"That's what I want to say. See if you can find some statistics to prove it."

Statistical Inference

(Lies, damned lies, and … ?)

What are statistics?

- A statistic is a *number* that represents something important about the object of study.

- Most statistics summarise general characteristics of a (possibly large) set of data.

- With any statistic, you have to ask **how well it measures** the property of interest.

What are statistics?

- The most common statistics are *averages* (mean, median) and *measures of spread* (standard deviation, variance).
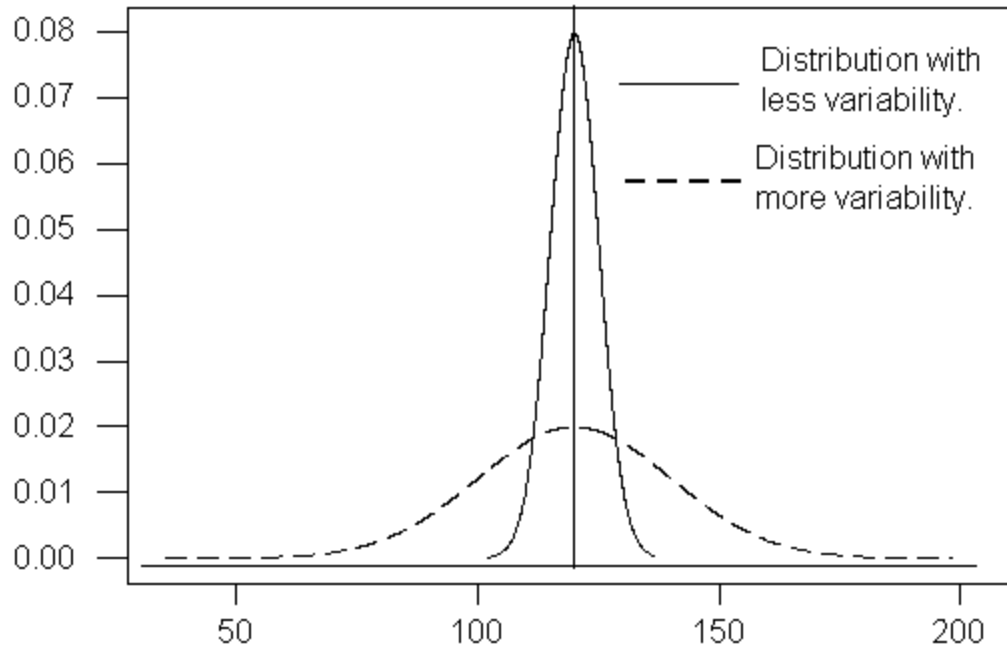
Sampling

- The group of objects that one is studying (e.g. Canadian women over the age of 40) is called the *population*.

- But, in order to get information about the population, one cannot usually measure them all. There are too many!

- Instead, one measures a tiny fraction of the population, called the *sample*.

Representative Samples

- A "fair sample", or *representative* sample, has the same general characteristics (e.g. mean, variance) as the population, for the property of interest.

- Of course we can't tell *directly* whether we have a representative sample, as the population itself is unobservable.

- So we use techniques that make it *likely* that we have a sample that is *approximately* representative.

Techniques

1. Use a sufficient sample *size*.

2. Use a *random* sampling method, i.e. one that gives each member of the population an equal chance of being selected. (The sampling method is *unbiased*.)

3. Use a *stratified* sample, i.e. one that is engineered to match the population in certain known characteristics deemed to be relevant. E.g. make sure that you have 50 men and 50 women, if sex may be relevant.

Points to remember

1. A random sample is always unbiased, but it can still be unrepresentative, through sheer bad luck.

   – E.g. for an election poll you might happen to sample mostly Greens.

   – (A random sample with some stratification is more reliable.)

2. A true random sample is usually impossible, so stratification w.r.t. known relevant factors attempts to compensate for this.

   – But, in order to be successful, the stratification needs to use the most relevant categories.

Points to remember

3. A large, heavily-biased sample is useless.
   - Don't be fooled by impressive-sounding sample sizes.

4. Concerning the 'size' of a sample, the important thing is the actual *number* of objects sampled, not the *percentage* of the population sampled.
   - E.g. a sample of 10,000 Canadians is *large*, even though it is only 0.03% of the whole population.

Larger sample = see smaller effects

sample of 2000+

sample of 30 - 100

sample of 10 - 30

Example:

"It is commonly held that women have, on average, slightly higher verbal ability than men. To test this hypothesis, we took a random sample of 100 current male creative writing students at UBC, and another random sample of 100 current female creative writing students at UBC.

However, when we measured the verbal IQ of these students, there was almost no difference between the average scores for the men and the women. So this common idea is a myth.

Do you agree?

Biased sampling
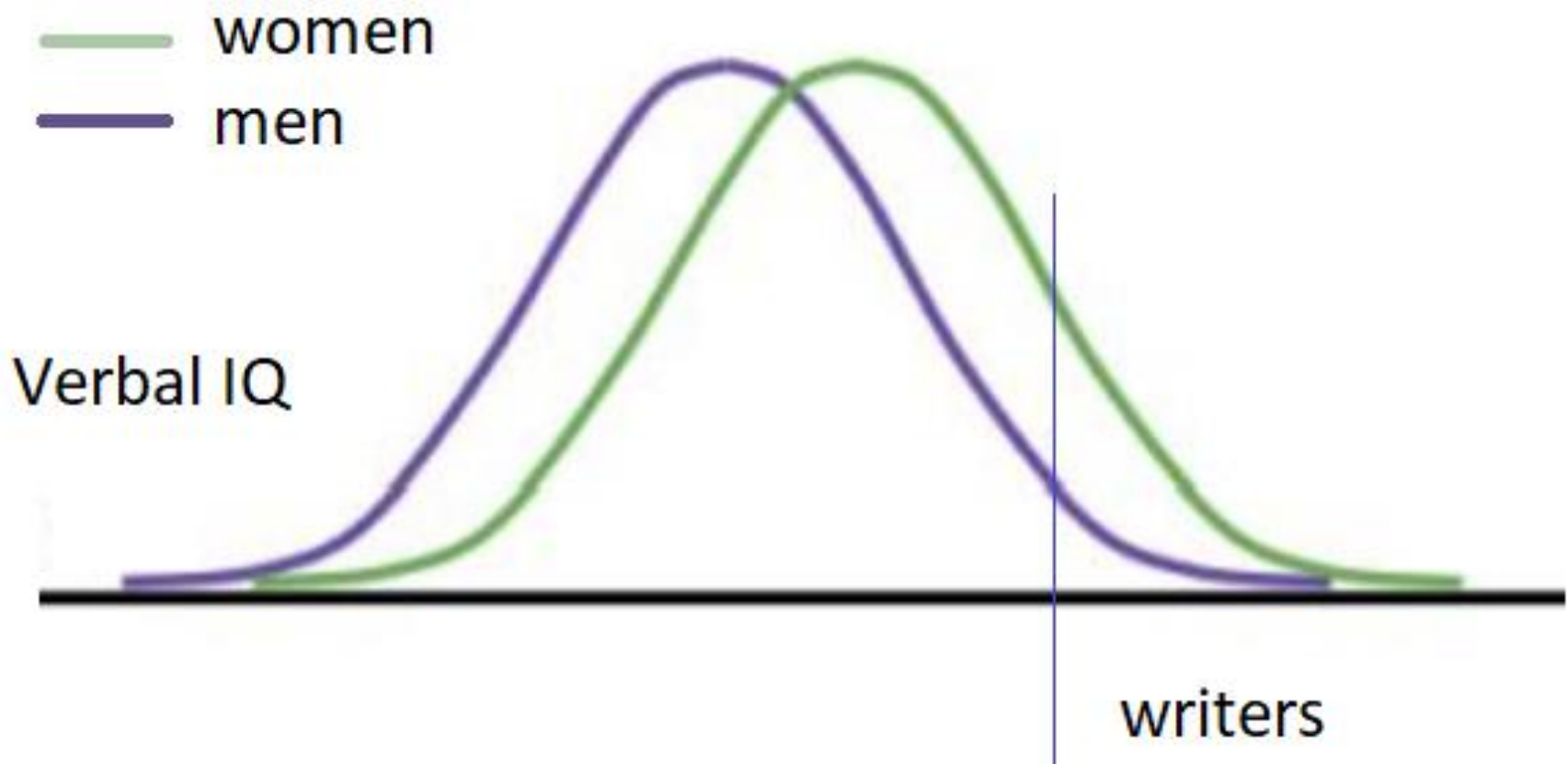
What do you measure?

- Before you choose a statistic, you need to decide how to measure the property of interest.

- **Motto**: *If you don't count it, then it doesn't count.*

  - Properties like "safety" (or "risk"), health, prosperity, quality of life, poverty, etc. *can* all be represented with numbers. But it can be tricky to decide what the best measure is.

2014 Transit Score Rankings — CANADA

TOP CANADIAN CITIES	TRANSIT SCORE		
1 Toronto	78	3 Vancouver	74
2 Montréal	77	4 Winnipeg	51
		5 Ottawa	49

Find rentals near public transit on **WalkScore.com**.

Canadian Transit Scores by Walk Score (Used with permission)

Question: *Is the measure suitable?*

13

Which is the best measure of safety?

a. Cycling is about as safe as driving a car. Cyclists average 0.51 fatalities per million hours of riding, whereas car drivers average 0.47 fatalities per million hours of driving.

b. Driving a car is much safer than cycling. In Canada, for example, studies show that cyclists have 3.7 times as many fatalities as motorists travelling the same distance.

c. Cycling is much safer than driving a car as a means of regular transportation. People who ride a bike even 40km a week have all-cause mortality just 0.72 of the average (even after adjusting for age, sex, education level, leisure time physical activity, body mass index, blood lipid levels, smoking and blood pressure).

d. Cycling is much safer than driving, from the point of view of other road users. Compared to a car driver, a cyclist has less than one fiftieth of the chance of killing another road user.

These alternative measures highlight the fact that safety is always:

- *For* some person(s), and
- *From* some risk(s).

Which persons should be included?
Which risks should be included?

"If you don't count it, then it doesn't count"

"Conventional planning tends to value motorized travel more than nonmotorized travel. A motor vehicle trip to a health club is counted, but a recreational walk or cycling trip is often ignored." (Todd Litman, 2004)

BTW: a one man show!

Victoria Transport Policy Institute

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Who We Are

The Victoria Transport Policy Institute is an **independent research organization dedicated to developing innovative and practical solutions to transportation problems**. We provide a variety of **resources available free** at this website to **help improve**

Newest Resources

Congestion Costing Critique: Critical Evaluation of the "Urban Mobility Report"
The *Urban Mobility Report* (UMR) is a widely-cited study that estimates U.S. traffic congestion costs and recommends congestion reduction solutions. This study identifies various biases in the UMR's analysis. As a result of these problems the UMR's congestion cost estimates represent upper-bound values, which are much higher than the results from other studies that use more realistic assumptions. The UMR

Which persons should be included?

- E.g. John Adams and others have found that car seatbelt legislation *decreases* the number of deaths among vehicle drivers and passengers, but *increases* the number among pedestrians and cyclists.

- Should the **risks to pedestrians** be included, when considering the safety of seatbelt legislation?

Seat belt laws: why we should keep them

Table 1. Figures obtained from percentage changes in deaths and killed or seriously injured (KSI), applied to the totals for 1982

Road user group	Change in deaths		Change in KSI	
	Percent	Number	Percent	Number
Car drivers	−18	−267	−23	−4476
Front seat passengers	−25	−165	−30	−2837
Rear seat passengers	+27	+80	+3	+141
Pedestrians	+8	+150	−0.5	−95
Pedal cyclists	+13	+38	+5	+298
Total	−3.6	−164	−12	−6969

Allsop et. al (*Significance*, June 2008.)

Take "*exposure*" into account

"Why people get so scared about swimming with man-eating sharks is beyond me. It's much safer than driving to the mall, which everyone does without a thought.

Every year in the US there is about 1 person killed by a shark, while 33,000 are killed on the roads."

While in 1971, 80% of seven- and eight-year-old children went to school on their own, by 1990 only 9% were making the journey unaccompanied, with more than four times as many seven- to 11-year-olds being driven in 1990 compared with 20 years earlier.

Why are parents now driving their children to school, instead of letting them travel independently? Most say it is because the roads have become busier, and are now too dangerous for their children to walk or cycle on by themselves.

Yet official statistics show the opposite trend. Over this 20-year period the roads became steadily safer, as measured by decreasing numbers of road accidents, injuries and deaths. In fact, the number of children killed on the roads fell from 1,000 in 1971 to just 400 in 1990.

Glenn Welander (*Swedish Bicycle Helmet Initiative*)

"Still more scientific findings show that mandatory bicycle-helmet wearing is an effective road safety intervention. In New Zealand, helmet legislation has led to a 19% reduction in head injuries among bicyclist of all age groups in its first 3 years."

Malcolm Wardlaw

"Careful readers will note that nowhere does Welander claim helmets have reduced the risk of head injury *per individual cyclist*. This is because helmet compulsion only achieves a reduction in head injuries by deterring cycling. He mentions that head injuries in New Zealand have fallen by 19%, but this is less than the fall in the level of cycling since the helmet law."

Part 2

More about applying numerical measures

Ratios or differences?

- Suppose your hourly wage increases from $12 to $14. Is that a big or a small increase?

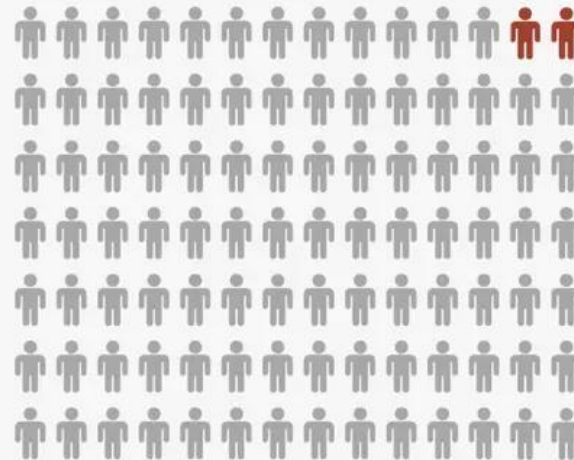- Your boss's hourly wage increases from $30 to $34. Is that a bigger increase than yours?

	You	Boss
Difference	$2	$4
Ratio	1.17 (17% increase)	1.13 (13% increase)

one less had heart attack

Relative Risk Reduction: 50%
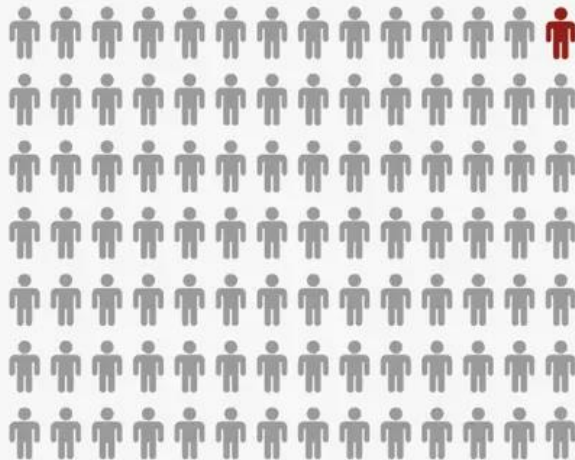
Experimental Pill

Placebo

Reporting the results of a large 2008 study, The *New York Times* noted that the risk of heart attack was "more than cut in half" by statins.

"You know that in relative terms, this
is roughly equivalent to Bill Gates
giving you five million dollars."

SIPRESS

The Telegraph

Global warming? No, actually we're cooling, claim scientists

A cold Arctic summer has led to a record increase in the ice cap, leading experts to predict a period of global cooling.
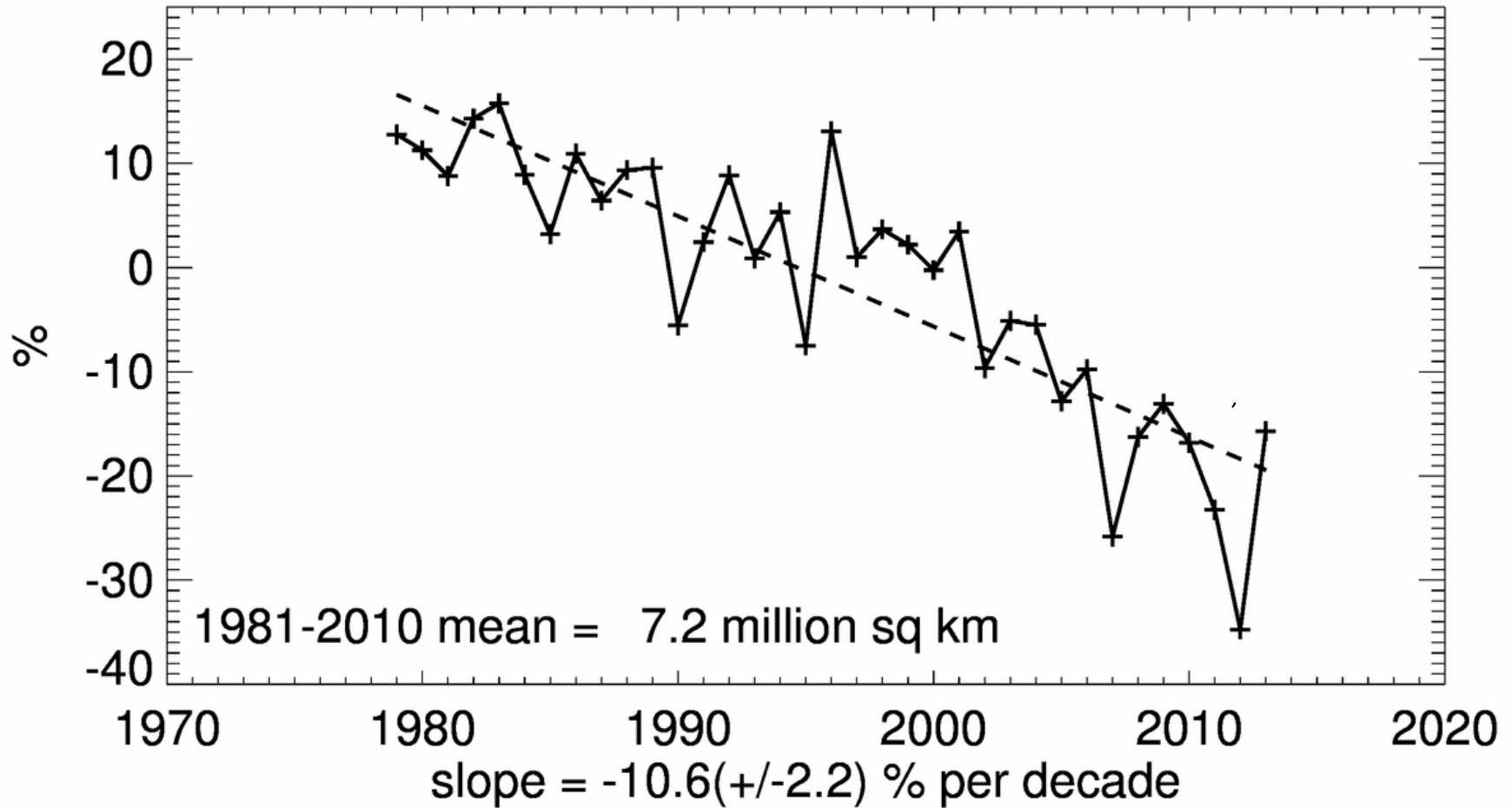
By Hayley Dixon

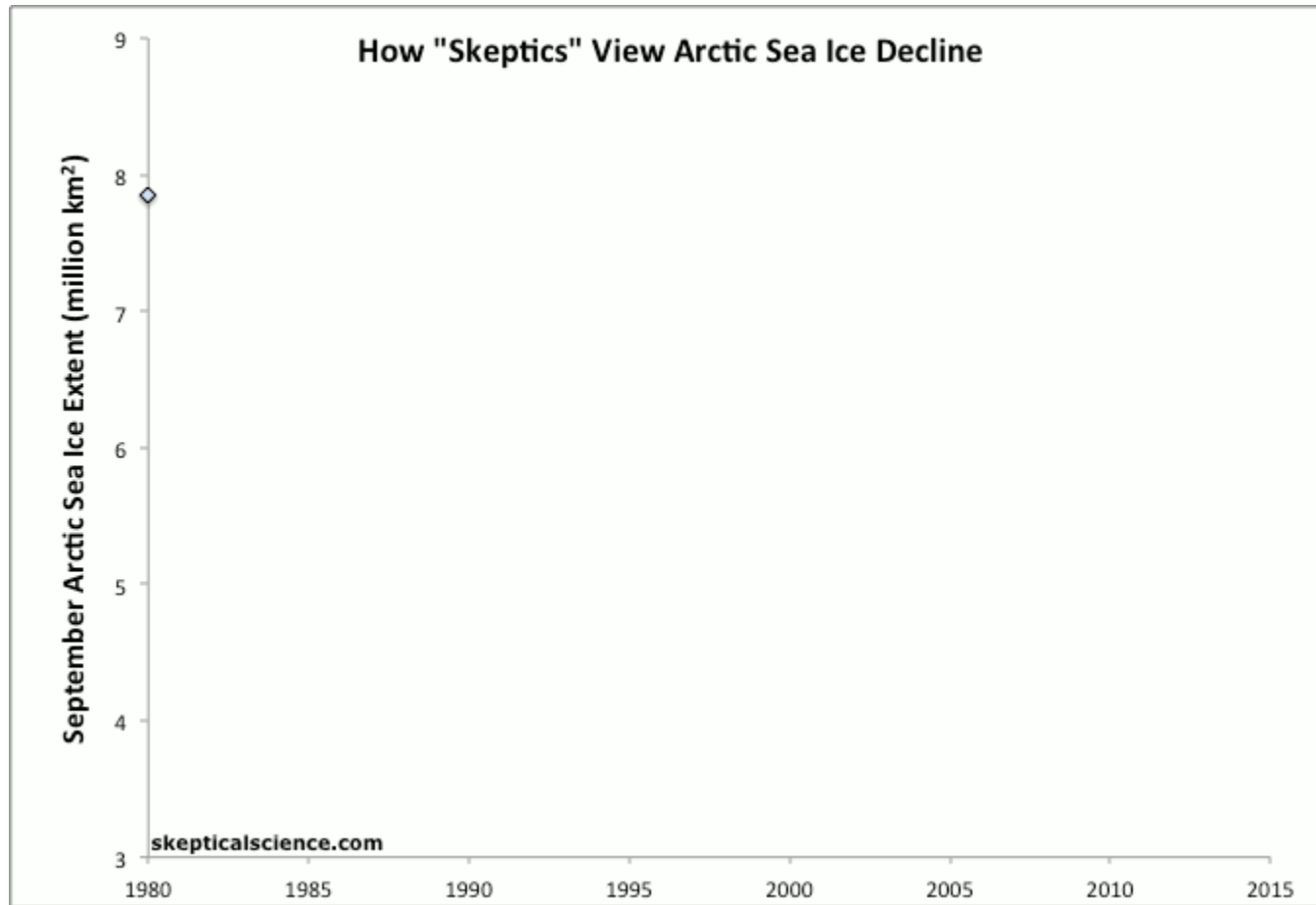9:55AM BST 08 Sep 2013

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2113 Comments

There has been a 60 per cent increase in the amount of ocean covered with ice compared to this time last year, they equivalent of almost a million square miles.

Northern Hemisphere Extent Anomalies Aug 2013

1981-2010 mean = 7.2 million sq km

slope = -10.6(+/-2.2) % per decade

- Is the recent decline in Arctic sea ice now over?

"There has been a 60 per cent increase in the amount of ocean covered with ice compared to this time last year …"

-- *The Daily Telegraph,* Sept. 8th 2013.

- People who eat hamburgers have 28 times the chance of developing variant Creutzfeldt-Jakob disease, which is always fatal. Don't have a cow, man!

- 170 cases of vCJD in the UK, among 62 million population. Suppose this results from 40 million Brits eating beef once per week, for 10 years.

  Then risk of vCJD per hamburger = 8×10^{-9}.

  If the average death costs 30 years, then **the average burger costs 8 life-seconds** from vCJD risk.

Deaths vs. YLL

- YLL = "Years of Life Lost"

- The life expectancy of an 80 year old is about 7 years.
  - So when an 80 year old dies from an external cause (e.g. car crash) they have lost – on average – 7 years of life.
  - And those 7 years are often "quality of life" adjusted to show that they're equivalent to maybe 2-3 years of healthy life. (QALYs)
  - But the death of a 20 year old means a loss of about 60 years, maybe adjusted to 55 healthy years.

disability weights (mostly WHO 2004)

Disability/disease	Utility reduction
Blindness	0.552
Infertility	0.180
AIDS (with ART treatment)	0.167
Bipolar disorder	0.367
Severe hearing loss, untreated	0.333
Loss of leg	0.300
Severe depression	0.8 – 1.0
Alzheimer's	0.625 – 0.9

Measuring risk as loss of life expectancy

- How can you measure risk?

- Usually risks are given in terms of the probability of death, or probability of serious injury. But can you tell how *serious* these risks are?

- There is one death per 100,000 skydiving jumps. Is this an acceptable risk or not?

- The fatality risk of driving a car in Canada averages 8.2 deaths per billion km. If you drive 20km one day, getting to Langara and back, the probability of death from that is about 0.000000164. Is that a problem? Should you take the bus?

Measuring risk as loss of life expectancy

- Suppose you're 20 years old. Then if you die today, you're losing about 55 years of life.

- Hence a probability of death 0.000000164 means an *expected* loss of 0.00000902 years.

- 0.00000902 years = 4.74 minutes. So choosing to drive to school, on one day, costs you an *expected 5 minutes of life*. Is that worth it?
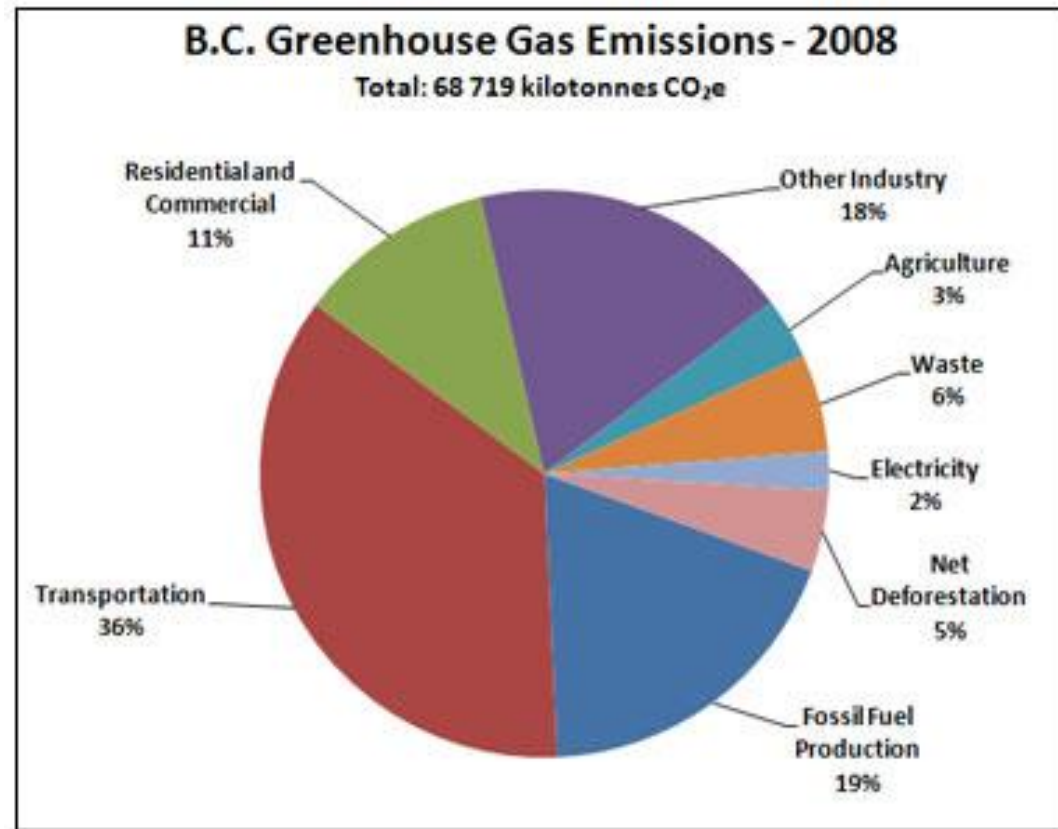
Disability-adjusted life years (DALYs)

- Actually the collision risk is higher than that, as you're more likely to suffer a serious injury than to die. Serious injuries often cause permanent disabilities that reduce one's quality of life.

- E.g. 55 years with a serious disability might be preference-equivalent to (say) 30 healthy years.

- So (e.g.) the risk of driving 20km might end up being more like 20 disability-adjusted life minutes.

Lumping and Splitting

- Data can be grouped, or separated.

- E.g. what is the biggest source of greenhouse gases in B.C.?

B.C. Greenhouse Gas Emissions - 2008
Total: 68 719 kilotonnes CO_2e

- Residential and Commercial 11%
- Other Industry 18%
- Agriculture 3%
- Waste 6%
- Electricity 2%
- Net Deforestation 5%
- Fossil Fuel Production 19%
- Transportation 36%

Lumping and Splitting

"Accidental injury is the most widespread epidemic in the Western world today"

(P. Docking, "Cycle helmets: promotion or legislation?", *Accident and Emergency Nursing*, 1996.)

-- Sure, if you count each disease separately, and lump all kinds of accident together!

-- "accidents" includes:

motor vehicle crashes, poisoning, deaths from falls, choking, drowning and fire.

- Poisoning is the only kind that's growing rapidly = "Epidemic". Road accident rates are declining!!

Part 3

Correlation and Causation

Correlation

- Two factors are (positively) *correlated* when they "vary together", so that one is more often present when the other is present, compared with when it is absent.

- For example, smoking and cancer are correlated. This means that cancer occurs more frequently in smokers than in non-smokers.

Formal Definition

- Let $F(X \mid Y)$ denote the proportion of objects with property X *among* those with property Y. We read this as "The frequency of X among the Y"

- Then X and Y are positively correlated when

$$F(X \mid Y) > F(X)$$

Or equivalently: $F(X \mid Y) > F(X \mid \text{non-Y})$

Or $F(Y \mid X) > F(Y)$

- **E.g.** Are children (age 10) who eat candy every day more likely to get arrested for a violent offense by age 34?

	Violent offense	**No violent offense**
Daily candy eater	6,932	3,228
Not a daily candy eater	1,887	4,842

- Note that correlation (unlike causation) is a *symmetric relation*.
  - If A is *positively* correlated with B, then B is *positively* correlated with A.
  - If A is negatively correlated with B, then B is negatively correlated with A.

Correlation and Causation

- If two variables are correlated, then it could be *just a coincidence*.

  – 'spurious', 'accidental', 'just due to chance'.

- But if the correlation is persistent, then there's *likely* to be a causal connection of some kind between those variables.

Ice cream and forest fires
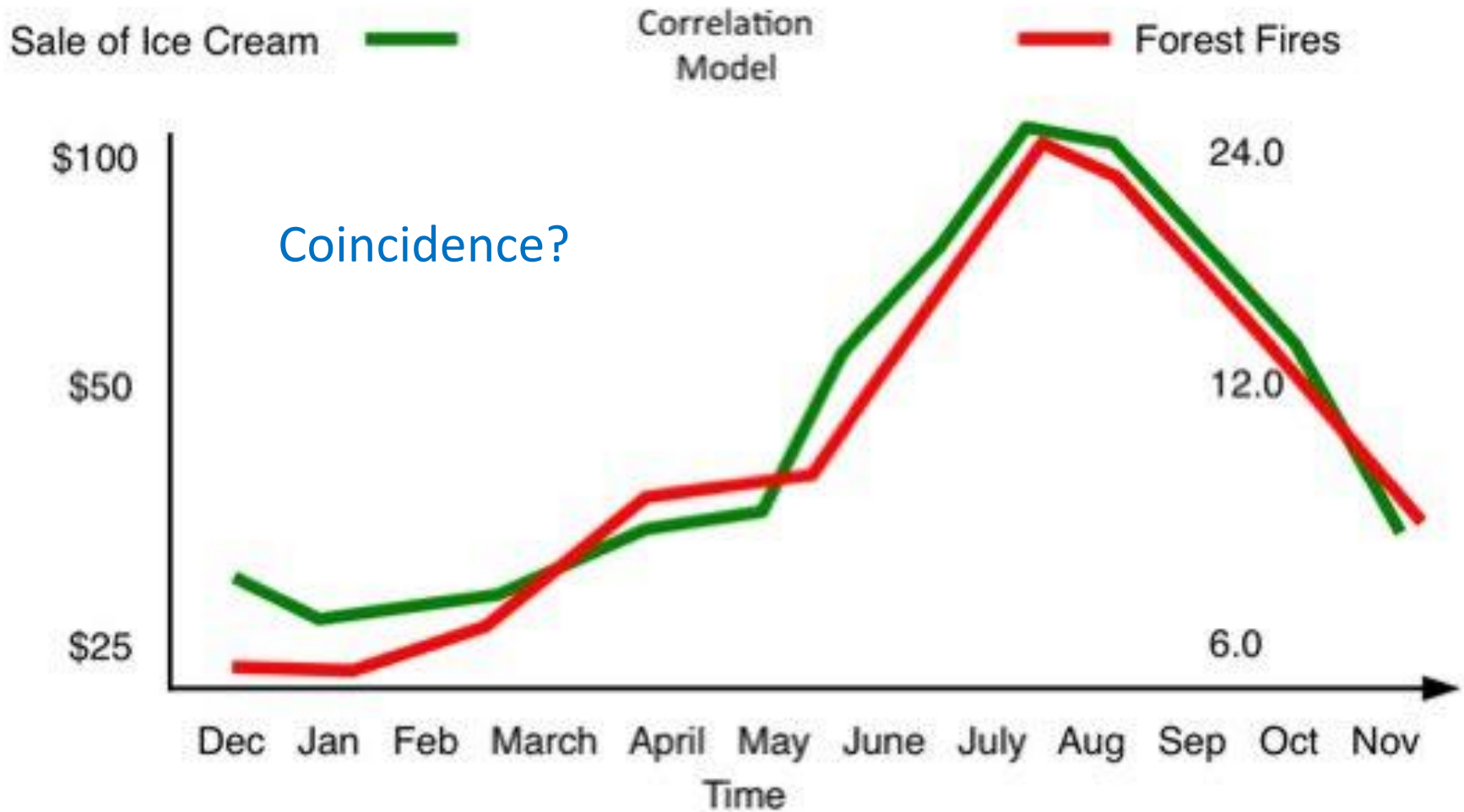
Tiffany was diagnosed with breast cancer at age 21. She had been keeping her cell phone in her bra for 4 years, in exactly the place where the tumour appeared.

- As imports of Mexican lemons have increased in the USA, highway fatalities have decreased. (**Five** data points from 1996 to 2000, $R^2 = 0.97$)

- N.B. This correlation was found by 'data mining'.
  - If you check for correlations between thousands of pairs of variables, you're bound to find a few strong correlations, even if there are no causal connections.

- The main general patterns of causal connection between A and B (e.g. smoking and cancer) are:

1. A causes B
2. B causes A
3. There is a third variable X, such that X causes A, and X causes B.

Smoking

↓

Cancer

Cancer

↓

Smoking

X factor

↙   ↘

Smoking   Cancer

5. It is well established that the death rate from heart attacks among widows is higher than the general rate among married women. Alice says this is because being married reduces stress and thus inhibits heart attacks.

Is there any other possible explanation for this correlation? Describe one such explanation that seems reasonable to you.

- **Marriage and wealth**. Married women tend to be richer than single women. Find yourself a mate, girls!

- **Bald people and hats**. Bald people are more likely to wear hats. So if you want to keep your hair, don't wear one!

- Whiskey makes a good general?

Abraham Lincoln's aides were alarmed by reports that General Grant was drinking too much whiskey. When Lincoln was informed he said, "Find out what brand it is and send a case to my other generals."

(From Porter)

- A careful study of smoking at Langara college linked smoking with academic success. The GPA of each student was categorised as 'high' or 'low', and each student was also classes as a smoker or a non-smoker. The results are shown in the table below.

	Smoker	Non-smoker
High GPA	25	160
Low GPA	41	142

(i) What is meant by the claim that smoking is *positively correlated* with having a low GPA? Show that such a correlation exists here.

(ii) What typical causal patterns are used to explain an observed correlation between two factors A and B?

(iii) Write down what you see as the two or three best explanations of the *specific* correlation observed in this case, between smoking and GPA. (Use different causal patterns.)

- N.B.

"A causes B" = not-A causes not-B.

(Assumes "causes" = "increases the chance".)

- If the chance of B is higher when A happens, then the chance of B is *automatically* lower when A doesn't happen.
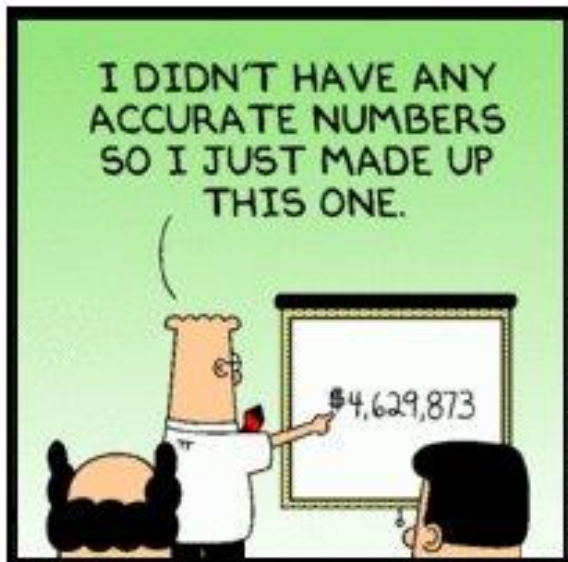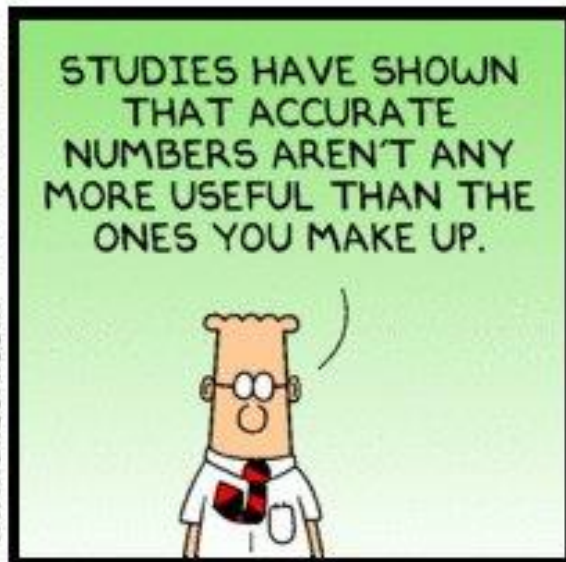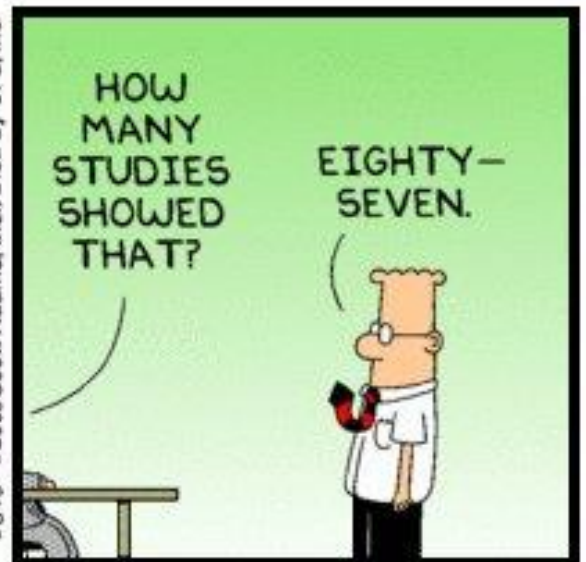
"Statistical significance"

- Suppose you want to compare Langara students with UBC students, concerning their height. So you pick **one** student randomly from each school, and we get:
  - UBC: 188 cm
  - Langara: 162 cm

- Is that a significant difference?
  - Yes

- Is it *statistically significant?*
  - No. (It's quite likely due to chance.)

"Statistical significance"

- Now suppose you take random samples of 5,000 students from each school. The results:
  - UBC: 170 cm   95% confidence [169.5, 170.5]
  - Langara 168.5 cm 95% confidence [168, 169]

- Is this a significant difference?
  - No.

- Is it *statistically significant*?
  - Yes. (The difference is probably not due to chance)

John Arnold ✓
@JohnArnoldFndtn

How to turn $1 bln into $50 bln:
1) Start a sugar pill company
2) Paint them 20 different colors
3) Test each color as a pathway to slow cognitive decline from Alzheimer's
4) Hope law of averages gets at least 1 false positive
5) Sell to a Big Pharma co that doesnt do its own R&D

7:53 AM · Nov 1, 2023 · **78.9K** Views

- **N.B.** It's very likely that *at least one* colour will coincide with a "statistically significant" improvement.

Part 4

Surveys, bad graphs, and practice questions

Surveys

- A survey is one method used to gain information about a population.

- A sample of people is selected, and they are *asked questions*. Their answers are recorded, analyzed, etc.

- Of course people sometimes lie! Due to:
  - The desire to be socially acceptable
  - Sensitive questions
  - Protecting self-worth, etc.

Problems with survey questions

1. **Confusing questions**. In some cases, it may not be clear exactly what answering "yes" or "no" entails, especially with *negative questions.*

E.g.

"1. Private property should not be expropriated for treaty settlements. (Yes/No)"

(From the British Columbia aboriginal treaty referendum, 2002. Angus Reid: "one of the most amateurish, one-sided attempts to gauge the public will that I have seen in my professional career.")

Leading questions

2. A **leading question** sets a context that encourages one kind of answer.

(b) Do you watch the trashy, voyeuristic, TV show *The Real Housewives of Orange County*? (yes/no)

(e) Do you acknowledge the obvious fact of God's existence?

3. Restricted answering options

Respondents can also be guided by giving them a rather restricted range of options.

(c) What is the best way to deal with panhandlers? (i) stiff fines, or (ii) jail sentences?

(d) Are you in favour of war? (yes/no)

Issues with graphs

- Truncated y-axis

- Unsuitable scale of y-axis

- Represent numbers with 2D (or 3D) objects

x and y axis
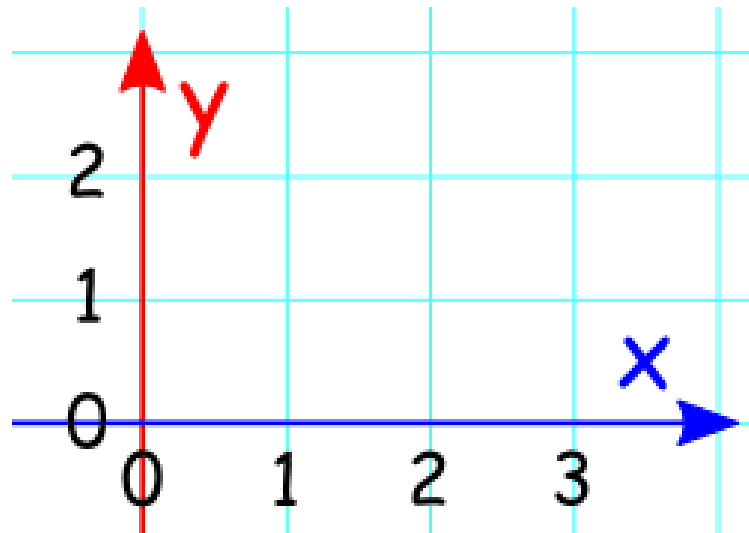
- The "x axis" is the horizontal one. Usually this is the "input" variable.
- The "y axis" is the vertical one. Usually this is the "output" variable.

"Truncating the y-axis"

- Instead of showing the *whole* y axis, right down to zero, people sometimes only show the top section.
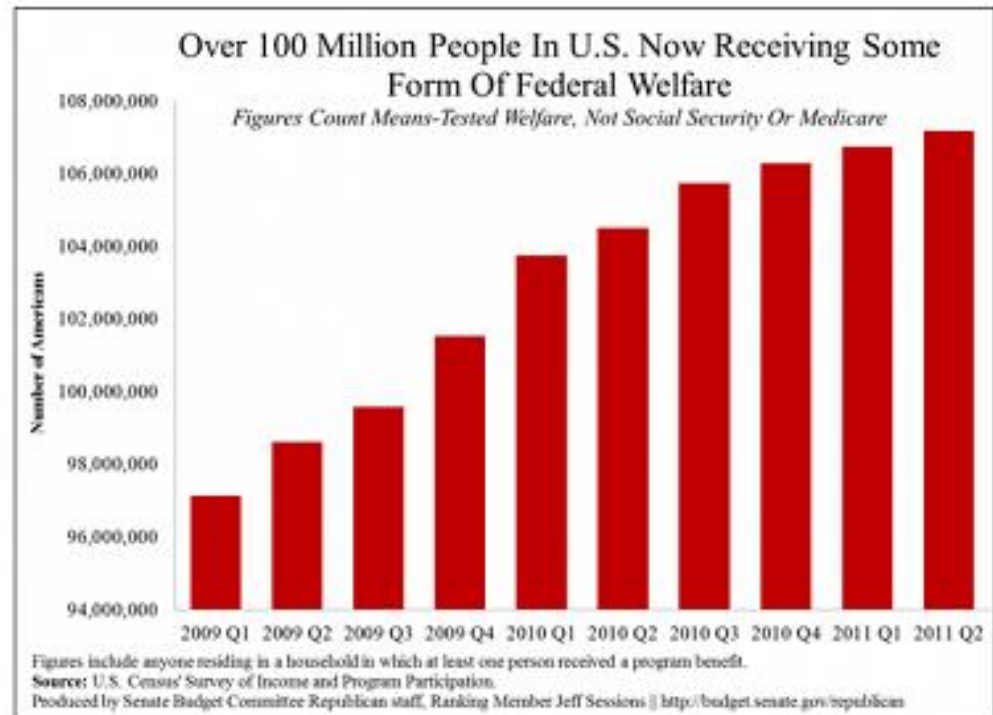
IF BUSH TAX CUTS EXPIRE

TOP TAX RATE

NOW 35%

JAN. 1, 2013 39.6%
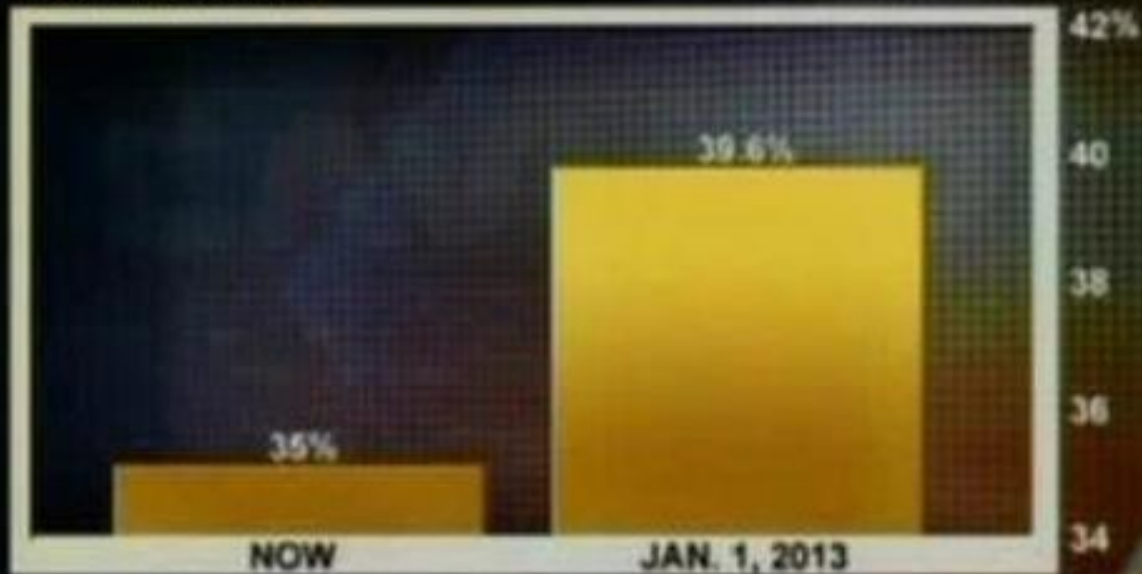
8:01p ET

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TOP STORIES   TECHNOLOGY   CONSUMER

WITH THE JUSTICE DEPARTMENT AND AQUIRES FULL T

DOW 13008.68 ▼ 64.33   S&P 1379.32 ▼ 5.98   NASDAQ 2939.52 ▼ 6.32
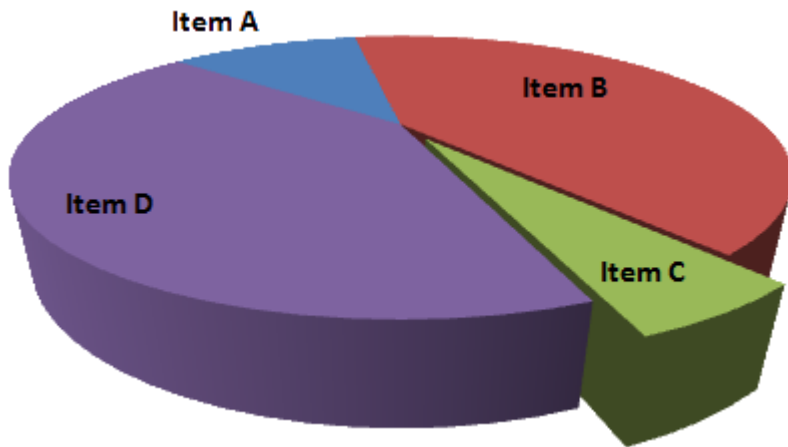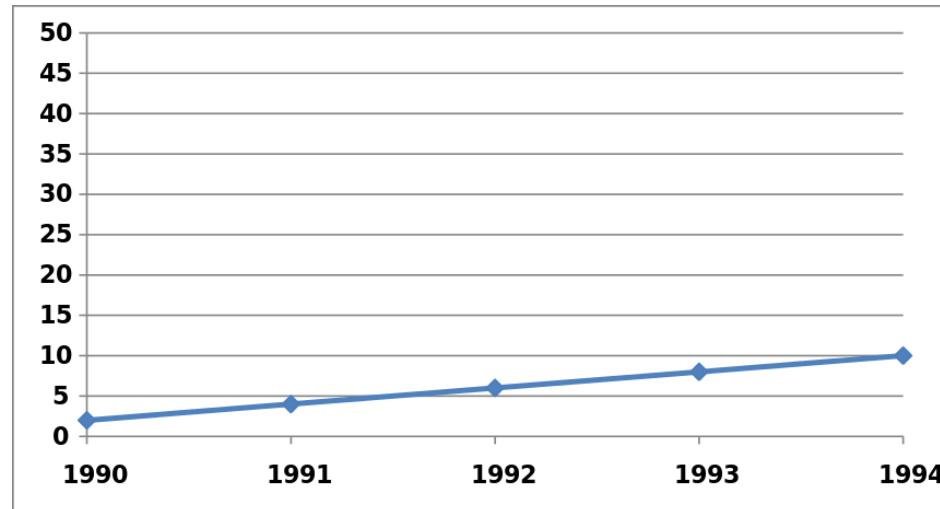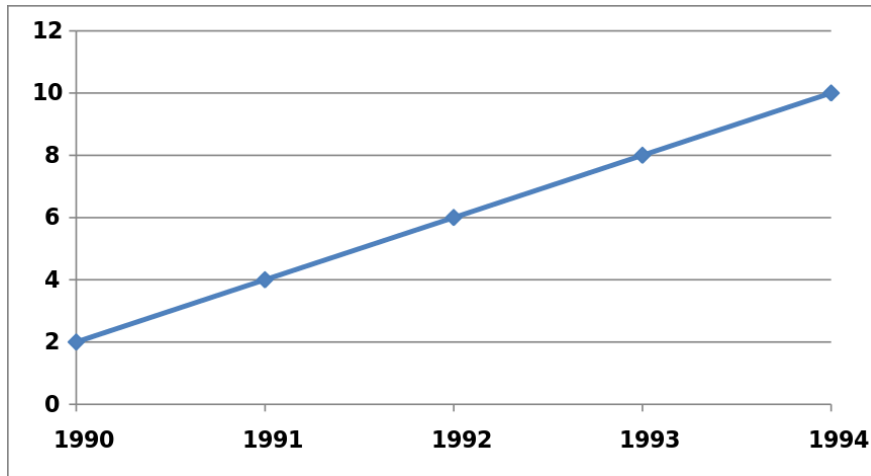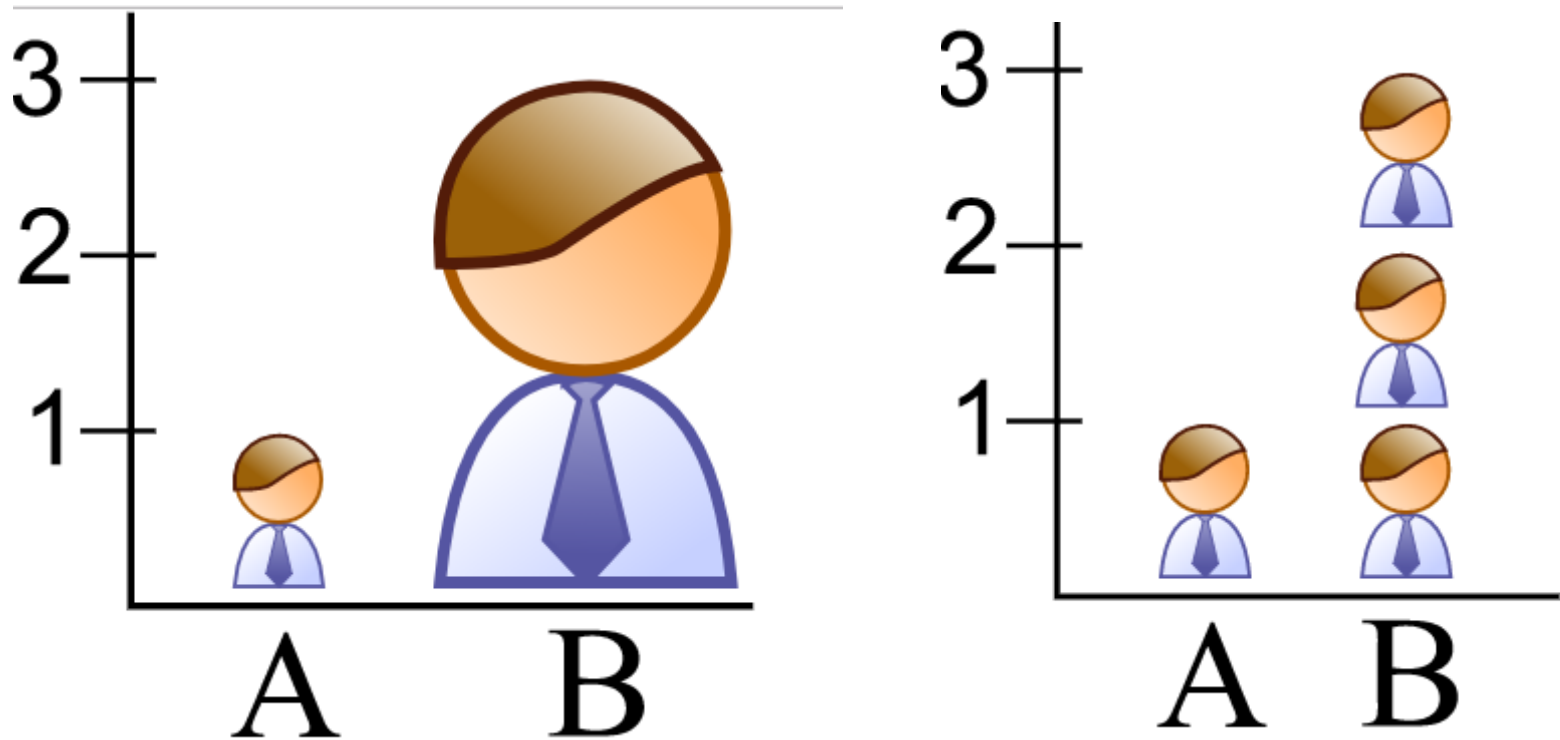
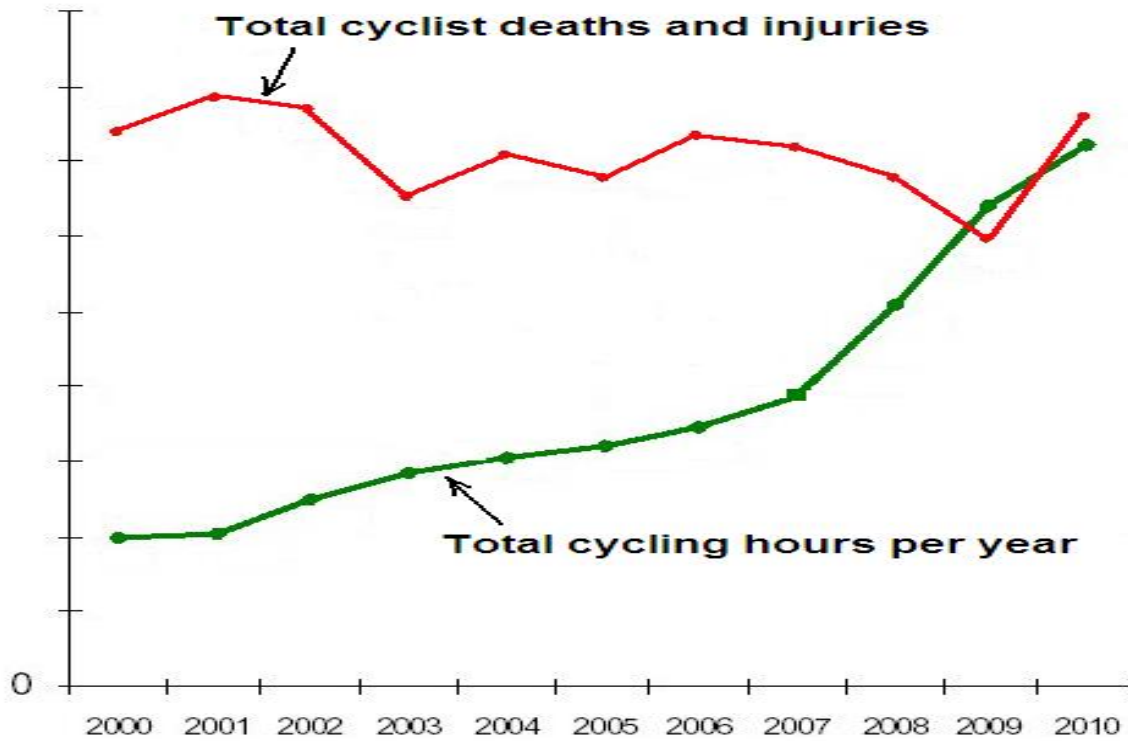Is truncating the Y–axis misleading?
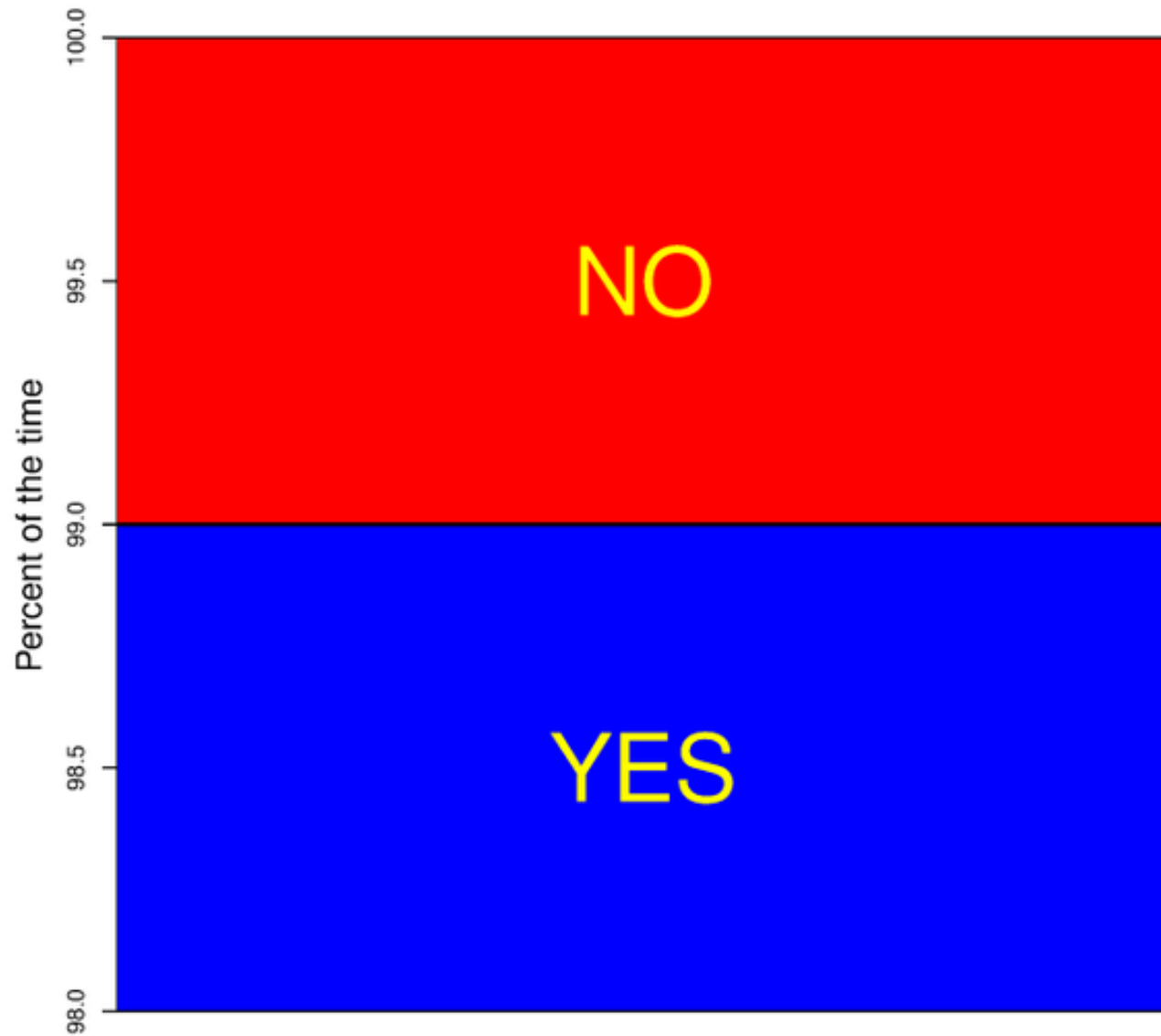
3D is better?
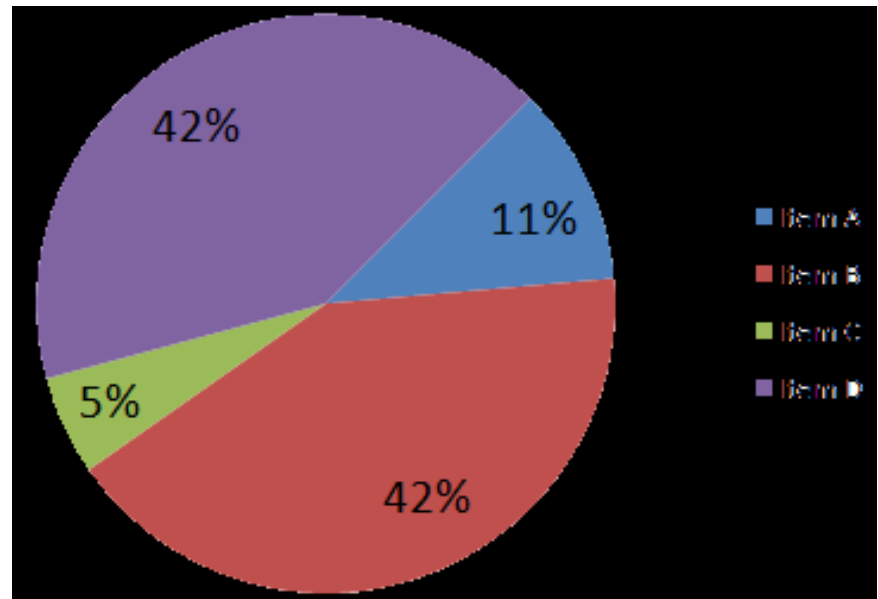
Most suitable scale of y-axis

Using 2D representations

Practice Questions

- The following questions are taken from former quizzes.

Total cyclist deaths and injuries

Total cycling hours per year

0

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

(i) What relationship does this graph show between the general popularity of cycling (measured as the total hours of cycling) and the risk of death and injury per hour of cycling?

(ii) Using Mill's methods, what seems (superficially at least) to be a reasonable *causal* conclusion to draw from these data? Briefly explain your answer.

(iii) Is there any alternative causal hypothesis that might explain this graph? Suggest any you can think of, and identify any additional variables that you might examine to distinguish between these alternative accounts.

6. For each of the following, comment on the use of statistics, pointing out any flaws.

(i) Jack has just moved to a new city, and is complaining about the weather. "It's just so harsh, so extreme," he moans. A local, somewhat offended, retorts that the year-round average temperature is a very comfortable 17 Celsius.

N.B. "A statistician is someone who can have his head in an oven and his feet in ice, and will say that on the average he feels fine."
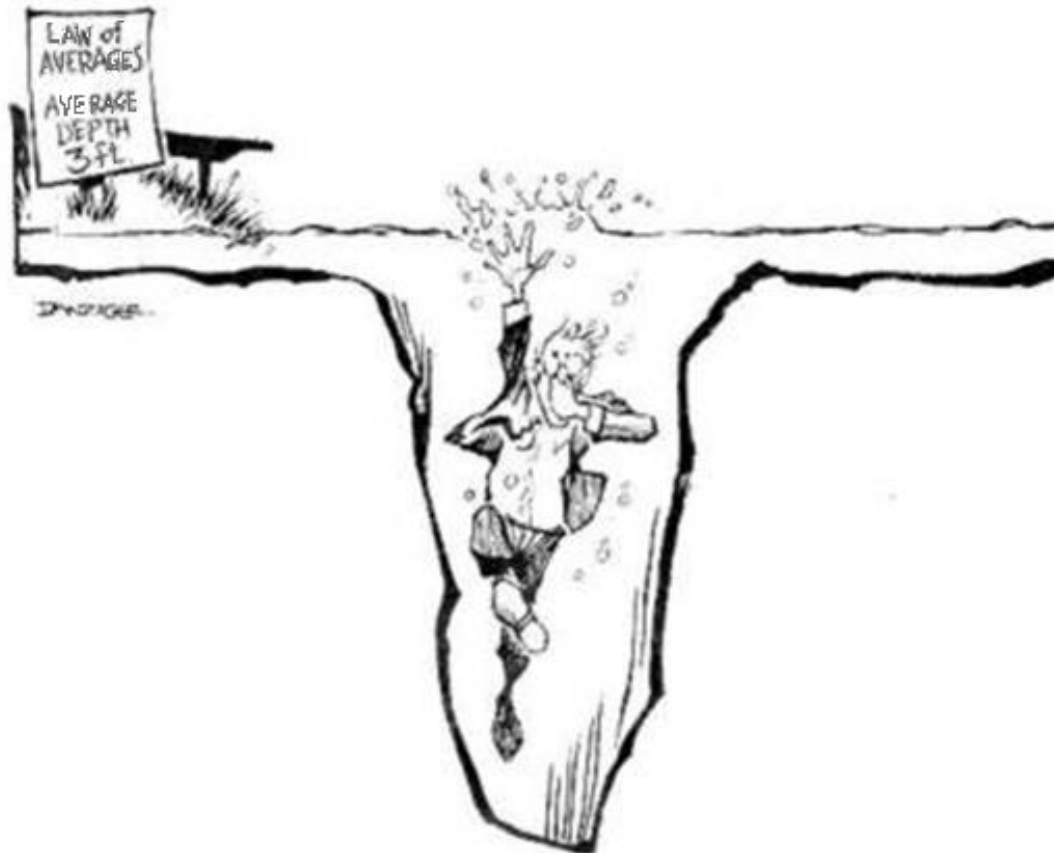
Gun deaths in Florida

Number of murders committed using firearms

2005
Florida enacted
its 'Stand Your
Ground' law

873

721

1990s
2000s
2010s
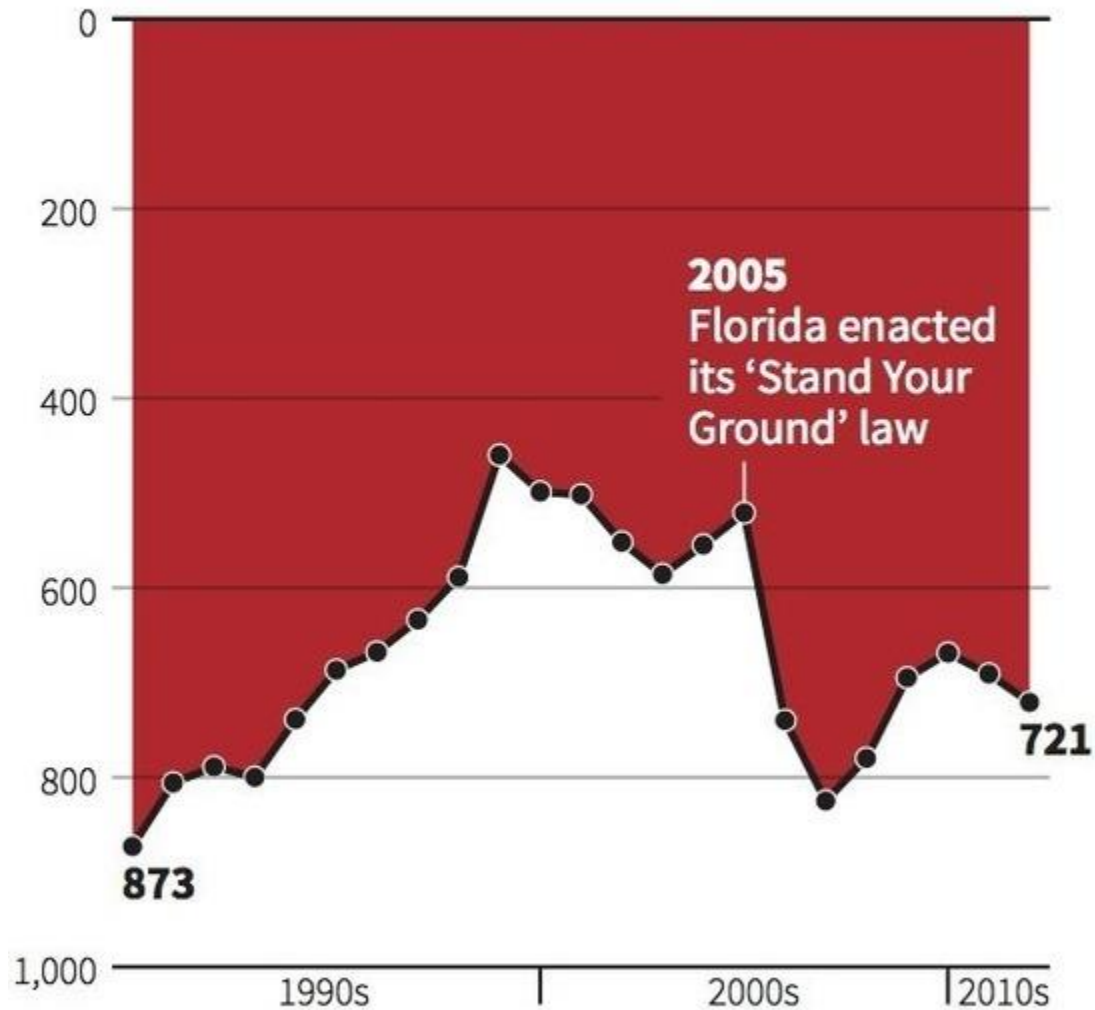
Source: Florida Department of Law Enforcement

C. Chan 16/02/2014

REUTERS

(ii) I wouldn't take anti-depressants if I were you. A recent study showed that people on anti-depressants have much higher rates of suicide than those who are not.

N.B. This is called "intervention selection bias"

(iii) Campbell isn't going to survive the next election. We did a survey, and only 24% of people agreed with the statement:

"Gordon Campbell, a convicted criminal, is the right person to lead our province"

(iv) Some people claim that the new study by Qiu and Hudson totally refutes the old Bennett study. But this is ridiculous. Bennett looked at over 10,000 cases, whereas Qiu and Hudson's sample included only 2,100 cases.

(v) A lot more men are gay than is commonly realised. A study of 1,300 men in Canadian prisons shows that more than 25% of them have at least one homosexual encounter per year.

Existing parks and protected areas should be off the table, for native treaty negotiations. 95% of British Columbians answered "yes" to:

"Parks and protected areas should be maintained for the use and benefit of all British Columbians. (Yes/No)"