

# Why Statistical Thinking Matters

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May 18, 2004 - Greater Cleveland Council  
of Teachers of Mathematics

# "Doing The Math"



7/5 of Americans Don't Bother To  
Do The Math

**53%**

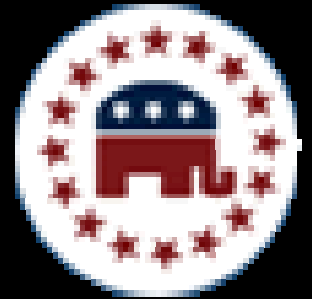
**49%**

**19%**



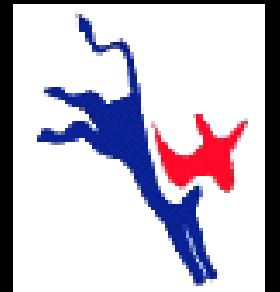
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\$1,000,000,000,000  
\$1,000,000

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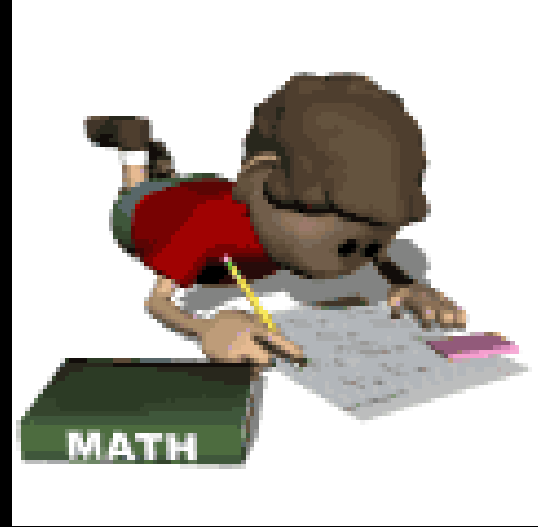


"Mathematical apathy is one of the top three educational problems this nation faces," the Secretary of Education warned.

"The other one is illiteracy."

Source for "Doing the Math": [www.defectiveyeti.com](http://www.defectiveyeti.com)

# Grim Realities



- Math teachers do noble work for minimal earthly rewards.
- Our students are not just younger versions of ourselves, and the ways in which they are different are important.
- “It is easy to lie with statistics. But it is easier to lie without them.” – F Mosteller

# Statistical Thinking Involves Making Sense of Data

- What has happened?
- What is happening?
- What comes next?
- How can we better understand what the data have to tell us, and how can we use that information to help us better understand the truth?

# How Much Does Extra Time on the SAT Help?

- SAT I: Reasoning Test
  - Is speed particularly important?
  - # of students requesting extra time is way up
  - Are students gaming the system effectively?
- Do students benefit from additional time?
  - October 2000 administration (3 math sections, 3 verbal and 1 experimental)
  - 100,000 examinees randomly allocated to 10 configurations (sizes) of the experimental section

Wainer, Bridgeman, Najarian and Trapani (2004) How much does extra time on the SAT help? *Chance* magazine, volume 17, # 2, pp. 19-24

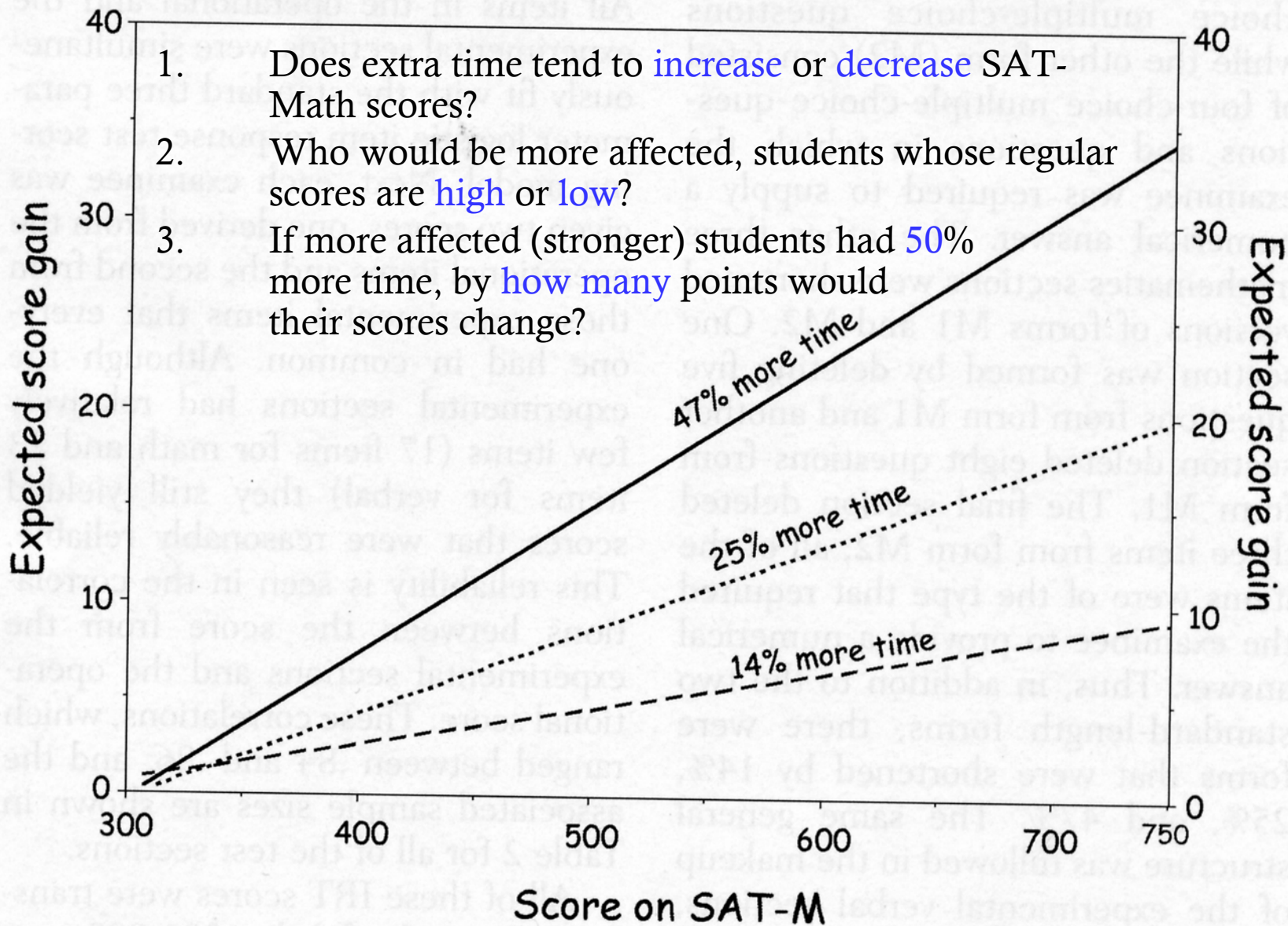


# Does Extra Time on the SAT Help? Four Key Questions

1. Does extra time tend to **increase** or **decrease** student SAT-Math scores?
2. Who would be **more** affected, students whose scores on the regular test are **high** or **low**?
3. If the more affected students had **50%** more time, by **how many** points would you expect their scores to change?
4. Would scores be more affected on the **Math** or on the **Verbal** sections of SAT?

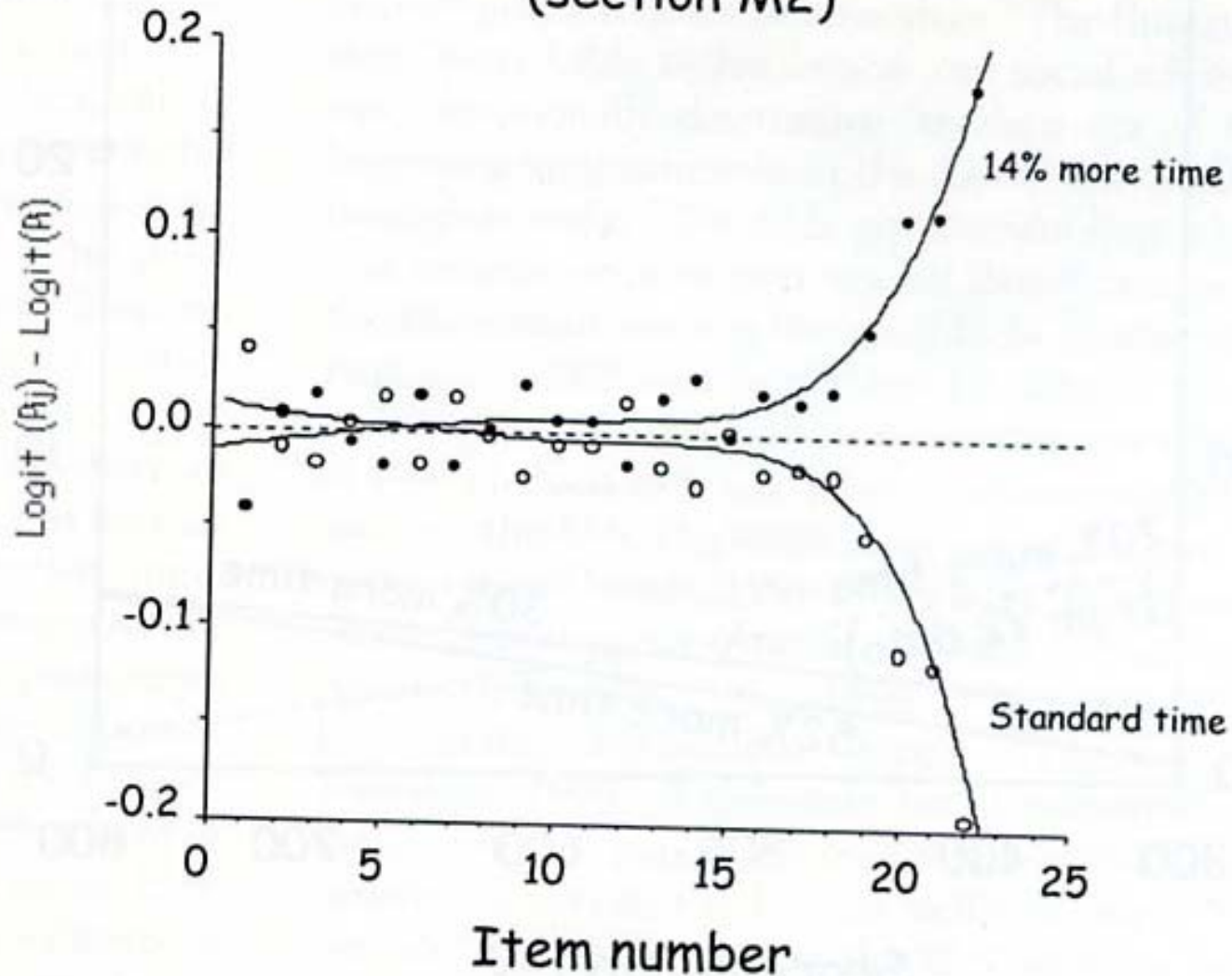
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# The more time available on SAT-M the greater the gain



1. Does extra time tend to **increase** or **decrease** SAT-Math scores?
2. Who would be more affected, students whose regular scores are **high** or **low**?
3. If more affected (stronger) students had **50%** more time, by **how many** points would their scores change?

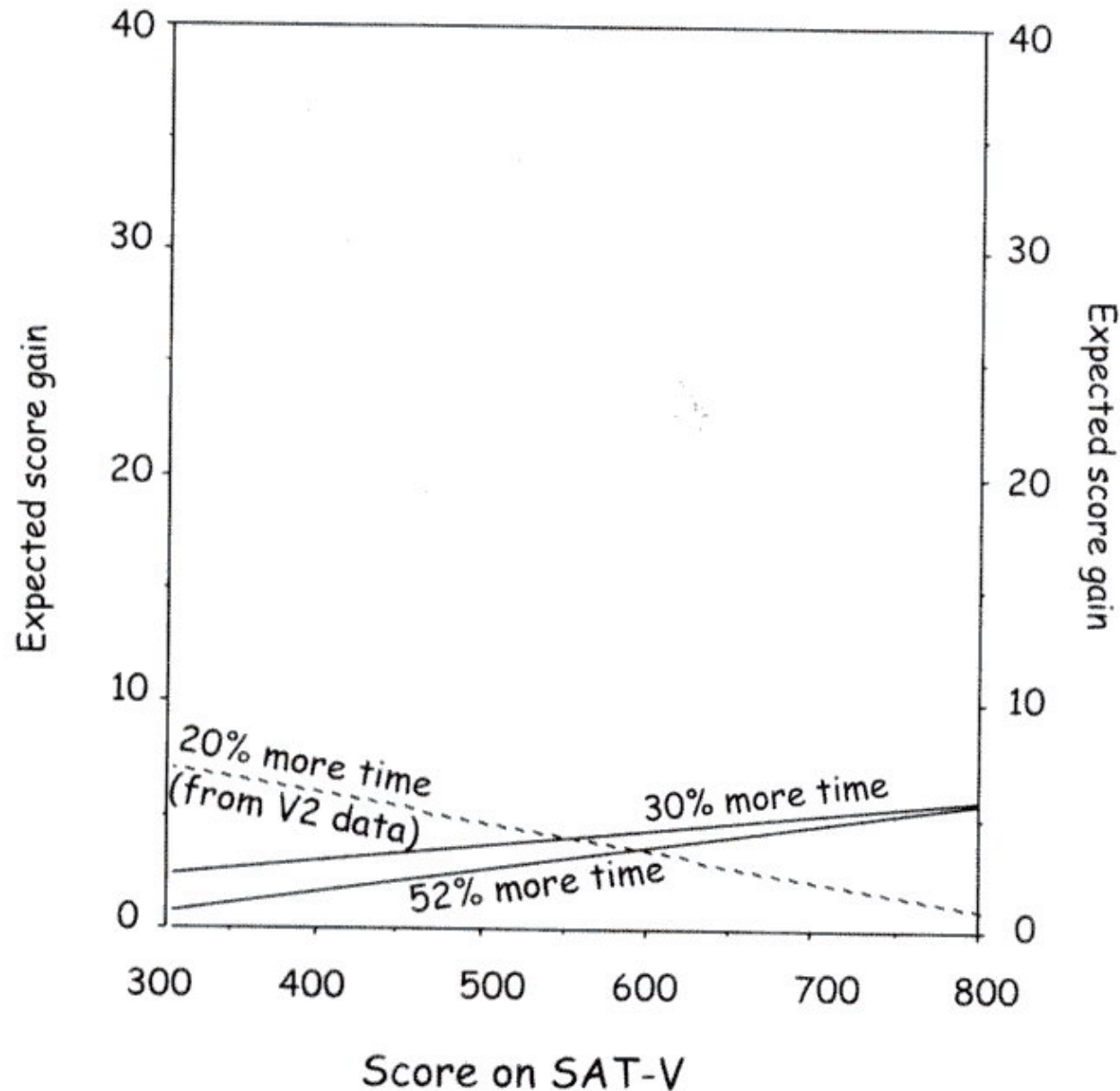
When more time is available students  
score higher on mathematics items  
(section M2)



# Conclusions

1. More time **increases** Math scores
2. Most affected are **strongest** students.
3. 50% more time could lead to **35** pt. increases
4. **No** large verbal effect.

Extra time on the verbal section has a small and inconsistent effect



# Statistical Thinking is a crucial part of our lives ...

- As educators
- As decision-makers
- As community leaders
- As people

# The New Statistical Literacy

- Only Big Ideas Need Apply (details automated)
  - The omnipresence of variation
  - CONCLUSIONS ARE UNCERTAIN
  - Avoid inference from short-run irregularity
  - Avoid inference from coincidence

Source: David Moore, Statistical Literacy and Statistical Competence in the New Century (visit [www.statlit.org](http://www.statlit.org))

# Appreciation of the Scientific Method

- We want students to understand what they are doing!
  - The need for data
  - Collecting data well
  - Omnipresence of uncertainty
  - Variability's impact on decision-making
  - The “big picture”



# Wisdom from Research in Mathematics Education

- Students learn by their own activities
- Understanding and procedures are separate domains
- We can't teach a wide audience what we used to think we covered

Source: David Moore, Statistical Literacy and Statistical Competence in the New Century (visit [www.statlit.org](http://www.statlit.org))



# Barriers to Effective Teaching of Statistical Thinking

- Students equate statistics with mathematics, and expect the focus to be on numbers, computations and one right answer
- Many familiar words have different or more precise meanings statistically

# What Makes Statistical Thinking Hard To Teach?

- Students are uncomfortable with
  - The **messiness** of data
  - The different possible interpretations based on different assumptions
  - The **extensive use of writing and communication** skills
  - The importance of familiar contexts

# Implications for Instruction - Developing Good Habits

- How to best obtain meaningful, relevant data to answer the question at hand?
- Relation of data to the context
- Interpretation of conclusions in non-statistical terms
- Thinking beyond the textbook
- Help students see relevance of statistics outside of math class

# Assessing Statistical Thinking

The FBI reports that nationally 55% of all homicides were the result of gunshot wounds.

In a recent sample in one community, 66% of all homicides were the result of gunshot wounds.

- A. What three possible conclusions could you draw about the percentage from this community compared to the national percentage?
- B. What additional information would you need to begin to choose one conclusion over another?

# Assessing Statistical Thinking

- As part of its twenty-fifth reunion celebration, the Class of '80 of Central University mails a questionnaire to its members. One question asks the respondent to give his or her total income last year.
- Of the 820 members of the class of '80, the university alumni office has addresses for 583. Of these, 421 return the questionnaire.
- The reunion committee computes the mean income given in the responses and announces, “The members of the class of '80 has enjoyed resounded success. The average income of class members is \$120,000!”.
- Suggest three different sources of bias or misleading information in this result, being explicit about the direction of bias you expect.

# Statistical Thinking and an Effective TV Ad

- Three teen-agers bungee out of an airplane while chugging their favorite soda. Two of the boys positively beam with satisfaction.  
The other boy's head explodes.
- Tobacco, the ad concludes, is the only product that kills one in three people who use it. [Duck – Duck – Goose]

# What is "One in Three" (CDC)

- "Of young American adults who smoke, we project that 55 percent will become lifetime smokers, and there is a 50 percent chance that they will suffer a smoking-attributable death. The other 45 percent, who will quit sometime in their adult life, have a 10 percent chance of suffering a smoking-attributable death."
- So, 50 percent of 55 percent plus 10 percent of 45 percent comes out to 32 percent, or—more or less—one in three.

# So What's the Answer?

- Of young American adults who smoke, one in three will die of smoking-attributable diseases.
- Of young American adults who smoke, one in three will die of smoking-attributable diseases, assuming current patterns of smoking and smoking-related death do not change....
- Of young American adults who smoke, one in three will die of smoking-attributable diseases, unless we convince more people to quit than do now, in which case fewer might die.
- Of young American adults who smoke, one in three will die of smoking-attributable diseases, unless increased seatbelt use allows more of them to survive long enough to die of lung cancer, in which case more might die.
- Of young American adults who smoke, one in three will die of smoking-attributable diseases, unless they're socioeconomically skewed so differently from the current crop of smokers that the data's unusable, in which case who knows?



# Statistical Thinking for Community Leaders: Paulos' Ten Question Quiz

1. A crucial number to know is the population of the country of which you want to be president.
  - What is the approximate population of the United States?
  - Of the world?
  - What percentage of the latter is the former?

# Statistical Thinking and Paulos' Ten Question Quiz

2. A news article claims that 15 percent of all strokes occur sometime between noon and midnight on either Friday or Saturday, perhaps because of increased celebrating on the weekends.
  - Do you check with the Centers for Disease Control?
  - Do you stop campaigning on weekends?
  - What's your reaction to this statistic?

# Paulos' Ten Question Quiz

4. Approximately how many Americans died in the attacks on 9/11?
  - There's no moral comparison, of course, but approximately how many die in auto accidents annually?
  - From heart disease annually?

# Paulos' Ten Question Quiz

9. An ace pollster on your staff claims that 63.86 percent of 100 Americans surveyed support your foreign policy.
  - What's your reaction to these numbers?

Source: [http://abcnews.go.com/sections/science/whoscounting\\_index/whoscounting\\_index.html](http://abcnews.go.com/sections/science/whoscounting_index/whoscounting_index.html) (see “Arithmetic and the Candidates”)

# Statistical Thinking and Our Lives

*There are a lot of people in the public who are intimidated by numbers and I think a lot of them become reporters and editors."* – Tom Barrett, political reporter, The Vancouver Sun

# How To Help Reporters Tell The Truth

Tell them candidly about both the strengths and weaknesses of your evidence, your statistics and studies...

1. The Certainty of Uncertainty
2. The Use of Probability
3. The Power of Large Numbers
4. The Danger of Bias

# "Feline High-Rise Syndrome"

NY Times August 22, 1989

- From June-Nov 1984, 132 such cats were admitted to the Animal Medical Center.... Most had landed on concrete.
- 107/132 survived.
- Why?
  - Laws of physics
  - Superior balance
  - Flying-squirrel tactic
- 132 Cats Fell 2-32 stories and were admitted...
  - 17 were put to sleep, largely due to \$\$\$
  - 8 more died from injuries
- Cats who fell further had better outcomes. Why?
  - 0 of 13 cats died that plunged from > 9 stories.
  - Sabrina fell 32 stories on concrete, had [mild] lung puncture and chipped tooth

# Why Did Cats from Higher Floors Fare Better?

- Terminal velocity for a cat is 60 MPH (humans: 120 MPH).
- Until terminal velocity, cat may react to acceleration by reflexively extending its legs, making it more prone to injury?
- But after terminal velocity is reached, the cat might relax and stretch its legs out like a flying squirrel, increasing air resistance and helping distribute the impact more evenly?

What is the real reason for this phenomenon?



# How To Help Reporters Tell The Truth

5. The Ubiquity of Variation
6. The Hierarchy of Studies
7. Reporting (Publication) Bias
  - There sometimes seem to be only two types of medical / public health stories: New Hope and No Hope. All else gets ignored or buried.
8. Look out for missed explanations

# Correlation is NOT Causation

- Nations that add fluoride to their water have a higher cancer rate than those that don't. Is fluoridation a plot?
- Nations that add fluoride to their water are generally wealthier; more health-conscious.
- Thus a greater percentage of their citizens live long enough to develop cancer, which is to a large extent, a disease of old age.



# Statistical Thinking and Our Lives - Medicine

- Fostering understanding is tricky...
  - Probability statement: You have a 30% chance of a side effect from this drug
  - Frequency statements: “Three out of every 10 patients have a side effect from this drug”

Gigerenzer G and Edwards A (2003) *British Medical Journal*, volume 327 (27 September) 741-744

# Fostering Insight On Relative Risks

- About 4 out of every 1000 women (age 40 or older) who do not undergo mammography screening die of breast cancer, compared with three out of every 1000 who are screened...
  - Relative Risk: “Mammography reduces breast cancer mortality by 25%.”
  - Absolute Risks: “In every 1000 women who undergo screening one will be saved from dying of breast C.”
  - “To prevent one death from breast cancer, 1000 women need to undergo screening for 10 years.”

# An Experiment: 2 Ways To Represent the Same Statistical Information

- Conditional Probabilities

The probability that a woman has breast cancer is 0.8%. If she has breast cancer, the probability that a mammogram will show a positive result is 90%. If a woman does not have breast cancer, the probability of a positive result is 7%.

What is the probability that a woman who has a positive result actually has breast cancer?

- Natural Frequencies

Eight out of every 1000 women have breast cancer. Of these 8 women with breast cancer, seven will have a positive result on mammography. Of the 992 women who do not have breast cancer, some 70 will still have a positive mammogram.

Take, for example, a sample of women who have positive mammograms. What percentage of these women actually have breast cancer?



# Statistical Thinking is about ...

- The need for data
- The importance of data production
- The omnipresence of variability
- The measuring and modeling of variability
- Interpreting results in context

**Statistics is  
too important  
to be left to  
Statisticians !**