is the probability that the null hypothesis is correct."
2. "A p-value is the probability that the null hypothesis is correct given the data."

We can think of the common misconceptions as:

1. $P(\beta = \beta_0)$
2. $P(\beta = \beta_0 || x| > X)$

P-Values

A p-value is the probability that we obtain a test statistic more extreme than the observed one given that the null hypothesis is true, or:

$$P(|x| > X|\beta = \beta_0)$$

P-Values

Suppose the p-value is 0.1.

Actual Interpretation: "The probability of obtaining a test statistic more extreme than the observed given that the null hypothesis is true is 0.1."

My Advice: Treat a p-value as evidence, not an absolute truth.

Statistical vs. Clinical Significance

Common Misconception: "This variable is statistically significant. That must mean that it is meaningful."

Statistical vs. Clinical Significance

Just because something is statistically significant does not mean that it has clinical relevance. This could be due to unadjusted confounding or it could be due to a small estimated value or it could just be an artifact of the data.

Statistical vs. Clinical Significance

```
##
## Call:
## lm(formula = sys.bp ~ ht)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -6.096 -2.141  0.197  1.654  6.510
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 121.3515     3.1949   37.98   <2e-16 ***
## ht           -0.0188     0.0460   -0.41     0.68
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1
##
## Residual standard error: 2.67 on 98 degrees of freedom
## Multiple R-squared:  0.00171,    Adjusted R-squared:  -0
## F-statistic: 0.168 on 1 and 98 DF,  p-value: 0.683
```

Statistical vs. Clinical Significance

My Advice: Do not abandon your scientific reasoning. Just because a variable is significant in your analysis does not mean it has a scientific impact.

Be sure that you have not left out potential confounders. Ask yourself if it makes sense for a variable to be significant. Pay attention to the estimate. Does the estimated coefficient lead to large changes in the outcome?

Correlation vs. Causality

Common Misconception: "These two variables have an association. One must cause the other."

Correlation vs. Causality

Think of an easy example: The sales of suntan lotion increase as the sales of ice cream increase. Does one cause the other? The most likely explanation is that the temperature outside has a causal effect on both sales.

There are various things that must be assessed in order to make a causal argument, which we will discuss shortly.

Correlation vs. Causality

Actual Interpretation: “These two variables have an association. We should investigate further into the causal relationship between the two variables.”

Discussion Time

When you read papers, what are some things you are interested in knowing about the results? What information helps you understand the findings of the paper?

Discuss in your groups before we share as a class.

Reporting Results

Now that we have addressed some common statistical misconceptions, we can begin to discuss how to report the results of an analysis.

Keep in mind that every field and every journal has its own way of reporting results. The following points should be common to most fields but in the future, take guidance from others in your field of research.

Reporting Results

Function: Present the key results, within the context of the analysis but without interpretation, in a logical sequence using text and illustrations, such as tables and graphics.

Reporting Results

1. Address the results of assessing model assumptions.
   - This is often left out of results sections.
2. Use properly formatted tables to summarize the numerical results.
3. Give standard errors, p-values, and confidence intervals for estimates in the tables.
4. Indicate the significance level used.
5. Indicate the reference group for factor variables.
   - Ex: If one of the predictors is gender, indicate whether the parameter is estimating association compared to men or women.
6. Report goodness of fit results.
   - This can be brief but should not be ignored.
7. Report results of any sensitivity analysis.
8. Use interesting graphics when applicable.

Helpful Tips

1. Make sure you have provided results for all the methods discussed in the methods section.
2. Write the results section in the order the results were obtained.
3. Use tables and graphics as summaries.
4. Include non-significant and/or negative findings as well in the results.

Things to Avoid

1. Do not include raw data in the results section.
2. Do not write it in the present tense.
    - It implies generalizability.
3. Do not add interpretations. That is for the discussion section.
4. Reference values in the tables and figures.
5. Avoid repetition. Do not use tables and figures that tell the same story. Each table and figure should offer unique information.

Defending Results

If you choose a career of academic research, your research will constantly be evaluated by your peers. It is important that your work can stand against such evaluation. One way to do that is to explain why your results are feasible and address limitations of your work.

My Advice: Be as transparent as possible!

Common Limitations

Some of these limitations are specifically with regards to regression modeling but others are applicable to more than regression.

1. Extrapolation
2. Linearity
3. Confounding
4. Generalizability
5. Causality
6. Predictive ability
7. Contradictory findings

Extrapolation

Extrapolation is "the process of estimating, beyond the original observation range, the value of a variable on the basis of its relationship with another variable." -Wikipedia

Regression, like other statistical methods, does not handle extrapolation well. There is no guarantee that observed associations extend beyond the range of the observed data. As a result, extrapolation can produce greater uncertainty at best and incorrect results at worst.

Linearity

Regression assumes linearity in the parameters, i.e. the parameters are written as a linear equation. Many times, a variable has a non-linear association with an outcome. In such a case, we can include quadratic or even cubic terms of the variable:

$$Y = \beta_0 + \beta_1 X + \epsilon$$
$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \epsilon$$

However, it can be difficult to model the true relationship between the predictor and the outcome. Additionally, if the parameters are not linearly related, then regression models may lead to incorrect information and inference. GLMs do allow for non-linearly related parameters, but it may not be the relation needed.

Confounding

As previously discussed, make sure that the model is properly specified and that all confounders are included. If there is uncertainty as to whether a variable is a confounder, fit the model with and without the potential confounder and compare the model fits.

Generalizability

Generalizability tends to be a data issue. Identify your target population and use a source population that will allow you to obtain a proper study population. There may be times where the data is not very generalizable. Acknowledge it!

Overfitting can be related to generalizability, in a sense. The model may fit the observed data but might not fit data from the same population well. Be careful not to overfit. One way to avoid it is to compare models to obtain the most parsimonious one that explains the data the best.

Causality

Regression models can only provide information about associations and, as stated previously, correlation differs from causality.

There are various criteria that exist for proving causality. A rather famous one is the Bradford-Hill criteria:

1. Strength of the association
2. Consistent findings
3. Specificity of population, site, and disease
4. Temporality
5. Biological gradient of the dose-response
6. Plausibility
7. Coherence between laboratory and epidemiological findings
8. Experimental confirmation
9. Analogy

Causality

I like to think of it in terms of three points:

1. Association
2. Temporality
3. Isolation

Bottom Line: When using regression, be careful not to make statements that might imply causality.

NOTE: There's an entire branch of statistics devoted to causal inference!

Predictive Ability

Even if a model has a good fit, it may not be very good as predicting unobserved outcomes.

Reasons include:

- Model misspecification
- Overfitting
- Artifact of the data
- Changing association over time

Predictive Ability

Try not to add irrelevant variables into the model. At the same time, do not leave out relevant variables either.

Make sure that the data has been properly sampled from the population. If survey weights were used, they should be accounted for in the model building.

Also, check to make sure that the relationship remains unchanged as time passes. This is particularly important when pooling cross-sectional observations across time. (Researchers often do so with NHANES data.)

Contradictory Findings

Sometimes, the model does not provide the expected results with regards to scientific knowledge. It is up to you to determine if it is:

- Errors in the data analysis
- Random artifact of the data
- Alternative explanation
- True inconsistency

Unfortunately, contradicting results tend not to be published, a criticism of the modern peer-reviewed journal.

Active Learning Exercise

Active Learning Exercise: Suppose you are a researcher with an unlimited amount of funding and resources. How would you perform causal inference with your research question? In other words, how would you assess whether your independent variable of interest causes your outcome? Think about the requirements of causality.

Defending Results

The best tool for defending your results is the discussion section of your paper.

Function: Interpret the results with regards to known scientific knowledge about the research question and to explain the new understanding of the problem by taking the results into consideration.

Discussion Section

It should explain the findings of your analysis and the potential reasons for observing the findings as well as address any limitations of the analysis. Overall, it should describe how our knowledge has moved further than where it was at the end of the introduction.

Discussion Section

1. Provide an answer to your research question.
2. If the findings agree, detail the literature that has similar findings. If not, explain possible reasons for your different results.
3. Discuss some plausible reason for your findings.
4. Highlight the new understanding that your analysis has created.
5. Explain why the findings are important.
6. Discuss strengths and limitations of your work.
7. Make suggestions for further research.

Discussion Section

The limitations subsection of the discussion section is your way to address any potential shortcomings in your work before someone else does. It allows you to explain why it is a limitation and why it was necessary. It also shows that you have an objective view of your work.

Helpful Tips

1. Restate your research question or hypotheses along with your answer for them.
2. You can speak in first person here but do not overdo it.
3. Make clear and concise points.
4. Do not introduce new results.
5. Do not restate your results.
6. Do not leave out any limitations!

Final Words

Your results are your contributed knowledge to science. Share it with the world so that as many people can utilize it as possible. Be prepared to defend it, as it may have great implications for medicine and public health.

Active Learning Exercise

Think about the potential limitations for your data project. List them, describe their potential effects on your findings, and why you cannot strengthen them.

References

1. Interpreting research results
2. How to Write an Effective Discussion
3. Anatomy of a Research Paper