The Scientific Method

what is the scientific method?
“… systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses.” (Oxford English Dictionary)
why use the scientific method?
empiricism
allows for systematic, objective collection of data (note: collections of anecdotes are not data)
construct falsifiable hypotheses (Karl Popper)

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fact
a statement about a direct observation of nature that is so consistently repeated that virtually no doubt exists as to its truth value
theory
a collection of statements (propositions) that together attempt to explain a set of observed phenomena hypothesis
a clear but tentative explanation for an observed phenomenon

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what is the question?
is questions - in the scientific domain
ought questions - not in the scientific domain
cannot infer ought from is (is-ought fallacy)
what is the theory?
coherent set of propositions that are used to describe, understand and explain phenomena
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examples of theories
- tiredness leads to irritability
- lecturing improves student knowledge
- schizophrenia is genetically determined
- phonological skills underlie reading ability

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background research
before you begin, survey the literature
- what is already known?
- how would your research contribute to the topic?
- how are other researchers answering the question?
- how can you do better?

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formulate a testable hypothesis
- theory generates a testable hypothesis
- a statement made prior to data collection
  - a priori hypothesis as opposed to a posteriori
  - less prone to error and bias than bending the theory to fit the numbers
  - although data that don’t conform to expectations can be used to modify theory to generate a new testable hypothesis

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hypotheses make specific predictions and must be:
- falsifiable: can the hypothesis potentially be disproven?
- testable: can a test be designed to adequately test the hypothesis?
- precisely stated: are all terms clearly defined?
- rational: is hypothesis consistent with known information?
- parsimonious: is the explanation the simplest possible? (Occam’s razor)

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determine the variables and how to measure them
- variables are any characteristic that can take on different values and vary across participants
- the challenge is to find the right tool for the job

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types of variables

<table>
<thead>
<tr>
<th>Nominal</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>category membership</td>
<td>intervals between successive values are equal but no “true” zero point</td>
</tr>
<tr>
<td>numbers assigned serve as labels but do not indicate numerical relationship</td>
<td>e.g., temperature in °C/F, shoe size</td>
</tr>
<tr>
<td>e.g., gender, political party, religion</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ordinal</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>data can be ranked along a continuum</td>
<td>highest level of data</td>
</tr>
<tr>
<td>intervals between ranks are not equal</td>
<td>equal intervals and a true zero point</td>
</tr>
<tr>
<td>e.g., race positions, attractiveness</td>
<td>e.g., height, distance</td>
</tr>
</tbody>
</table>
The Scientific Method

- systematic observation & data collection
- cannot study the entire population
- study a sample – a group selected from the population
- reported as n or N (e.g., n = 54 participants)
- generalisability
  - the extent to which a single sample represents the population
  - sample must be representative of population

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- sample bias (more on this later)
- sample must not be chosen to fit preconceptions (cherry picking)
  - e.g. 1, telephone polls
  - e.g. 2, dialect
- what about self-selected populations?
  - are undergraduates who are interested in participating in studies representative of all people in the world?
  - WEIRD (Western, Educated, Industrialised, Rich & Democratic)

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- evaluating the evidence
  - convert observations into data (quantitative analyses)
  - use statistics to describe your sample (descriptive statistics) and to test your hypotheses (inferential statistics)
  - basically, what is the probability that your results are due to chance?

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- reliability & validity
  - reliability refers to consistency, namely can the data be replicated
  - validity is the true measure of what is meant to be studied
    - ecological validity – does the experiment approximate real-life phenomena
    - external validity – how generalisable is the study (e.g., representative of population)

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- reliability & validity
  - validity is affected by confounds (or confounding variables) – unwanted sources of variability
  - control variables can be measured (e.g., sex, age, IQ or world knowledge of participants)
  - control conditions can be used as a baseline (more on this later)
true experiments
researcher controls variables in an experiment
the aspect that is systematically manipulated is the **independent variable (IV)**
the measurable effects of the manipulation are the **dependent variables (DV)**
random assignment of participants eliminates biased sampling

quasiexperiments
random assignment is not always possible (e.g., gender, age, ethnicity, socioeconomic status)
statistical techniques can be used to remove confounds (e.g., age and social influence)

descriptive research
describes a behaviour or phenomenon

**what conclusions can we draw?**
more students are asleep after lunch
time of day causes sleepiness
sleepiness causes time to move faster or slower
Methods & Tools

**Relational Research**

- Looks for a relationship between phenomena.

**What conclusions can we draw?**

- Employees earning £25K take 3 times as many sick days as those with £40K.
- The higher the salary, the fewer sick days.
- Low earners are sick more because they are paid less.

**Sick days by salary**

<table>
<thead>
<tr>
<th>Annual Salary (£)</th>
<th>Sick Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>20000</td>
<td>0</td>
</tr>
<tr>
<td>25000</td>
<td>10</td>
</tr>
<tr>
<td>30000</td>
<td>20</td>
</tr>
<tr>
<td>35000</td>
<td>30</td>
</tr>
<tr>
<td>40000</td>
<td>40</td>
</tr>
</tbody>
</table>

Methods & Tools

**Relational Research**

Correlation does not mean causation.

- E.g., red cars are more likely to be involved in fatal accidents than brown cars.
- E.g., ice cream sales and the number of drowning incidents are positively correlated.
- Outside variables can influence the results.

Methods & Tools

**Experimental Research**

- Manipulates one or more variables to see the effect on other variables.
- Other variables which may affect the outcome are ‘held constant’.
- Determines whether any differences arise as a direct result of the manipulation.

Methods & Tools

**Hangover intensity after champagne & wine**

- What conclusions can we draw?
  - Hangover intensity is greater following nights on wine than champagne.
  - Hangover intensity will be greater following a night on wine.
  - Wine causes a more intense hangover than champagne.

Methods & Tools

**Hangover intensity after champagne & wine**

- What conclusions can we draw?
  - Hangover intensity is greater following nights on wine than champagne.
  - Hangover intensity will be greater following a night on wine.
  - Wine causes a more intense hangover than champagne.
Methods & Tools

descriptive: y is described
relational: x is related to y
experimental: x is responsible for y
causation depends on the ability to rule out alternative explanations for observed behaviours
to achieve this we must design our studies carefully, taking care to control for other variables

Methods & Tools

triangulation
all methods are limited in some ways
methodological pluralism – use of multiple methods
methodological triangulation - convergence of the findings of methodologically varying studies can lend credence to the theory pattern

Methods & Tools

naturalistic observation
descriptive research typically, but can also be correlational (e.g., compare people in different settings)
e.g., corpus studies
can also be used to generate hypotheses

Ethics

prior to the 1970s, there were no ethical standards for experiments
e.g., Milgram obedience study (1960s)
e.g., Tuskegee syphilis experiment (1930s-70s)

Ethics

3 basic principles of the 1979 Belmont Report (USA)
respect for persons: treating persons as autonomous agents and protecting those with diminished autonomy
beneficence: minimising possible harms and maximising benefits
justice: distributing benefits and risks of research fairly
Ethics

modern principles of the APA (American Psychological Association)

• failure to adhere to principles can lead to reprimand, non-publication and expulsion from the APA
• lawsuits can result
• universities can fire researchers

Ethics

modern principles of the APA (American Psychological Association)

• Principle A: beneficence and nonmaleficence: protection of research participants
  • avoid harming research participants
  • obtain informed consent and make clear participants can withdraw at any time
  • avoid deception except in limited circumstances
  • maintain privacy and confidentiality, including data protection

Ethics

• Principle B: fidelity and responsibility: achieve valid results
  • pursuit of objective knowledge
  • need to provide a clear justification for study, including sample size and statistics, that will lead to publishable results

Ethics

• Principle C: maintaining professional integrity
  • provide detailed methods section that can allow for replication of results
  • disclose conflicts of interest, including funding sources

Ethics

• Principle D: justice
  • researcher must be aware of potential biases and limits in expertise so as not to lead to or condone unjust practices
  • Principle E: respect for people’s rights and dignity sensitivity to cultural and individual differences, including age, gender, gender identity, race, ethnicity, culture, national origin, religion, sexual orientation, disability, language and socioeconomic status

Ethics

• approval
  • all studies require consent from an IRB (Internal Review Board) or equivalent
  • the PI (Principle Investigator) can be personally liable for any ethical breaches
  • check for necessary approval within your institution, with journals you want to publish into
  • different procedures for different methods/populations (e.g., medical research, developmental research, testing patients or atypical populations)
Ethics

fraud
recent high profile cases involved researchers who systematically faked data

social psychologist Diederik Stapel at Tilburg University fabricated entire studies, was revealed by data that were too good

comparative psychologist Marc Hauser at Harvard University made up control data, was reported by students

Discussion

consider your own work
what is the theory that you want to test?
is it suitable for scientific testing?
how will you determine the test’s validity?
what would be your independent and dependent variables?
would your study be descriptive, correlational or experimental?
what ethical problems can you anticipate?

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What issues to look for in experimental papers?

Missing stats
Missing drop outs
Exclusion criteria
Counterbalancing
Interobserver reliability, if relevant