Types of Research

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Goals for Today

• What are your research goals?

• How can you collect data in a way that will allow you to achieve these goals?

• How does your data collection procedure influence the type of conclusions you will be able to make?
What is your research goal?

- Do you want a *qualitative* idea of what is going on or statistical results that can only be established *quantitatively*?

- Is your goal to *describe* the results in the sample you studied, or to *make inferences* about some underlying truth(s) in a larger population?

- Do you care about making causal conclusions?
Qualitative Research

Collecting and summarizing qualitative (non-numeric) information about the topic you are interested in

Usually qualitative research pertains to questions with unspecified answers (i.e. “Why?”)
Qualitative Research

COLLECTING “DATA”

• Informal Conversations
  • Discussions with students
  • Discussions with other professors about their experiences

• Formal interviews
  • Specific agenda
  • Trained interviewer

• Open-ended questions
  • Surveys, feedback forms and evaluations
  • “What did you find most useful for learning the concepts?”

• Observations
  • “The class seems much more engaged when...”

• Applying existing theory and literature to your topic
Qualitative Research

SUMMARIZING THE “DATA”

• Describe your observations
  • “A general theme was...”
  • “Many people mentioned...”

• Code responses into categories
  • Pie charts
  • Analyze as you would quantitative data

• Often the point isn’t to summarize the qualitative research, but to use it to motivate a quantitative study
Qualitative Research

PROS

• Allows you to probe deeply into a topic of interest, and can help you to understand

• Great way to generate hypotheses which can then be tested quantitatively

• Can be used to investigate the “why” behind quantitative results

• Often more flexible and adaptable than quantitative research

• Usually necessary to have some qualitative research justifying or explaining the quantitative research
Qualitative Research

CONS

• Usually requires a great deal of human time (conducting interviews, observing situations, coding data, ...)

• Impossible to separate the actual results from the researcher’s interpretation of the results

• Difficult to actually “prove” anything new
Quantitative Research

Collecting and analyzing numeric data or non-numeric data using numeric summaries

Quantitative research is needed when you have a hypothesis that you want to test rigorously
Quantitative Research

COLLECTING DATA

• Existing databases

• Observational Studies
  • Measurement without intervention
  • Example: Collect data on whether students choose to participate in an activity and their grade on the related homework
  • Common special case: surveys

• Randomized Experiments
  • Randomize subjects to a treatment and control group, and collect data on some outcome measure
Quantitative Research

ANALYZING DATA

• Visual Displays of Data
  • Histograms
  • Scatterplots

• Numeric Summaries of Data
  • Mean (average)
  • Proportion
  • Correlation

• Statistical Inference
  • Test for significance
  • Intervals for the true population value
  • Statistical models
Quantitative Research

PROS

• A useful way to summarize and display data

• Necessary to test whether there is a significant association between two variables or statistically test other well-defined hypotheses

• In some cases, can be used to establish causality

• Models can be developed that can help to shed light on underlying truth

• Data can be used to predict unobserved values
Quantitative Research
CONS

• While quantitative research is good at summarizing what is going on, it often cannot answer why.

• The why usually has to be evaluated using relevant theory and existing literature, and can be explored through qualitative research.
Qualitative and Quantitative Research

- Quantitative research is needed to prove or establish pretty much any new research hypothesis.

- Quantitative results should be founded in qualitative research (observations, literature, etc.)

- Qualitative research is most useful as a precursor or follow-up to quantitative research.

- The combination of qualitative and quantitative research can be extremely powerful.
Qualitative and Quantitative Research

EXEMPLARY

• Course on “lean manufacturing” instituted a real-world project in which students had to work with industries on a real project in lean manufacturing

• The first year of the project, qualitative research was employed: students were simply asked on their end-of-the-year evaluations about the impact of the experience

• The next year, quantitative research was employed: students were asked to rate the project on 1-5 scale

Qualitative and/or Quantitative Research

• Do you plan to use qualitative research? How?

• Do you plan to use quantitative research? How?

• If doing both, which will you do first?

• How can you make the two approaches work together towards achieving your research goal?
What is your research goal?

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Descriptive Research

Collect data and *describe* the results

- Example: The lean manufacturing project reported results as “the students gave the project an average of 4.0 on a 1-5 scale”

- No implications for any greater population
- No control group for comparison
- No thought of statistical significance

**DESCRIPTIVE RESEARCH ≠ RIGOROUS RESEARCH**
Inferential Research

Collect data, *describe* the results, and perform *statistical inference* on the results
Population to Sample

• Your **target population** is the population you want to generalize to. Your target population should be well-defined.

• Your **sample** is the people you actually collect data on.

• To make valid inferences about the population of interest, you need a **representative sample**, a sample that is representative of your population.
Population to Sample

• Some factors to consider:
  • Previous educational background?
  • Previous engineering courses?
  • Gender?
  • Class size?
  • Age of students?
  • Class Topic?
  • Motivation of students/professors?
  • ...

• Decide which variables should be restricted in your target population
• All other variables should be similar in the sample and population
Population to Sample

• Ideally, a representative sample is achieved by taking a **random sample**: choosing your sample units randomly from your target population

• In engineering, this is often possible
• In education research, this is usually not possible

• How else can we get a representative sample?
Population to Sample

• If a random sample is not possible, try to diversify your sample to match the diversity of the population (as much as possible)
  • Several professors
  • Several colleges/universities
  • Several classes (if not target population class specific)

• Report the demographics of your sample so readers can judge for themselves whether to generalize to their situation

• Think hard about whether properties specific to your sample may have an impact on the results

• Typically samples achieved on a volunteer basis are not representative (although sometimes all you can get)

• Depending on your research, a representative sample may not be necessary, but it definitely helps in generalizing your results
Replication

• To get an idea for how much your results can be trusted, you need replication: you need to collect measurements on many units in order to generalize your results

• If you only measure one unit, you have no way to estimate uncertainty. If you only measure two units, you have no idea whether the observed difference is due to something you care about or random variation

• The bigger your sample size, the more precision you have when making inferences about the population
Selecting a Sample

• What is your target population?

• Is it possible to select a random sample?

• If not, what can you do to make your sample more representative?

• How will your sample differ from the target population?

• Does your sampling scheme include replication?
What is your research goal?

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• Is your goal to *describe* the results in the sample you studied, or to *make inferences* about some underlying truth(s) in a larger population?

• Do you care about making causal conclusions?
Fat Intake and Life Expectancy for 40 countries

ASSOCIATION ≠ CAUSATION
Confounding Factors

• A **confounding factor** is something that is related to both the treatment variable (the variable “causing” the effect) and the outcome variable.

• In the fat vs. life expectancy example, fat grams consumed would be the “treatment” of interest, life expectancy would be the outcome, but plenty of confounding factors (i.e. wealth of the country) prevent causal conclusions.

• Whenever data is simply observed without an experiment, confounding factors prevent making causal conclusions.
Confounding Factors in Education Research

• If students are free to decide which group they are in (which class they take, whether or not to participate in an optional activity, etc.) confounding factors may be the motivation or preferences of the students.

• If instructors are free to choose between a new method or an old method, confounding factors may be the age of the professor, the willingness of a professor to try new things, or the way a professor teaches.
Randomized Experiment

- The only way to establish a *causal relationship* is to conduct a controlled randomized experiment

- **RANDOMLY** divide your sample into treated and control groups

- If you observe a significant difference between the outcomes in your two groups, you can be confident that the difference is due to your treatment, since the groups are (in theory) otherwise identical

- Any confounding factors are “balanced out” by randomization
Randomized Experiment

EXAMPLE

• Researchers tried to determine whether “fading” the number of steps in worked examples helps people learn how to solve problems in electrical engineering

• They recruited subjects, and *randomly* assigned each of these subjects to a treatment level (a level of fading)

• Students watched an instructional video on parallel circuits, including a fully worked example. Next, students were lead electronically step-by-step through three more worked examples, *according to their treatment/fading level*. Finally, they were tested on the topic.

Pygmalion Effect

• In 1965, teachers were told that all their students had taken a test, and based on the test, some students had been identified as expected “growth spurters”

• Sure enough, at the end of the academic year, those students showed significantly more improvement in student achievement than their peers

• BUT... the test never existed, and the students identified to the teachers were chosen randomly

• This study has become very famous, and this idea that expectation can influence results is known as the Pygmalion effect

Hawthorne Effect

• In the 1920s, Henry Landsberger conducted an experiment to determine what the optimal lighting was for productivity in a factory. He found that regardless of the lighting (bright or dim), people performed better while they were being measured.

• This has become known as the Hawthorne Effect: the simple act of measurement or participation in an experiment may change people’s behavior.

• It’s very important to have a control group, a group not receiving the active treatment, but still participating in the experiment.
There have been many studies documenting the **placebo effect**: If you think something has the power to make you improve, that thought alone may make you improve.

- Powerful examples: knee surgery and drilling holes in the head.

- In education: if students think something will help them to improve, that may itself help them improve (even if the teaching method itself has no intrinsic value).

- The implication: the control group should ideally be receiving some kind of *placebo treatment*, something that shouldn’t have any active effect besides mental encouragement.
Randomized Experiment

BLINDING

• If possible, an experiment should be **double blinded**: neither the subjects nor the instructor/evaluator should be aware of which treatment each person is receiving.

• Either students or instructors/evaluators can either consciously or unconsciously bias the results.

• Sometimes this can be achieved by not telling subjects or instructors the exact premise of the experiment:
  • i.e. “This is an experiment about how students learn best”, rather than “This is an experiment about whether fading steps of a worked example is effective”.


Non-Randomized Experiment

- Often, you want to test something for which you cannot randomize the treatment effect

- Depending on the situation, you may or may not still be able to make an argument for causality
  - ex/\ You change the way you teach, evaluate the results, and find your students learn the concept(s) better than when you have taught the same class in the past
  - ex/\ You ask students to participate in an optional activity, and find that those who participated learned the material better than those who didn’t

- Defending a causal argument in a non-randomized experiment is much more difficult, and usually impossible
Non-Randomized Experiment

• Even though you can’t prove causality in a non-randomized experiment, you can (and should!) attempt to adjust for confounding factors

• If you can think of a *measurable* confounding factor (anything that could be an alternate explanation for your desired argument), you should collect data on it and it can potentially be adjusted for during analysis

• The more potential confounding factors you can eliminate, the better.
Observational Study

• Some of you may be planning on analyzing existing data, collecting survey data, or collecting other data with no form of “treatment” or “intervention”

• This can still be useful for establishing association between two (or more) variables, or simply for learning about your population
Observational Study
EXAMPLE

• In 2008 a study was conducted on “the perception of learning when tablet PCs are used as a presentation medium in engineering classrooms”

• No randomization, but students were surveyed afterwards and asked how it affected their learning (both qualitatively and quantitatively).

• This was not a randomized experiment, but a lot can be learned from this type of study.

Randomized Experiment vs. Observational Study

• Randomized Experiment
  • You randomly determine which subjects receive the treatment or control (or the different levels of treatment)
  • Any confounders should be washed away with randomization, so any effect observed is probably due to the treatment

• Observational Study
  • You have no control over which subjects get which treatment
  • You have to worry about confounding factors. Any effect observed many either be due to the treatment OR a confounding factor, so you usually can’t make causal conclusions
  • Usually conducted when a randomized experiment is not feasible OR when you don’t care about making causal conclusions
Randomized Experiment vs. Observational Study

• Do you care about making causal conclusions?

• If so, is it possible to randomize?

• If not, can you think of potential confounding factors? Are they measurable?

• Is it possible to re-design your study to allow for randomization?
Association vs. Causation

XKCD Comics: http://xkcd.com/552/
What is your research goal?

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• Do you care about making causal conclusions?
What is your research goal?

• Do you want a *qualitative* idea of what is going on or statistical results that can only be established *quantitatively*?

• Qualitative research is useful before quantitative research to help you generate a hypothesis to then test empirically.

• Qualitative research is also useful to justify and explain your quantitative results.
What is your research goal?

• Is your goal to *describe* the results in the sample you studied, or to *make inferences* about some underlying truth(s) in a larger population?

• Since the goal of this conference is *rigorous research*, you should aim to make inferences with your research.

• This includes specifying a target population, and making efforts to achieve a representative sample, or at least being aware of your sample and how it may differ from the population.
What is your research goal?

• Do you care about making causal conclusions?

• If you want to establish a causal relationship, you need to conduct a randomized experiment.

• If you can’t conduct a randomized experiment, you should think about potential confounding variables that could be alternative explanations for your results.

• If you only care about association or summarizing the attitudes of the population, then an observational study is sufficient.
THINK FIRST!

• These are all important issues to consider before you begin collecting data!

• Think deeply about your research goals, and how you need to go about collecting your data in a way that will allow you to achieve these goals.
What kind of data to collect?

• How do you decide on an outcome variable of interest?

• What makes a “good” measurement?

• Are there existing measurements that I can use?

TOMORROW: 9:30 – 10:30 am
Estimating the truth

• How close do you expect the population truth to be to your observed sample statistic?

• Once you have an estimate for some true quantity, how do you create an interval that represents your confidence in your estimate?

TOMORROW: 2:45 – 4:15 pm
Are my results significant?

• How do you know if the difference between the outcomes in your treated and control groups is real? How do you know you haven’t just randomly chosen some of the “better” students to receive the treatment?

• You observe an association, how do you know if it is strong enough to say an association actually exists?

• How do you know if your results are not due to “random chance”, but are actually statistically significant?

TOMORROW: 2:45 – 4:15 pm