MT4614 Design of Experiments

R. A. Bailey
University of St Andrews

17 January 2022

Chapter I: Overview

1.1 Stages in a statistically designed experiment

1. **Consultation** or collaboration with scientist.
   - In good time, or the day before?
   - Different vocabulary, different ideas about the whole truth — keep asking dumb questions.
   - The scientist's pre-conceived design from *Statistics for Science 101* may not be ideal.
2. **Statistical design** — that is what this course is about.
3. **Data collection**
   - paper or data-logger or direct to computer?
   - no copying by hand;
   - no re-ordering of the data;
   - no intermediate calculations;
   - no delegation to juniors.

Section 1.1: Stages, continued

4. **Data scrutiny** Look over data for obvious anomalies or outliers or bad practice
(for example, change of measurement units).
Query dubious data while there is still time to investigate.

Example

In an experiment at an agricultural research station in New Zealand, the hardness of kiwi fruit was measured. Preliminary data analysis made the statistician suspicious of the results. Then he noticed that the data had been recorded in two different handwritings. He re-analysed the data, including an unknown constant to multiply all the data in the second handwriting. The fitted value of the constant was 2.2.
What does this suggest?

Section1.1: Stages, continued again

Example

In an experiment on wheat yields, I noticed that the numbers recorded for the last 12 plots out of 72 were noticably lower than the rest. I asked why. "It started to rain during harvest, when the harvester was about 12 plots away from the end." I was able to include a covariate in the data analysis to allow for this.

5. **Data analysis** This should be planned at the design stage. It is a good idea to do a dummy analysis on dummy data. It may have to be modified if unexpected things happen.
6. **Interpretation** The scientist may not really understand ANOVA tables, or P-values, or lists of means and standard errors, etc. The statistician must interpret these in terms that the scientist can understand.

Break for non-technical stuff

All information about MT4614, including timetable, summary of material covered, problem sheets (when available), data files (when needed), is on the web page
`http://www-groups.mcs.st-and.ac.uk/~rab/MT4614/`
There is a direct link to this from MMS.

I encourage you all to write out the notes of each lecture in your own handwriting, with your own comments and explanations added. This is really the only way that the material will get into your brain.

If you have any questions, do not hesitate to email me at
`rab24@st-andrews.ac.uk`
(but do not expect replies during weekends).

Any questions on this lecture so far?

Section 1.2: The ideal versus the reality

Why is the experiment being done?
It should be to answer specific questions, typically

- to estimate something
  (e.g. how much better is drug A than drug B?):
  then we need unbiased estimators, with low variance;
- to test a hypothesis
  (e.g. that there is effective difference between organic and inorganic fertilizer):
  then we want high power for practically relevant differences;
- does this drug have bad side effects?

Section 1.2: The ideal versus the reality (replication)

More replication (the number of times that each treatment is tested)

- lowers variance
  (because the mean has a larger denominator);
- can increase variance
  (if a larger number of experimental units are more variable);
- usually raises power (because of more degrees of freedom);
- increases costs.

Section 1.2: The ideal versus the reality (local control)

More local control (grouping the experimental units into blocks of alike units)

- lowers variance (by removing some sources of variability from treatment comparisons);
- can increase variance (in non-orthogonal designs);
- usually raises power;
- reduces residual degrees of freedom, so can reduce power if the number of experimental units is small;
  (I know a professional statistician who was threatened with court action by a famous scientist because the statistician used blocks in a small experiment and the results did not convincingly prove that his favoured treatment was better.)
- increases the complexity of the design, data analysis, and interpretation of the results.

Section 1.2: The ideal versus the reality (constraints)

Constraints

- Costs
  (but a cheap experiment may be a waste of resources);
- Availability of test materials
  (e.g. limited quantities of seed of a new variety);
- Availability of experimental units
  (e.g. land, bench space in a lab,
  patients with a certain disease);
- Concerns about safety and ethics;
- Pre-existing natural blocks among the experimental units;
- Other management constraints
  (e.g. who does which task, and when).

Section 1.2: The ideal versus the reality (constraints)

Choice

- Which treatments?
  - which combinations?
  - which quantities?
  - do we include a "control"?
- Which experimental units?
  - university student volunteers or the general population?
  - representative farmers' fields or a well-controlled experimental farm?