Suggestions for Researchers

> *The most common error in statistics is to assume that statistical procedures can take the pace of sustained effort.*
>
> Good and Hardin (2006) *Common Errors in Statistics*, p. 186

Throughout: Look for, take into account, and report sources of uncertainty.

Specific suggestions for <u>planning</u> research:

- Decide what questions you will be studying.
  - Trying to study too many things at once is likely to create problems with multiple testing, so it may be wise to limit your study.
- If you will be gathering data, think about how you will gather *and* analyze it *before* you start to gather the data.
  - Read reports on related research, focusing on problems that were encountered and how you might get around them and/or how you might plan your research to fill in gaps in current knowledge in the area.
  - If you are planning an experiment, look for possible sources of variability and design your experiment to take these into account as much as possible.
    - The design will depend on the particular situation.
    - The literature on design of experiments is extensive; consult it.
    - Remember that the design affects what method of analysis is appropriate.
  - If you are gathering observational data, think about possible confounding factors and plan your data gathering to reduce confounding.
  - Be sure to record any time and spatial variables present, or any other variables that might influence outcome, whether or not you initially plan to use them in your analysis.
  - Also think about any factors that might make the sample biased.
    - You may need to limit your study to a smaller population than originally intended.
  - Think carefully about what measures you will use.
    - If your data gathering involves asking questions, put careful thought into choosing and phrasing. Then check them out with a test-run and revise as needed.
  - Think carefully about how you will randomize (for an experiment) or sample (for an observational study).
  - Think carefully about whether or not the model of your intended method of analysis are likely to be reasonable.
    - If not, revise either your plan for data gathering or your plan for analysis, or both.
  - If possible, conduct a pilot study to trouble shoot and obtain variance estimates for a power analysis.

        - Revise plans as needed.
    - Decide on appropriate levels of Type I and Type II error, taking into account consequences of each type of error.
    - Plan how to deal with multiple inferences, including "data snooping" questions that might arise later
    - Do a power analysis to estimate what sample size you need to detect meaningful differences.
        - Take into account any relevant considerations such as multiple inference, Intent-to-Treat analysis, or how you plan to handle missing data.
        - Revise plans as needed.
- If you plan to use existing data, modify the suggestions above, as in the suggestions under Item II(b) at http://www.ma.utexas.edu/users/mks/statmistakes/datasnooping.html
- For additional suggestions, see Chapter 8 of van Belle (2008), *Statistical Rules of Thumb*.

Specific suggestions for <u>analyzing</u> data:

- Before doing any formal analysis, ask whether or not the model assumptions of the procedure are plausible in the context of the data.
- Plot the data (or residuals, as appropriate) as possible to get additional checks on whether or not model assumptions hold.
    - If model assumptions appear to be violated, consider transformations of the data, or use alternate methods of analysis as appropriate.
- If more than one statistical inference is used, be sure to take that into account by using appropriate methodology for multiple inference.
- If you use hypothesis tests, be sure to calculate corresponding confidence intervals as well.
    - But be aware that there may also be other sources of uncertainty not captured by confidence intervals.
- Keep careful records of decisions made in data cleaning and in using software.

    - For more discussion, see:

        - K. Baggerly and D. Berry, Reproducible Research, AMTAT NEWS Science Policy Column, January 2011, http://magazine.amstat.org/blog/2011/01/01/scipolicyjan11/
        - A. Gelman (2010) and commentators, Forensic bioinformatics, or , Don't believe everything you read in the (scientific) papers, http://www.stat.columbia.edu/~cook/movabletype/archives/2010/10/forensic_bioinf.html, and references therein.

Specific suggestions for <u>writing up</u> research:

> *Critics may complain that we advocate interpreting reports not merely with a grain of salt but with an entire shaker; so be it. ... Neither society nor we can afford to be led down false pathways.*
>
> Good and Hardin (2006), *Common Errors in Statistics*, p. 119

> *Until a happier future arrives, imperfections in models require further thought, and routine disclosure of imperfections would be helpful.*
> David Freedman (2008, p. 61)

- Aim for transparency and reproducibility.
    - Include enough detail so the reader can critique both the data gathering and the analysis.
        - Look for and report possible sources of bias or other sources of additional uncertainty in results.
        - For more detailed suggestions on recognizing and reporting bias, see Chapter 1 and pp. 113 - 115 of Good and Hardin (2006). All of Chapter 7 of that book is a good supplement to the suggestions here.
        - Consider including a "limitations" section, but be sure to reiterate or summarize the limitations in stating conclusions -- including in the abstract.
    - Include enough detail so that another researcher could replicate both the data gathering and the analysis.
        - For example, "SAS Proc Mixed was used" is *not* adequate detail. You also need to explain which factors were fixed, which random, which nested, etc. Refer to the notes you have made when performing the analysis.
    - If space limitations do not permit all the detail needed to be included in the actual paper, provide them in a website to accompany the article.
        - Some journals now include websites for supplementary information; publish in these when possible.
- When citing sources, give explicit page numbers, especially for books.
- Include discussion of *why* the analyses you have used are appropriate
    - i.e., why the model assumptions are well enough satisfied for the robustness criteria for the specific technique, or whether they are iffy.
    - This might go in a supplementary information website.
- If you do hypothesis testing, be sure to report p-values (rather than just phrases such as "significant at the .05 level") *and also* give confidence intervals.
    - In some situations, other measures such as "number to treat" would be appropriate. See pp. 151 - 153 of van Belle (2008) for more discussion.
- Be careful to use language (both in the abstract and in the body of the article) that expresses any uncertainty and limitations.

- If you have built a model, be sure to explain the decisions that went into the selection of that model
    - See Good and Hardin (2006, pp. 181 – 182) for more suggestions
- For more suggestions and details, see
    - Chapters 8 and 9 of van Belle (2008)
    - Chapters 7 and 9 of Good and Hardin (2006)
    - Harris et al (2009)
    - Miller (2004)
    - Robbins (2004)
    - Strasak et al (2007)

And bear in mind the advice of Nobel Laureate in Physics Richard Feynman:

> "The only way to have real success in science ... is to describe the evidence very carefully without regard to the way you feel it should be. If you have a theory, you must try to explain what's good and what's bad about it equally. In science, you learn a kind of standard integrity and honesty.
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> *What Do You Care What Other People Think? (1988) p. 217*
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> "There is one feature I notice that is generally missing in 'cargo cult science'... It's a kind of scientific integrity, a principle of scientific thought that corresponds to a kind of utter honesty — a kind of leaning over backwards... For example, if you're doing an experiment, you should report everything that you think might make it invalid — not only what you think is right about it... Details that could throw doubt on your interpretation must be given, if you know them. ... If you make a theory, for example, and advertise it, or put it out, then you must also put down all the facts that disagree with it, as well as those that agree with it. ... In summary, the idea is to try to give *all* of the information to help others to judge the value of your contribution; not just the information that leads to judgment in one particular direction or another. ... The first principle is that you must not fool yourself -- and you are the easiest person to fool. So you have to be very careful about that.
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> "Cargo Cult Science", adapted from a 1974 commencement address at Cal Tech, http://calteches.library.caltech.edu/51/02/CargoCult.pdf

References:

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Miller, Jane (2004), *The Chicago Guide to Writing about Numbers: The Effective Presentation of Quantitative Information*, University of Chicago Press

Robbins, N. (2004), *Creating More Effective Graphs*, Wiley

Strasak, A. M. et al (2007), The Use of Statistics in Medical Research, *The American Statistician*, February 1, 2007, 61(1): 47-55

van Belle, G. (2008) *Statistical Rules of Thumb*, Wiley

Note: For an online version of these suggestions with embedded links, see http://www.ma.utexas.edu/users/mks/statmistakes/suggestionsforresearchers.html