Greater Cleveland Council of Teachers of Mathematics
"Back to the University" Mathematics Workshop
October 10, 2003
Keynote Address for
"**Data Analysis and Probability:**
Aligning Instruction with the Ohio Model Curriculum"

"Statistical Thinking and Data Awareness"

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National Council of Teachers of Mathematics (www.nctm.org)
Principles and Standards for School Mathematics
Data Analysis and Probability Standard

The Data Analysis and Probability Standard recommends that students **formulate questions that can be answered using data** and addresses what is involved in **gathering and using the data wisely**. Students should learn how to **collect** data, **organize** their own or others' data, and **display** the data in graphs and charts that will be useful in answering their questions. This Standard also includes learning some **methods for analyzing data** and some **ways of making inferences and conclusions** from data. The basic concepts and applications of probability are also addressed, with an emphasis on the way that probability and statistics are related.

Instructional programs from pre-kindergarten through grade 12 should enable all students to:

- Formulate questions that can be addressed with data and collect, organize and display relevant data to answer them
- Select and use appropriate statistical methods to analyze data
- Develop and evaluate inferences and predictions that are based on data
- Understand and apply basic concepts of probability

Statistical Thinking and Data Awareness

Greater Cleveland Council of Teachers of Mathematics – October 10, 2003

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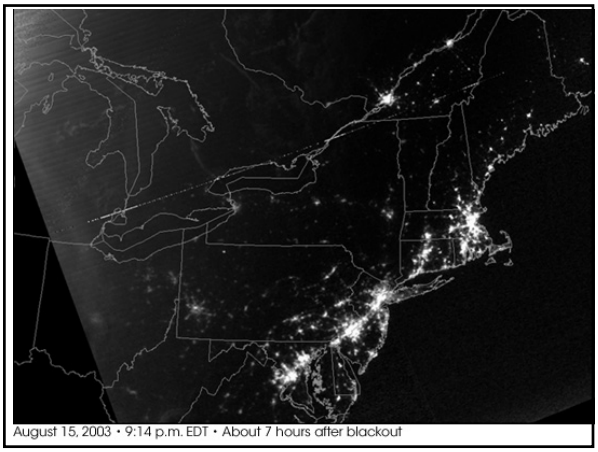


Goals for Today

- Describe what statistics is (and isn't).
- Help you see the value of statistical thinking in your life and teaching.
- Give you some "news you can use".
  - Provide some strategies for teaching and learning about statistical ideas
  - Provide strategies for learning from data

Statistics is…

- about VARIATION
  - Variation results when two or more things, which we may think are exactly the same, turn out to be different.
  - Understanding and reducing variation in processes are keys to success
  - Variation is everywhere, in everything.

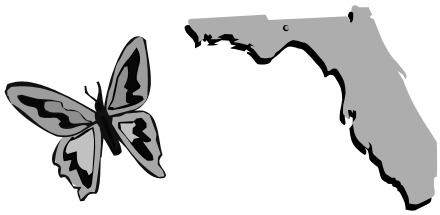
Statistics is …

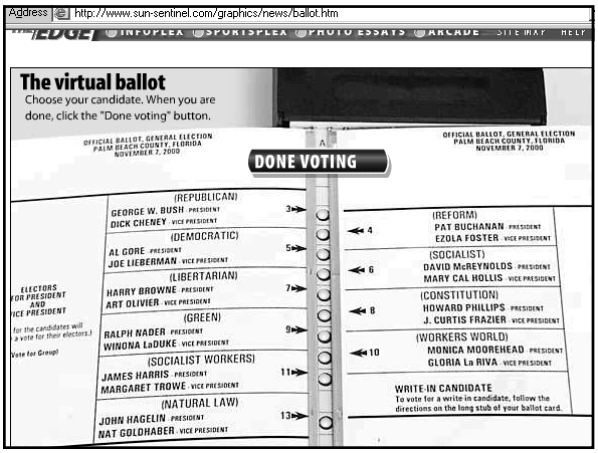
- about making sense of DATA
  - How do we gather the data?
  - How do we summarize the data, using both pictures and summary numbers?
  - How do we use the data to drive decisions or predictions about the world or the future?

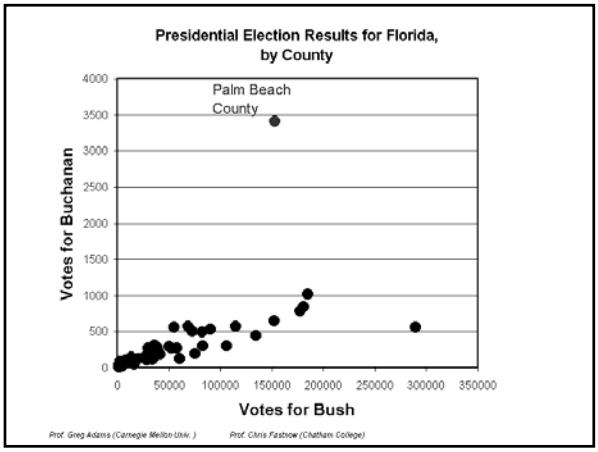
Why Do We Need Data To Make Decisions?

- Without data …
  - Everyone is an expert.
  - Discussions produce more heat than light.
  - Historical memory is poor.
- Data fuel "truth machines"
- Data help us triage the information flood

Data can have a strong impact on how we view the world.

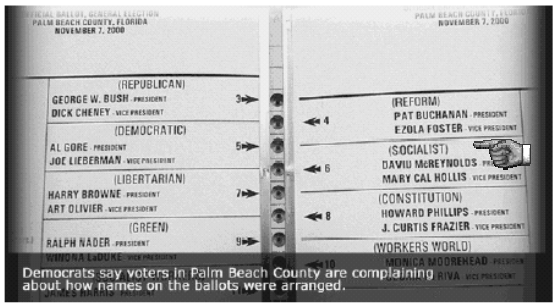




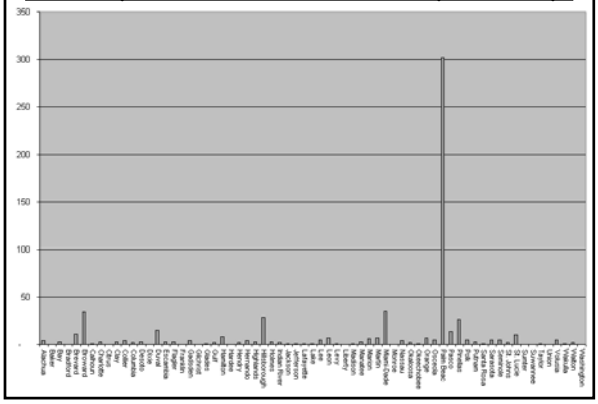


McReynolds Effect?

Sample ballot



McReynolds Votes in FL, by County



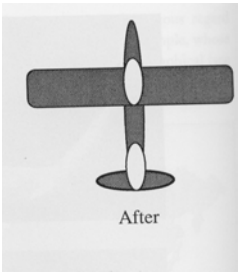
First Law of Statistics: *DTDP*

- Draw
- The
- D@$%
- Picture

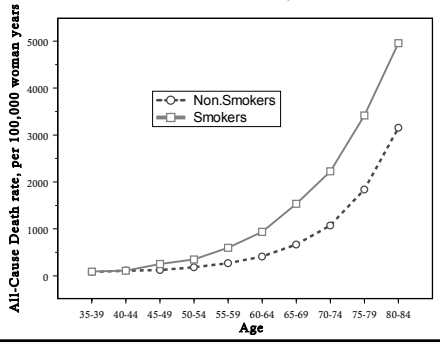
A picture is worth a lot of numbers...

Abraham Wald

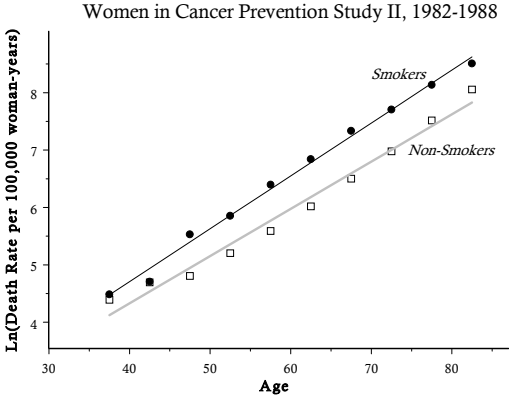
- WW II
- Trying to determine where to add extra armor to planes
- Data used to drive decisions
- Assumptions?



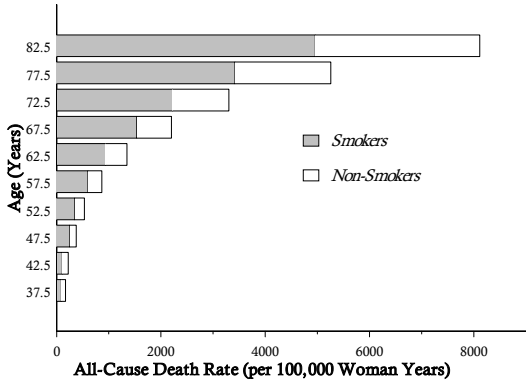
All-Cause Death Rates for Women:
Current Smokers and Lifelong Non-Smokers
Cancer Prevention Study II, 1982-88



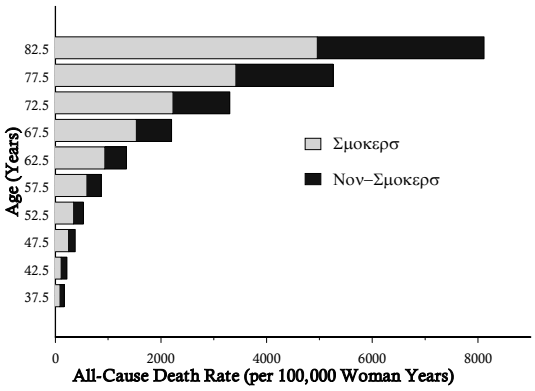
All-Cause Death Rate (Log Scale) Plotted Against Age
Women in Cancer Prevention Study II, 1982-1988



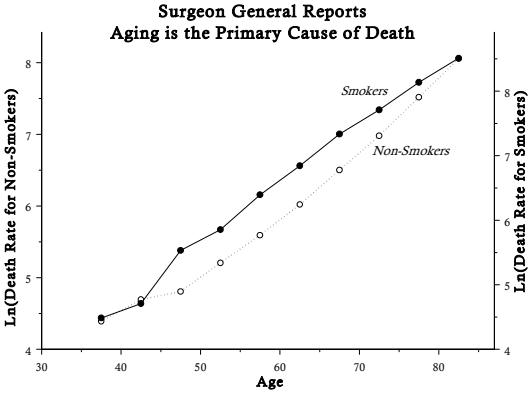
Smoking and Death Rates Shown by Age



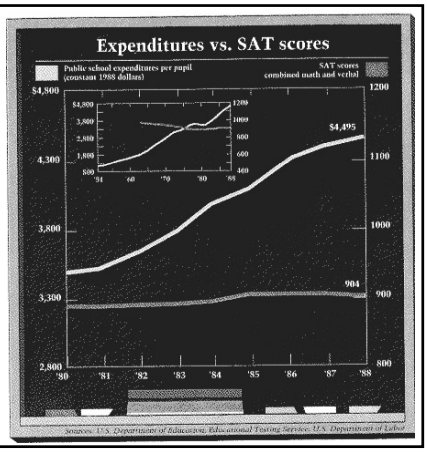
Smoking and Death Rates Shown by Age

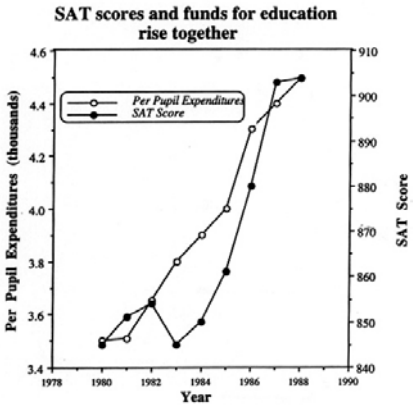


Surgeon General Reports
Aging is the Primary Cause of Death



Forbes
May 14
1990





Statistics is …

- about interacting with TECHNOLOGY
  - Students should think, machines should calculate.
  - Collecting the data is easier than thinking clearly about what you will do with it.
  - Detailed analyses can be generated with great speed – garbage in, garbage out…
  - Thinking about technology is unavoidable

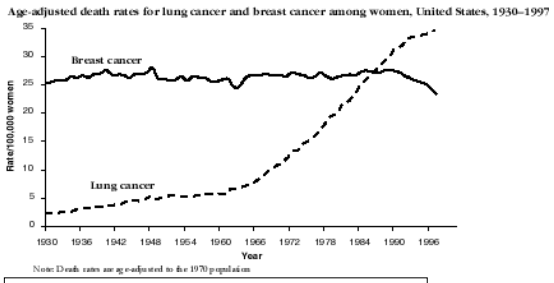
What Are Data?

- Data are numbers?
- Data are useless without context…
  - WHAT is described by these data
  - HOW were these data collected
    - WHO collected these data?
    - WHEN and WHERE were these data collected?
  - WHY were these data collected?

Data Strategies
(details to fit the context)

- Plot your data
- Interpret what you see
- Remember the context
  - HOW, WHAT, WHY
- Consider the best "next step"
  - Numerical summary?
  - Mathematical model?

Age-adjusted death rates for lung cancer and breast cancer among women, U.S., 1930-1997



http://www.cdc.gov/tobacco/sgr/sgr_forwomen/ataglance.htm

On Collecting Data Thoughtfully

"Far better an approximate answer to the right question … than an exact answer to the wrong question."

- John Tukey

When the Answer is Important

In order to conduct a study properly,

- Get a representative sample.
- Get a large enough sample.
- Decide whether it should be an observational study or an experiment.
- Decide precisely what you want to know - what question(s) do you need answered?
- Never spend your entire budget on the 1st run.

Randomized Trials vs. Observational Studies

- We have an outcome measured on two groups of subjects (treated and control).
- We want to make a fair comparison between the treated group and the control group in terms of the outcome.
- Observational Study: people come to us as members of a group (treated or control)
- Randomized Trial: we assign people to groups (using a random mechanism)

A Randomized Trial: Therapeutic Touch

- In Therapeutic Touch (TT) therapy, the practitioner moves her hands near a patient, attempting to manipulate a "human energy field" (HEF), ostensibly to promote healing.
- We'll discuss a trial using 15 TT practitioners.
- Research Question: Can the TT practitioner detect which of their hands (left or right) the investigator's hand is hovering over? (chosen at random via a coin flip)

Rosa L, Rose E et al. "A Close Look at Therapeutic Touch" JAMA, 279(13), 1005-1010.

Experimental Procedure

Emily Rosa showing how her apparatus was marked to facilitate placement of her hands.

- Challenge to practitioners:
  - Each of the 15 subjects warmed up first, then attempted 10 trials each.
  - Of 150 trials, there were 70 successes, or 46.7%.
- Can TT practitioners detect a HEF?

Results of the TT Trial

- We want to know if the TT practitioners can detect a HEF at better than chance levels. [Null hypothesis: pr(detection) = .50]
  - Choice of hand randomized by coin flip
- Result: 70 out of 170 yields P value = .795.
  - If the true proportion of successes is 50%, then an observed proportion of 46.7% successes or more would occur at random about 8 times out of 10.
  - That's not a rare event, so there is insufficient evidence to conclude that the practitioners are performing better than if they were just guessing.

Statistical Thinking in Designing an Experiment

- A credit card bank wanted to test the sensitivity of the market to two factors:
  - the annual fee charged for a card and
  - the annual percentage rate charged.
- The bank selected people at random from a mailing list and offered …
  - 50,000 people a low rate card with no fee
  - 50,000 a higher rate card with a $50 annual fee
- What happened?

Does Prayer Lower Blood Pressure?

USATODAY.com

Prayer can lower blood pressure:[FINAL Edition]

Robert Davis. **USA Today**. Arlington: Aug 11, 1998. pg. 01.D

Abstract (Article Summary)

Attending religious services lowers blood pressure more than tuning into religious TV or radio, a new study says.

People who attended a religious service once a week and prayed or studied the Bible once a day were 40% less likely to have high blood pressure than those who don't go to church every week and prayed and studied the Bible less.

- "Attending religious services lowers blood pressure more than tuning into religious TV or radio, a new study says"

Details of the Prayer Study

- NIH-conducted observational study that followed 2391 people age 65+ for 6 yrs
  - "People who attended a religious service once a week and prayed or studied the Bible once a day were 40% less likely to have high blood pressure than those who don't go to church every week and prayed and studied the Bible less."

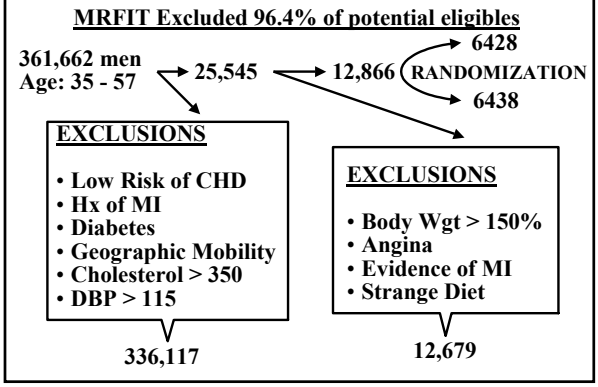
Does Prayer Cause Lower Blood Pressure?

- In observational studies, the groups usually differ in many important ways that may contribute to the observed relationship.
- Could church-goers who pray regularly be different from the other people in the study in ways that might affect their blood pressure?

Why Not Always Do Randomized Trials?

- Randomized Trials…
  - Are Expensive and Time-Consuming
  - May be unethical (e.g., smoking)
  - Practice patterns may make them difficult to conduct (e.g., rehab for stroke, right heart cath for seriously ill patients)
  - Often suffer from limited generalizability, owing to the need to exclude subjects

RCT Subject Selection



Advantages of Observational Studies

- Are widely available, with detailed data
- Enable study of exposures not amenable to randomized trials
- Often work better for exposures with small effect sizes
- Enable study of effects in the "real world"

"Hormone Replacement Therapy Should Be Recommended for Nearly All Women"

Col NF, Eckman MH, *et al.* (1997) Patient-specific decisions about hormone replacement therapy in postmenopausal women. *Journal of the American Medical Association (JAMA),* 277: 1140-47.

"Do not use estrogen/progestin to prevent chronic disease"

Fletcher SW, Colditz G. (2002) Failure of estrogen plus progestin therapy for prevention. *JAMA*, 288: 366-67.

Manson JE et al. for WHI Investigators (2003) Estrogen plus Progestin and the Risk of Coronary Heart Disease. *New England Journal of Medicine*, 349: 523-534.

Observational Studies vs. Randomized Clinical Trials

- In the observational study, patients were either taking HRT or not, on the basis of their desires and their doctor's recommendation.
- In the RCT, 16,608 women ages 50-79 were randomly assigned to either HRT or to a placebo.

Relative Risk of Hormone Replacement Therapy and Coronary Heart Disease

- Observational Studies (1997 and earlier): CHD risk for patients using HRT was **0.60** times as high as those not using HRT
- WHI Randomized Clinical Trial: CHD risk for patients using HRT was **1.29** times as high as those not using HRT

How Did This Happen?

- Selection Bias! Women taking HRT may be more likely to…
  - engage in other CHD-related healthy behaviors (exercise, diet, not smoking)
  - have fewer CHD-related co-morbid illnesses (diabetes, high blood pressure)
  - Take other cardio-protective drugs (lipid-lowering agents, etc.)

Data and Probability Why Bother?

- Five Great Motivators
  - Greed
  - Exclusivity
  - Fear
  - Guilt
  - Need for Approval

Motorcycle Helmets: Necessary?

- In testimony before a committee of the Hawaii State Senate, considering a law requiring all motorcyclists to wear a helmet, one witness declared that despite having been in several accidents during his 20 years of motorcycle riding, a helmet would not have prevented any of the injuries he received.

If you had to do it over again, would you have children?

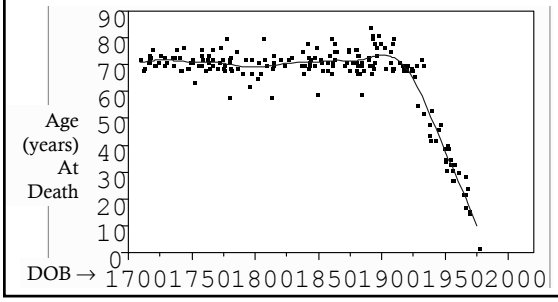
- Ann Landers asked parents this question.
- 70% of the more than 10,000 people who wrote in said "No"

Starting and Finishing Fights

- In 90% of all deaths resulting from barroom brawls, the victim was the one who instigated the fight.

The Lombard Surprise

- Data: 204 birth and death dates from NJ cemetery
- Average age at death relatively constant until 1920 birth dates, then declines rapidly … Why?

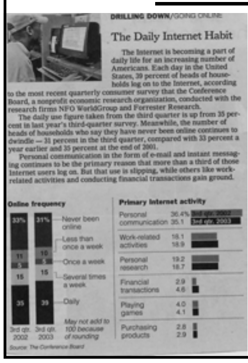


This is serious stuff.

- Understanding chance variation.
  - Patterns and deviations (fit and residual)
  - Model-data dialogue (diagnostics / checking underlying assumptions)
- One pass through software is not enough.
  - Models as interpretive tools.
  - Strategies, not just methods.

Statistics is too important to be left to Statisticians !

Monday, October 6, 2003
NY Times, page C9



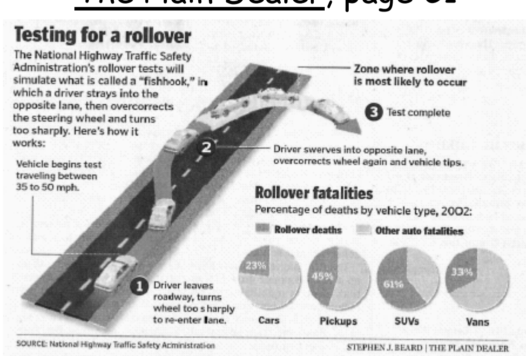
- 2003 Q3 Study of "heads of households" conducted by the Conference Board

Status	% of HHs
Never been online	31
User, not daily	30
Daily	39

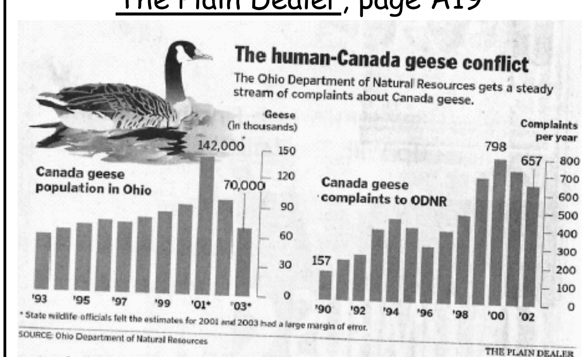
Tuesday, October 7, 2003
NY Times, page D6

- 15,000 children ages 9 to 14 tracked for 3 yrs
- Those who reported going on diets gained more weight than those who did not.
- Possible explanations?

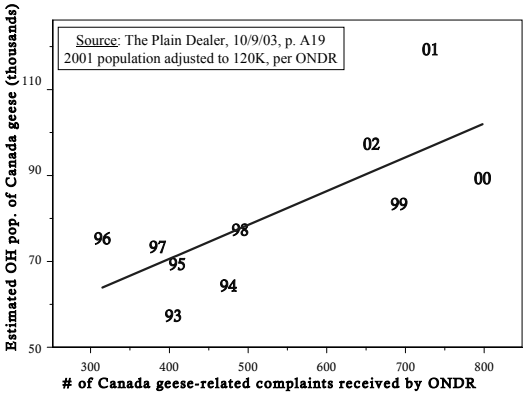
Wednesday, October 8, 2003
The Plain Dealer, page C1



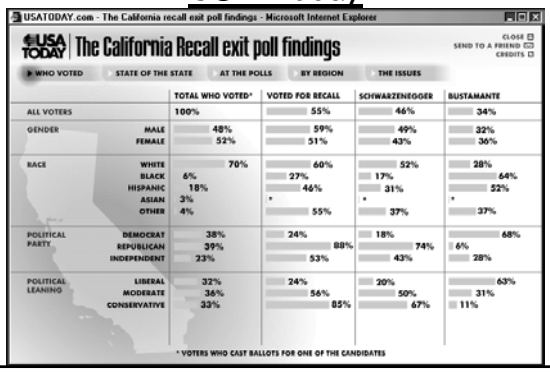
Thursday, October 9, 2003
The Plain Dealer, page A19



Ohio's Human-Canada Geese Conflict (1993-2002)



Wednesday, October 8, 2003
USA Today



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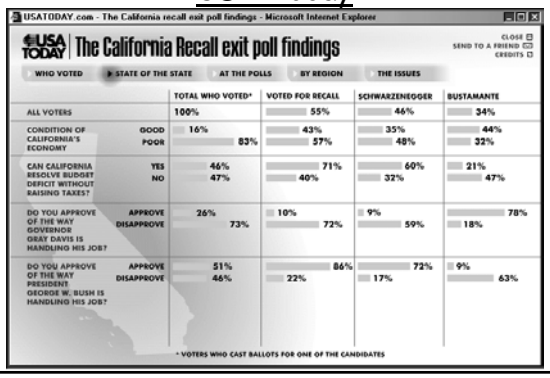

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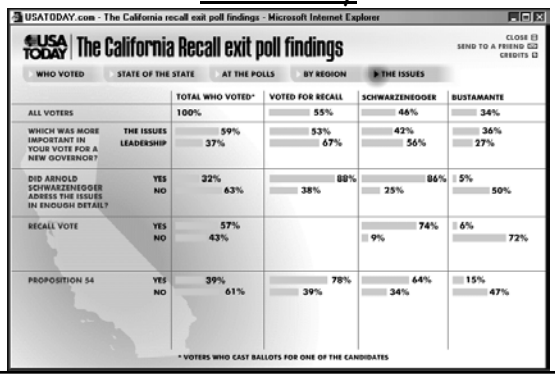
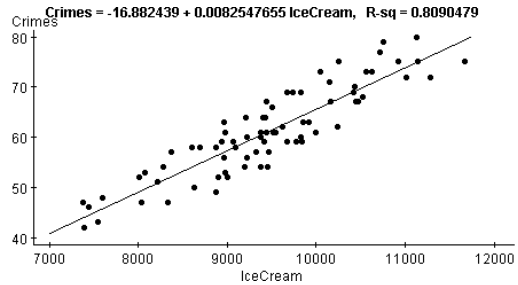


Life Is A Rocky Road



Y = # of crimes committed on a day

X = volume of ice cream sales on that day

Rocky Road Correlation: What's The Most Likely Explanation?

a. The content of ice cream (probably the sugar) encourages people to commit crimes.

b. Successful criminals celebrate by eating ice cream.

c. A pathological desire for ice cream is triggered in a certain percentage of individuals by certain environmental conditions (such as warm days), and these individuals will stop at nothing to satisfy their craving.

d. Another variable, such as temperature, is associated with both crime and ice cream sales.

Some Comments on Material Discussed in My Talk (with Sources and Pointers to Additional Resources)

August 14 Blackout Plot:

See http://www.breakthechain.org/exclusives/blackoutsat.html
http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16273
http://www.noaanews.noaa.gov/stories/s2015.htm

Florida and the 2000 Presidential Election:

The virtual ballot for the Florida election results (including a demo applet) is at:
http://www.sun-sentinel.com/graphics/news/ballot.htm
Greg Adams (at Carnegie-Mellon University) produced the first plot of Bush vs. Buchanan results that I saw, and that I present. For more details on Palm Beach County, the McReynolds study and far too many other links, check out
http://www.bestbookmarks.com/election/

Abraham Wald

A brief description of Wald's work on airplane armor is provided in Howard Wainer's wonderful book *Visual Revelations: Graphical Tales of Fate and Deception from Napoleon Bonaparte to Ross Perot*, which is largely a collection of his articles from *Chance* magazine, which has a website at http://www.stat.duke.edu/chance/

The relevant article in *Chance* is by Wainer, Palmer and Bradlow, as part of a survey of selection anomalies and appeared in the second issue of 1998. There is another picture of the key figure as slide 21 in the presentation entitled "Statistics in Aviation: Celebrating 100 Years of Flight" by Fritz Scholz of Boeing's Math Group that can be found at http://www.stat.uiowa.edu/SRC2003/papers/f-scholz.pdf.

A more technical description is given by Mangel M and Samaniego FJ (1984) "Abraham Wald's work on aircraft survivability," *Journal of the American Statistical Association, 79*, 259-267. Sadly, Wald's life was tragically cut short at age 48 in an airplane crash while on a lecture tour of India.

Smoking and Death of Women and Forbes SAT Scores vs. Education

Details on the Cancer Prevention Study II, including source material for my first plot can be found at http://www.cdc.gov/tobacco/sgr/sgr_forwomen/pdfs/chp3.pdf. The age-adjusted death rates for lung and breast cancer among U.S. women come from the CDC; see http://www.cdc.gov/tobacco/sgr/sgr_forwomen/ataglance.htm

The main story I told happened to Howard Wainer, who (using a different data set) recounts it in his book *Visual Revelations* (cited above). Howard also tells the story (including the Forbes SAT and Education example) much better than I can in his special one-hour lecture *How to Display Data Badly*, which is both informative and hilarious, as well as freely viewable over the internet (assuming you have a pretty fast connection) at the CHANCE website (see below).

The CHANCE website is http://www.dartmouth.edu/~chance/

The CHANCE web site is an outstanding resource of material for incorporating statistical and quantitative literacy ideas from current events into mathematics and statistics courses. There is, for instance, a free monthly e-mail newsletter, which I heartily recommend, and lots of teaching aids and links to other sources of material.

Therapeutic Touch
Detailed links to sites both supportive of and skeptical of TT and related phenomena can be found at http://www.phact.org/e/tt/ The picture of Emily I present comes from that site. A very nice CNN piece on Emily and the story can be accessed through http://www.cnn.com/HEALTH/9804/01/therapeutic.touch/

Credit Card Bank Experiment
This was described in the best textbook I am aware of for teaching statistics to high-school students – by David Bock, Paul Velleman and Richard DeVeaux, entitled *Stats: Modeling the World*, with a publication date of 2004 (it is available now) by Addison-Wesley. I don't work for Addison-Wesley, but I love the book.

Prayer and Blood Pressure
The USA Today story appeared August 11, 1998 on page 1-D. I read about it in a new textbook for undergraduate statistics by Jessica M. Utts and Bob Heckard, entitled *Mind on Statistics*. Jessica and Bob have a lot of interesting links at their sites, including some to Jessica's extensive work on psi phenomena and statistical thinking. May I suggest

http://anson.ucdavis.edu/~utts/statlinks.html
http://www.ruf.rice.edu/~lane/rvls.html

MRFIT and Randomized Trial Subject Selection
Doug Einstadter, MD, MPH (who works with me at the Center for Health Care Research and Policy) built the MRFIT slide. The Multiple Risk Factor Intervention Trial is discussed in the September 1982 issue of the *Journal of the American Medical Association*, and, later, in many other places. MRFIT was a randomized primary prevention trial to test the effect of a multifactor intervention program on mortality from coronary heart disease (CHD) in 12,866 high-risk men aged 35 to 57 years. Men were randomly assigned either to a special intervention (SI) program consisting of stepped-care treatment for hypertension, counseling for cigarette smoking, and dietary advice for lowering blood cholesterol levels, or to their usual sources of health care in the community (UC). Over an average follow-up of 7 years, risk factor levels declined in both groups, but to a greater degree for the SI men.

WHI Studies of Hormone Replacement Therapies

The Women's Health Initiative (WHI) is a major 15-year research program to address the most common causes of death, disability and poor quality of life in postmenopausal women -- cardiovascular disease, cancer, and osteoporosis. In July

2002, the investigators stopped the estrogen-plus-progestin study after finding that the associated health risks outweighed the benefits. The researchers are continuing to analyze and report on data from this trial while they complete other WHI studies. For more on the Women's Health Initiative, including detailed results on the WHI studies, visit http://www.nhlbi.nih.gov/whi/

The Lombard Surprise

The relevant article in *Chance* magazine describing the Lombard Surprise is by Wainer, Palmer and Bradlow, as part of a survey of selection anomalies and appeared in the second issue of 1998.

Life is a Rocky Road Example

This example comes from a terrific book called *The Statistical Sleuth* by Fred Ramsey and Dan Schaefer. The book's web site http://www.statisticalsleuth.com/ gives some additional details. Some nice additional data sets and problems for the book are given at http://oregonstate.edu/instruct/st511/schafer/webdata/

Ten Sites Every Statistics Instructor Should Bookmark (Dated but still useful)
http://it.stlawu.edu/~rlock/10sites.html

Other Useful And Free Resources

If I'm talking about something in a newspaper or journal other than the ones I read all the time, I probably saw it described in William Peterson's column "Topics for Discussion from Current Newspapers and Journals" which appears (approximately quarterly) at both the CHANCE web site described above and as part of the (also free) *Journal of Statistics Education*, which is available online at http://www.amstat.org/publications/jse/

I built most of the plots for this talk using S-PLUS, which is a terrific but expensive piece of software. Happily, there is a free version, called R – visit the R project at http://www.r-project.org/ which is so filled with stuff you can't believe it, if you're interested in really learning a lot about statistics and programming.

There are also several additional reasonable solutions to the issue of statistical software, including the Webstat online package at www.webstatsoftware.com which (for free) provides all the functionality you'd want for basic data analysis anywhere you have a connection to the Internet. I've successfully used this program.

You'll want to visit http://members.aol.com/johnp71/javastat.html to find a truly comprehensive list of free statistical stuff online. Also very useful is the Data and Story Library repository, at http://lib.stat.cmu.edu/DASL/