Causal Reasoning

Critical Thinking

Causal Reasoning and Causal Claims

- Causal reasoning is reasoning about causal claims. In particular, causal reasoning tries to establish causal claims.
- Causal claims are claims about causal connections:
  - Smoking causes lung cancer
  - If you don’t study hard, you won’t pass the course
  - Etc.

The Importance of Causal Claims (and hence of Causal Reasoning)

- Causal claims allow me to make predictions and decisions!
- Please note that ‘A causes B’ is used to express that B is more likely to happen with A than without A
  - E.g. ‘smoking causes cancer’ is true if smoking makes you more likely to get cancer than not smoking.
  - As usual, in real life we deal with these kinds of probabilities and likelihoods rather than certainties.
  - Often, A is only one of the many factors and conditions under which B will follow.
- Mainly because of these uncertainties, it turns out to be hard to make good arguments for (including finding evidence for) the claim that there is (or is not) a causal connection between two events.

How to Establish Causal Claims

- There are basically 3 methods to establish whether or not there is a causal connection between 2 events
  - Observing (or in some other way considering) the underlying mechanism: If we're lucky, we can directly observe or (based on what we already know) infer the mechanism by which the presence of A has an effect on the presence of B.
    - However, in many cases this is not the case, e.g. the exact mechanisms by which smoking causes cancer are still not exactly clear
  - Experiment: We could also try and perform some experiments; Have A present in one situation, don't have A present in another, and see what happens to B
    - However, we can't always run these experiments
      - Physically impossible (e.g. we can't go back in time)
      - Ethically impossible (e.g. we can't run experiments on smoking)
  - Correlation: Many times, the best we can do is to establish some kind of correlation between A and B: we just find that whenever A is present, B is more (or less) likely to be present
    - However, correlation is not causation!

Method of Agreement

- Often, we simply observe a number of cases where both A and B are present, and conclude that A causes B.
  - John has good looks, drives a nice car and has a beautiful wife: Maybe he impressed his wife with his good looks and his car?
  - 98% of all criminals eat carrots: does eating carrots cause one to be bad?!
- Special case: Post Hoc Ergo Propter Hoc: “After this, therefore, because of this”
  - We observe some event B happening after event A happens, and conclude that event A caused event B.

Correlations

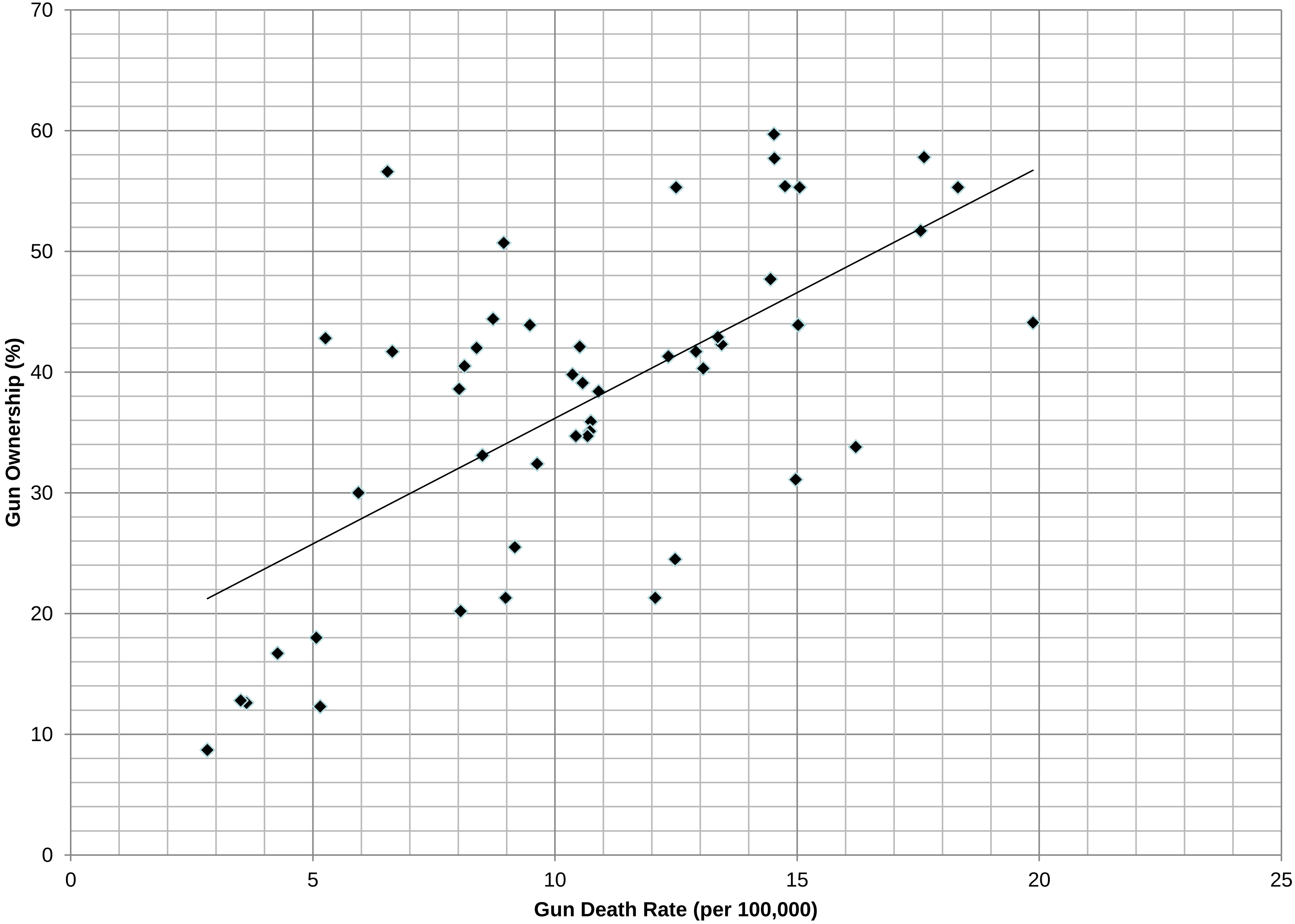
- Events A and B are correlated if we have observed a bunch of cases where A and B are present, and we find that there is a difference (percentage wise) in the number of cases where B is present between the cases where A is present and where A is not present.
- E.g. 100 cases
  - 40: both A and B
  - 30: A and not B
  - 20: not A and B
  - 10: neither A nor B
  - So, 70 cases with A: 40/70 = 57% B present
  - 30 cases without A: 20/30 =67% B present
  - Difference in percentages, so there is a correlation:
    - if A is present, B is less likely to be present (A and B are inversely or negatively correlated)

Method of Difference

- The ‘method of difference’ is a way to try and reason for a causal connection:
  - We see one or more cases where both A and B are present
  - We also see one or more cases where both A and B are absent
  - Thus, the difference between these two (sets of) cases (A present or not) is suspected to be the cause of the difference in effect (B)
- Notice that correlations represent a kind of statistical method of difference

Correlations are not causations

- Correlations are not causations!
  - Possible Reverse Causation: “There are more cars at intersections with traffic lights than at those without. So, traffic lights cause congestion”
  - Possible Common Cause: “People who sleep 8 hours or more die more quickly than those who sleep only 7 hours”
  - Or just Coincidence: “Over the past 50 years, people have gotten taller, and they are more watching TV as well: Obviously, watching television makes you taller”


Gun Ownership (%)
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Gun Death Rate (per 100,000)

Controlled Experiments

- To set up a controlled experiment to test whether A causes B:
  - Randomly generate two groups:
    - The Experimental Group: the group where A will be present
    - The Control Group: the group where A will not be present
  - Find the percentage e of cases of the experimental group where B is present
  - Find the percentage c of cases of the control group where B is present
  - See if the difference between e and c is ‘statistically significant’, i.e. there is less than a 5% chance that this difference may have come about by random variation.
  - If there is a statistically significant difference, then since the two groups should be alike (since they were randomly formed), the only difference that could explain the difference in the presence of B is the presence of A.

Statistically Significant Differences

Size Of Each Group	d (percentage the difference e – c has to exceed to be statistically significant)
10	40
25	27
50	19
100	13
250	8
500	6
1000	4
1500	3

Example

- 200 subjects with headaches
- Randomly split apart:
  - 100 subjects in experimental group get drug
  - 100 subjects in control group get placebo
- After 1 hour:
  - 40 of experimental group headache gone
    - So e = 40/100 = 40%
  - 20 of control group headache gone
    - So c = 20/100 = 20%
- So, d = e – c = 20% > 13%
- So, statistically significant difference!

Controlled Experiment Warning I

- To say that some statistically significant difference is found in a controlled experiment is to say that there is less than a 5% chance that this difference was due to random variation. In short, if there is a statistically significant difference, then it is likely that there is some causal effect taking place. But, this does not make it necessary.
  - Just because something is statistically significant does not mean that there is a genuine effect. In particular, if you run enough experiments, you will find some (roughly 1 out of 20) that have a statistically significant difference that is due to random variation (e.g. ‘cherry-pick’ through the many studies done on astrology, and you *will* find studies with statistically significant differences!)
  - See http://xkcd.com/882/
  - Solution: Run another experiment!

Controlled Experiment Warning II

- On the other hand, just because something is not statistically significant does not mean that there is no causal effect.
- In particular, if there was ‘only’ a 90% chance that the difference was not due to random variation, it in fact is still very likely that there was a real causal effect.
- In sum, like the margin of error, don’t regard ‘statistical significance’ as some kind of magical boundary. Remember that it merely reflects a (rather arbitrarily chosen) cut-off point of 95% confidence.
- Indeed, depending on the context and the stakes, you may want to either raise or lower this confidence level.
- Or, even better, don’t use this black-and-white significant-or-not distinction in the first place: just calculate your confidence level and be done with it!

Controlled Experiment Warning III

- As in reasoning involving statistics in general, the statistics are only meaningful if the experiment was properly conducted.
- In particular, it is actually pretty hard to really 'control' an experiment:
  - Factors that may make difference may not be anticipated and thus not controlled for.
  - Subjects may not be 'blind': the knowledge that they are in a certain kind of experimental setting (or in which group!) may effect the results
    - Hence, use of placebo's
  - Experimenters may not be blind either: experimenters themselves may (often unconsciously) treat subjects differently depending on whether they are in experimental or control group: experimenter bias
    - Hence, use of 'double-blind' studies