Chapter 1: Drawing Statistical Conclusions

2/2/09 M

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Slide 1 Chapter 1: Drawing Statistical Conclusions

NOTES:

Blackboard/Vista4

http://boston.umassonline.net

- In person office Hours: 11:40 - 1 pm, immediately after class
  - My office S-1-055
- Virtual Office Hours on WIMBA
  - Monday 7-8 pm
    - Note that homeworks will be due on Weds mornings by 9:50
  - Friday 1-2 pm

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Slide 2 Blackboard/Vista4

NOTES:

HW2 for Class 3 (2/4/09 W) [1 of 2]

Homework due electronically by start of class M

- Conceptual problems
  - Read all the conceptual problems on p. 22-24 and the brief discussion of these problems from the authors on p 26-27
  - Post 1 comment or question about the authors' solution to a conceptual problems on Blackboard/Vista4 discussions
  - A discussion thread has been posted for Chapter 1 Conceptual problems in the Blackboard/Vista4 Chapter 1 folder

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Slide 3 HW2 for Class 3 (2/4/09 W) [1 of 2]

NOTES:

HW2 for Class 3 (2/4/09 W)

Homework due electronically by start of class Monday

- Computational problems
  - Ex. 1.16 in Sleuth **Planet Distances and Order from the Sun**
    - Parts a through e
      - You should label the planets on the graph
      - Label the axes properly
      - Use an appropriate number of significant figures on the graph axes
    - Hints
      - Graphs/scatter or Graphs/Interactive/Scatter
      - Analyze/descriptive/explore
    - Try out different methods for saving graphs in Office or WordPerfect
  - Ex 1.21 (p. 25) in Sleuth
    - Do the analysis of 5 papers as described - brief
    - Pick the best of the five for a 2-3 paragraph description suitable for class presentation. Angeliki & I will pick three of these for a Weds (2/6/08) presentation

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Slide 4 HW2 for Class 3 (2/4/09 W)

NOTES:

Submission of Homework

Homework due electronically by start of class Mon

- Homework must be submitted electronically by 9:50 am on class days.
  - Post in gradebook section of Vista 4
  - Don't send by email
- You can submit work as MS Word or rtf
  - Contact me if you wish to submit in another format (e.g., wks is readable)
  - Please don't submit as pdf's
  - Angeliki Evgenidou will write comments electronically on your submission.

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Slide 5 Submission of Homework

NOTES:

Homework format

2-3 problems per class (usually about 1 hour required per problem)

- Homework due by the start of class
- Must be 2 pages or less per problem
  - Preferably 1 page
  - Never submit unedited SPSS output!
- Present the problem, the solution with presentation-quality graphics, the SPSS syntax if appropriate, and a strong conclusion [if appropriate]
- Submit as a Word or rtf document
- Submit time taken on HW

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Slide 6 Homework format

NOTES:

Homework grading

Hand the homework in on time!

- 10-point scale for most problems.
  - Minus 5 points if the homework not submitted by 9:55 am on class day.
  - **0 points if the homework isn't submitted 24 hours after it is due**
  - Homework solutions are provided at start of next class, so no partial credit will be granted for late homework
- You must interpret the results. If you submit just the computer printouts without interpretation, you will receive fewer than 5 out of 10 points.

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Slide 7 Homework grading

NOTES:

Readings for Class 3 (2/4/09 W)

- Please read all of Chapter 2. I will lecture on this material (Student's *t* distribution & *t* tests) during Monday's class.
- Load the Case 2.1 and 2.2 data
  - Movies and data posted on Blackboard/Vista4
  - You should be able to run the case studies by the start of class.
- Come prepared with questions on Chapters 1 and 2

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Slide 8 Readings for Class 3 (2/4/09 W)

NOTES:

Graduate & Faculty computing Resource Center

- This computing facility is on Healey library 5th floor.
- SPSS Release 16 is loaded on multiple Dell computers
  - There are very few differences between versions after SPSS Release 11
- There are laser printers available
- Matlab & SAS also available
- You can bring thumb drives and email data to yourself for entering problems

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Slide 9 Graduate & Faculty computing Resource Center

NOTES:

Statistical sleuthing

What do the authors mean?

- "Statistical sleuthing means carefully examining data to answer questions of interest." P. 1
- How DO you interpret statistical results?
  - Setting of chapter 1: the two-sample problem
  - One sample problem: Is the mean equal to some known value?
  - Two-sample problem: Are the means (medians, variance) of two groups equal?
  - K-sample problem: Comparing means of more than two groups

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Slide 10 Statistical sleuthing

NOTES:

Statistical sleuthing (continued)

Statistical analysis is applied probability

- All statistical analyses are based on probability models or chance mechanisms
  - Often, chance mechanisms are invented as conceptual frameworks for drawing statistical conclusions
  - Randomization & permutation methods often used to determine *p* values
    - These methods fall under the general heading of Monte Carlo methods
    - Fisher: p values have meaning only so far as they describe the result of a randomization or permutation test
    - Note that if the assumptions of the *parametric test* * are violated — e.g., producing erroneous p values and flawed Type I errors — then the p values generated by the Monte Carlo analysis based on that parametric statistic will also be wrong. [*parametric tests are based on probability distributions described by parameters, e.g., normal, Poisson, hypergeometric]
  - Computing Monte Carlo simulations
    - Monte Carlo methods can't be handled efficiently by SPSS, but there is a randomization module for SPSS available at high cost
    - Matlab & S-plus ('R') can handle Monte Carlo simulations
    - I'll provide Matlab code for Monte Carlo simulations throughout this course
    - R is free, Matlab costs about $100 for the student version

Slide 11 Statistical sleuthing (continued)

NOTES:

Case 1: Motivation & Creativity

– A randomized experiment

- Questions
  - Do grading systems promote creativity in students?
  - Do ranking systems and incentive awards programs increase productivity among students?
  - Do rewards and praise stimulate students to learn?

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Slide 12 Case 1: Motivation & Creativity

NOTES:

Motivation Experimental Design

- Subjects with considerable experience in creative writing were **randomly** assigned to two groups
  - Intrinsic
  - Extrinsic
- The groups were asked to complete a questionnaire, ranking reasons for writing
- All subjects asked to write a Haiku poem about laughter
- All Haikus submitted to a panel of 12 poets, to be graded on a 0 to 40 point scale

Slide 13 Motivation Experimental Design

NOTES:

Display 1.2 p. 3

Questionnaires given creative writers, to rank intrinsic and extrinsic reasons for writing

INSTRUCTIONS Please rank the following list of reasons for writing, in order of personal importance to you (1 = highest, 7 = lowest).

_ You get a lot of pleasure out of reading something good that you have written.
_ You enjoy the opportunity for self-expression.
_ You achieve new insights through your writing.
_ You derive satisfaction from expressing yourself clearly and eloquently.
_ You feel relaxed when writing.
_ You like to play with words.
_ You enjoy becoming involved with ideas, characters, events, and images in your writing.

List of **extrinsic** *reasons for writing* — *List of* **intrinsic** *reasons for writing*

INSTRUCTIONS Please rank the following list of reasons for writing, in order of personal importance to you (1 = highest, 7 = lowest).

_ You realize that, with the introduction of dozens of magazines every year, the market for free-lance writing is constantly expanding.
_ You want your writing teachers to be favorably impressed with your writing talent.
_ You have heard of cases where one bestselling novel or collection of poems has made the author financially secure.
_ You enjoy public recognition of your work.
_ You know that many of the best jobs available require good writing skills.
_ You know that writing ability is one of the major criteria for acceptance into graduate school.
_ Your teachers and parents have encouraged you to go into writing.

Slide 14 Intrinsic & extrinsic questionnaire

NOTES:

Results of Motivation Experiment

Display 1.1 p. 2

Creativity scores in two motivation groups, and their summary statistics

Why are 3 significant figures used in the table, but 4 significant figures in the descriptive statistics (average)?

	Intrinsic		Extrinsic	
	12.0	20.5	5.0	17.4
	12.0	20.6	5.4	17.5
	12.9	21.3	6.1	18.5
	13.6	21.6	10.9	18.7
	16.6	22.1	11.8	18.7
	17.2	22.2	12.0	19.2
	17.5	22.6	12.3	19.5
	18.2	23.1	14.8	20.7
	19.1	24.0	15.0	21.2
	19.3	24.3	16.8	22.1
	19.8	26.7	17.2	24.0
	20.3	29.7	17.2	
Sample Size:	24		23	
Average:	19.88		15.74	
Sample Standard Deviation:	4.44		5.25	

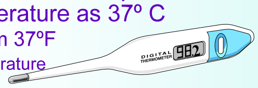
Slide 15 Results of Motivation Experiment

NOTES:

Misusing significant figures can cause a fever

From Paulos: "A mathematician reads the newspaper"

- Trick question for the day: What is "normal" human temperature?
- Answer: 98.2º F
- Wunderlich took thousands of measurements, and found that the "normal" temperature had high variance. With appropriate rounding to just 2 significant digits, Wunderlich reported the average human temperature as 37º C
  - 98.6º F is the conversion from 37ºF
  - http://en.wikipedia.org/wiki/Temperature



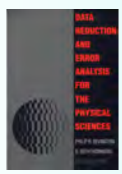
Slide 16 Misusing significant figures can cause a fever

NOTES:

Significant figures or digits

From Bevington & Robinson (1992, p. 4)
Another very good reference: Taylor (1997)

- **The leftmost nonzero digit is the most significant digit**
- **If there is no decimal point, the rightmost non-zero digit is the least significant digit**
- **If there is a decimal point, the rightmost digit is the least significant digit, even if it is zero**
- **All digits between the least and most significant digits are counted as significant digits.**



Slide 17 Significant figures or digits

NOTES:

Significant digits

How many digits should be reported?

- These numbers all have 4 significant digits (or figures): 1234, 123400, 123.4, 1001, 1000., 10.10, 0.0001010, 100.0
- Best to write in scientific notation with the appropriate number of digits 1.010×10^{-4}
- Bevington & Robinson (1992): *In calculations, carry only 1 digit more than the number of significant figures, round*
  - That statement is wrong. Carry all significant figures in calculations. This is done automatically in all computer programs (to about 14 significant figures in Intel processors)
  - **In summary statistics, report 1 more significant figure than is present in the data** (think of 98.6º F)
- Let the uncertainty define the number of significant digits
  - It is incorrect to report 9.979 ± 5.015
  - Due to **propagation of error**, the number of significant figures can not increase in a calculation

Slide 18 Significant digits

NOTES:

Display 1.1

Reporting significant digits

- **In calculations, carry all significant figures**
- **In summary statistics, especially of the average, report one more significan digit than the observations**
  - **That extra digit is needed for transformations to other scales**
  - **Our 98.6º F average human temperature is due to a violatio this rule**

Display 1.1 p. 2

Creativity scores in two motivation groups, and their summary statistics

	Motivation Group			
	Intrinsic		*Extrinsic*	
	12.0	20.5	5.0	17.4
	12.0	20.6	5.4	17.5
	12.9	21.3	6.1	18.5
	13.6	21.6	10.9	18.7
	16.6	22.1	11.8	18.7
	17.2	22.2	12.0	19.2
	17.5	22.6	12.3	19.5
	18.2	23.1	14.8	20.7
	19.1	24.0	15.0	21.2
	19.3	24.3	16.8	22.1
	19.8	26.7	17.2	24.0
	20.3	29.7	17.2	
Sample Size:	24		23	
Average:	19.88		15.74	
Sample Standard Deviation:	4.44		5.25	

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Slide 19 Display 1.1

NOTES:

Summary of statistical findings

Case study 1.1

- "There is strong evidence that a subject would receive a lower creativity score for a poem written after the extrinsic motivation questionnaire"
- Two-sided p-value=0.005 from a 2-sample t test.
- 4.1 point difference on a 0-40 point scale.
  - 95% confidence interval for the difference is 1.3 and 4.0 points

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Slide 20 Summary of statistical findings

NOTES:

Scope of inference

Case study 1.1

- Since this was a **randomized** experiment, difference in creativity was **caused** by the difference in motivational questionnaires
- **Because the individuals were not selected randomly** from a larger population, extending this inference to a larger population is speculative.

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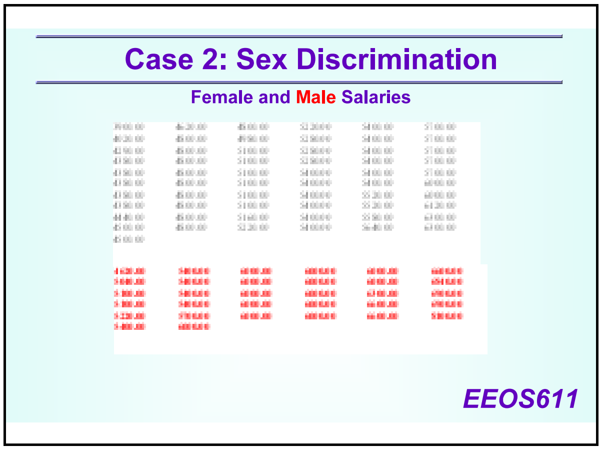
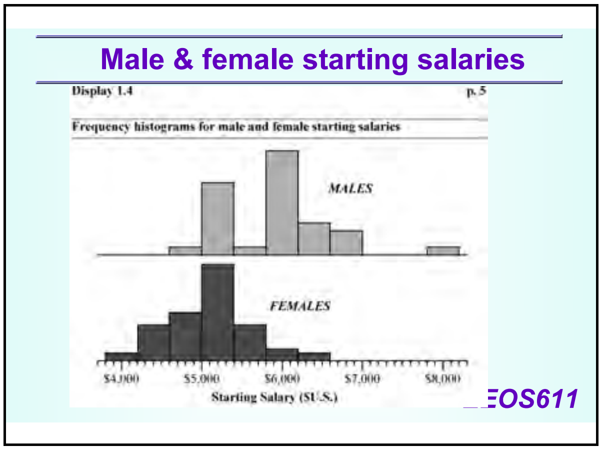
Slide 21 Scope of inference

NOTES:



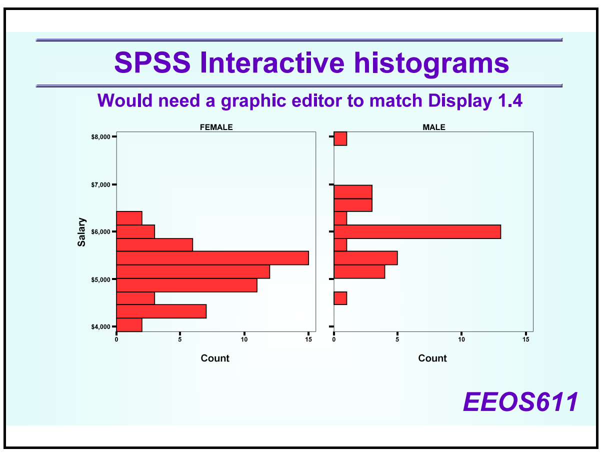
Slide 22 Case 2: Sex Discrimination

NOTES:



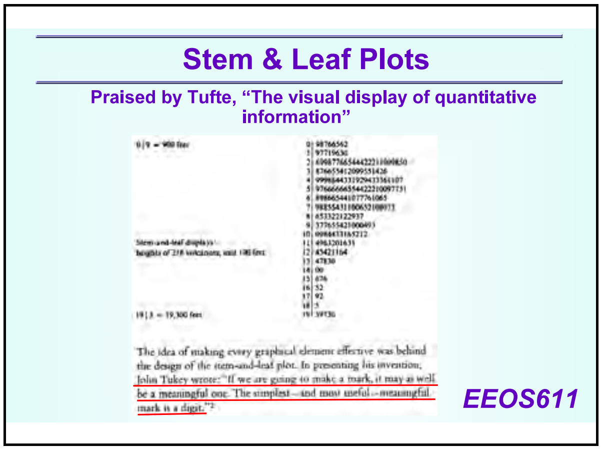
Slide 23 Male & female starting salaries

NOTES:



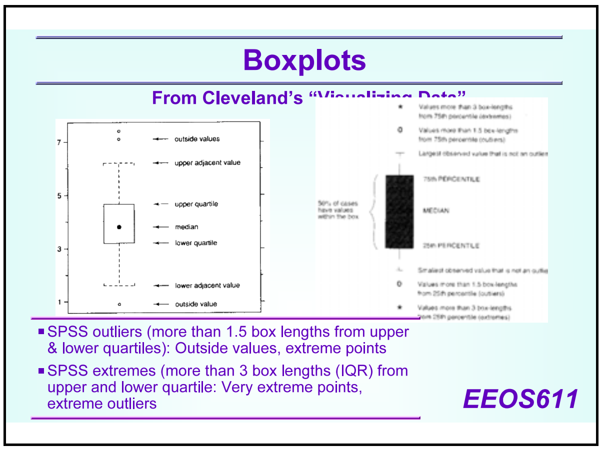
Slide 24 SPSS Interactive histograms

NOTES:



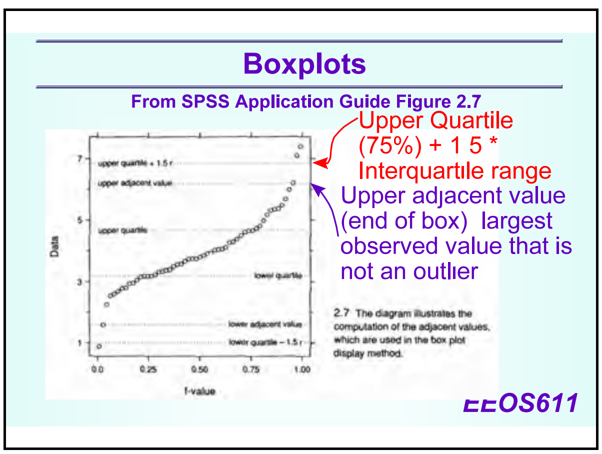
Slide 25 Stem & Leaf Plots

NOTES:



Slide 26 Boxplots

NOTES:

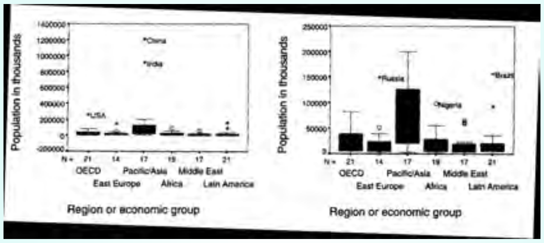


Slide 27 Boxplots

NOTES:

Boxplots

SPSS allows outliers to be labeled



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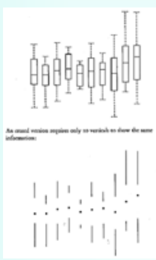
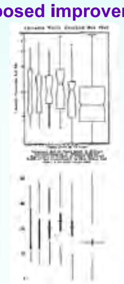
Slide 28 Boxplots

NOTES:

Improved boxplots?

Tufte's proposed improvements haven't caught on





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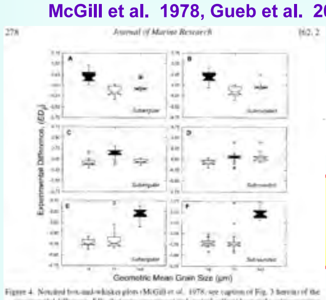
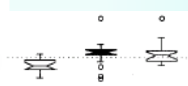
Slide 29 Improved boxplots?

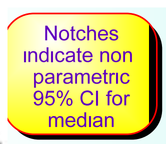
NOTES:

Notched box plots

McGill et al. 1978, Gueb et al. 2004 (JMR 62:261)







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Slide 30 Notched box plots

NOTES:

Matlab boxplots

Notched box plots, a robust estimator for the mean

BOXPLOT Display boxplots of a data sample.

BOXPLOT(X,NOTCH,SYM,VERT,WHIS) produces a box and whisker plot for each column of X. The box has lines at the lower quartile, median, and upper quartile values. The whiskers are lines extending from each end of the box to show the extent of the rest of the data. Outliers are data with values beyond the ends of the whiskers.

NOTCH = 1 produces a notched-box plot. Notches represent a robust estimate of the uncertainty about the means for box to box comparison. NOTCH = 0 (default) produces a rectangular box plot. SYM sets the symbol for the outlier values if any (default='+').

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Slide 31 Matlab boxplots

NOTES:

Why 1.57 for notched boxplots?

n1 = med + 1.57*(q3-q1)/sqrt(length(x));

```
% Set up (X,Y) data for notches if desired.
if ~notch
xx2 = [lbm lbp lbp lbm lbm];
yy2 = [q3 q3 q1 q1 q3];
xx3 = [lbm lbp];
else
n1 = med + 1.57*(q3-q1)/sqrt(length(x));
n2 = med - 1.57*(q3-q1)/sqrt(length(x));
if n1>q3, n1 = q3; end
if n2<q1, n2 = q1; end
lnm = lb-0.25*lf;
lnp = lb+0.25*lf;
xx2 = [lnm lbm lbm lbp lbp lnp lbp lbp lbm lbm lnm];
yy2 = [med n1 q3 q3 n1 med n2 q1 q1 n2 med];
xx3 = [lnm lnp];
end
yy3 = [med med];
```

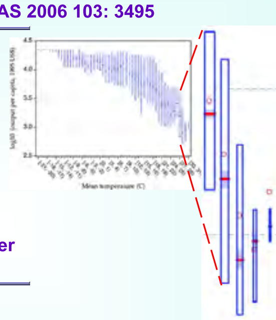
Slide 32 Why 1.57 for notched boxplots?

NOTES:

Data-filled boxplots

Nordhaus, W. PNAS 2006 103: 3495

- **means are red circles**
- **medians are the heavy red horizontal line**
- **one-sigma ranges of the median are the blue shaded regions**
- **interquartile ranges are the boxes**
- **box width is proportional to the square root of the number of observations in each bin**



Slide 33 Data-filled boxplots

NOTES:

On Boxes, Hinges, Leaves, Quartiles, Stems & Whiskers in the May 2003 High-Stakes MCAS Math Exam

Posted on Blackboard/Vista4, Session 2, whiskers.pdf

John Tukey

Slide 34 On Boxes, Hinges, Leaves, Quartiles, Stems & Whiskers in the May 2003 High-Stakes MCAS Math Exam

NOTES:

The box-and-whisker plot learning standard

Students engage in problem solving, communicating, reasoning, connecting, and representing as they:

10.D.1 Select, create, and interpret an appropriate graphical representation (e.g., scatter-plot, table, stem-and-leaf plots, box-and-whisker plots, circle graph, line graph, and line plot) for a set of data and use appropriate statistics (e.g., mean, median, range, and mode) to communicate information about the data. Use these notions to compare different sets of data.

10.D.2 Approximate a line of best fit (trend line) given a set of data (e.g., scatterplot). Use technology when appropriate.

10.D.3 Describe and explain how the relative sizes of a sample and the population affect the validity of predictions from a set of data.

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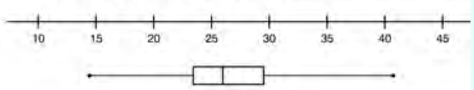
Slide 35 The box-and-whisker plot learning standard

NOTES:

Box & Whisker plots

Question 39, Spring 2001 Exam

39 The box and whisker graph shown below represents the results of a survey of the estimated gas mileage of 100 car models.



Which statistics—mean, median, mode, range—can be determined from this graph?

A. mean only

B. median only

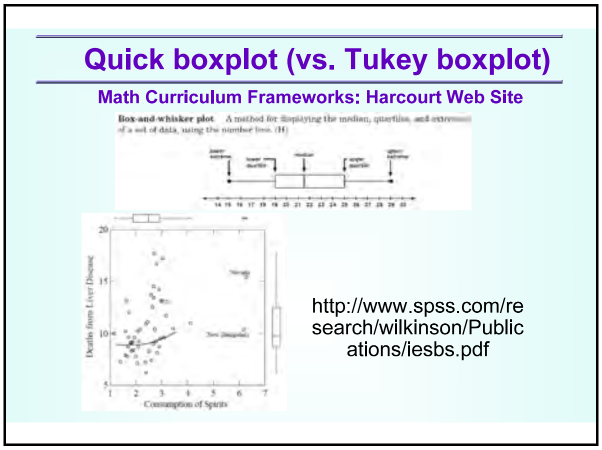
C. range and mean

D. range and median

Reporting Category for Item 39: **Data Analysis, Statistics, and Probability** (p. 288)

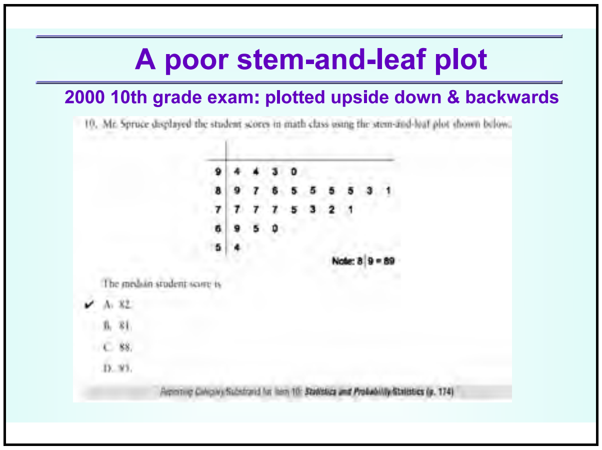
Slide 36 Box & Whisker plots

NOTES:



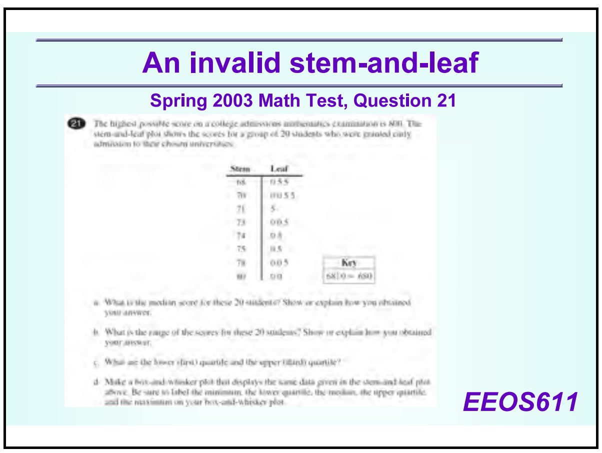
Slide 37 Quick boxplot (vs. Tukey boxplot)

NOTES:



Slide 38 A poor stem-and-leaf plot

NOTES:

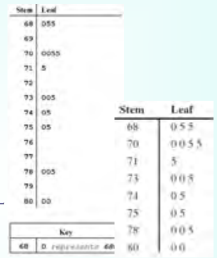


Slide 39 An invalid stem-and-leaf

NOTES:

Problems with MCAS stem-and-leaf plots

- The stem-and-leaf plot is plotted improperly
- There are numerous correct answers, especially in describing 1st and 3rd quartiles
  - The Dept. of Education is basing this 4-point question on approximations to quartiles, called hinges by Tukey.
  - The concept of cumulative frequency distributions needed to properly define quartiles is a Grade 11-12 learning standard
- DOE & MCAS is not testing on the key feature of boxplots or stem-and-leaf plots: a quick view of the distribution



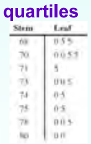
Slide 40 Problems with MCAS stem-and-leaf plots

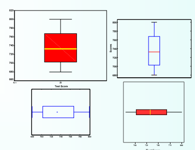
NOTES:

Tukey's hinges vs. Quartiles

Hyndman & Fan (1996) American Statistician *50*: 361-365: 9 different ways to calculate quartiles

- Tukey hinges: 702.5 & 767.5
- SPSS: 701.25 & 773.75
- Excel & Quattro Pro: 703.75 & 761.25





Slide 41 Tukey's hinges vs. Quartiles

NOTES:

Fisher's major contribution to statistics: randomization

http://bmj.com/cgi/content/full/322/7280/0

"The modern solution was first propounded by R. A. Fisher. We have already seen throughout this work that Fisher's contributions to statistical theory were remarkable and far-ranging. Nevertheless, it is probably no exaggeration to say that his advocacy of randomization in experimental design was the most important and the most influential of his many achievements in statistics."
Kendall & Stuart 1977

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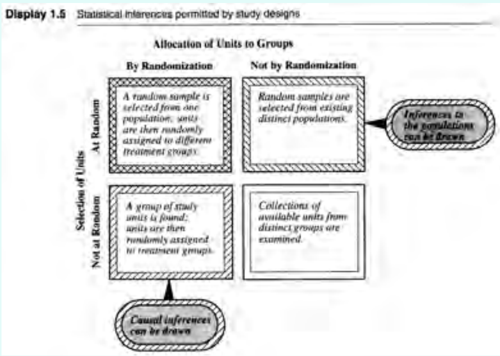
Slide 42 Fisher's major contribution to statistics: randomization

NOTES:



Slide 43

NOTES:

Statistical inferences and chance mechanisms

- An **inference** is a conclusion that patterns in the data are present in some broader context
- A **statistical inference** is an inference justified by a probability model linking the data to the broader context

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Slide 44 Statistical inferences and chance mechanisms

NOTES:

Randomization

From Kendall & Stuart's 'Advanced Theory of Statistics'

- **The principle of randomization is simply stated: Whenever experimental units are allocated to factor-combinations in an experiment, this should be done by a random process using equal probabilities.**
- Even if the relationship of the dependent variable with some unsuspected causal factor is not recognized until after the experiment, the validity of the inferences will not be impaired, provided that the factor's influence was "**randomized out**" of the experiment.

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Slide 45 Randomization

NOTES:

Kendall & Stuart on Experiments

Three classes of variables

- In any experiment the factors influencing the dependent variable are, explicitly or implicitly, divided by the experimenter into three classes:
  - Those incorporated into the structure of the experiment
  - Those "randomized out" of the experiment
  - Those neither incorporated nor randomized out
- Classes 1 & 2 require positive action, affecting the layout of the experiment, or the randomization procedure employed. A factor may find its way into class (3) by simply being overlooked.

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Slide 46 Kendall & Stuart on Experiments

NOTES:

What makes a good experimenter?

Kendall & Stuart (1977)

"A substantial part of the skill of the experimenter lies in his choice of factors to be randomized out of the experiment. If he is careful, he will randomize out all the factors which are suspected of being causally important but which are not actually part of the experimental procedure. But every experimenter necessarily neglects some conceivably causal factors; if this were not so, the randomization procedure required would be impossibly complicated. Thus the choice of what factors to be randomized out is essentially a matter of judgement."

Slide 47 What makes a good experimenter?

NOTES:

Experimental design should include

Hurlbert (1984), posted on Blackboard/Vista4

- The nature of the experimental units to be employed
- The number and kinds of treatments and the properties of the responses that will be measured.
- Specification of how the treatments will be assigned to the available experimental units (replicates)
- The physical arrangement of the experimental units, (and often) the temporal sequence in which treatments are applied to and measurements made on the different experimental units.'

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Slide 48 Experimental design should include

NOTES:

Randomized Experiments vs. Observational Studies

- Randomized experiment: a chance mechanism used to assign subject to groups
- Observational study: group status beyond the control of the investigator
- **"Statistical inferences of cause-and-effect relationships can be drawn from randomized experiments, but not from observational studies"**
- "A **confounding variable** is related both to group membership and to the outcome. Its presence makes it hard to establish the outcome as being a direct consequence of group membership." (Male experience)

Slide 49 Randomized Experiments vs. Observational Studies

NOTES:

Sample surveys *vs.* experiments

Kendall & Stuart's "The Advanced theory of statistics" (1977)

- The distinction between the design of experiments and the design of sample surveys is fairly clear-cut, and may be expressed by saying that
  - **In surveys we make observations on a sample taken from a finite population of individuals, whereas in experiments we make observations which are in principle generated by a hypothetical infinite population, in exactly the same way that the tosses of a coin are.**
  - Of course, we may sometimes experiment on the members of a sample resulting from a survey, or even make a sample survey of the results of an (extensive) experiment, but the essential distinction between the two fields should be clear.

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Slide 50 Sample surveys vs. experiments

NOTES:

Do observational studies have value?

- Establishing causation not always the goal of the study
- Establishing causation can be done in other ways.
- Analysis of observational data may lend evidence toward causal theories and suggest the direction for further research.

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Slide 51 Do observational studies have value?

NOTES:

Inferences to populations

- Inferences to populations can be drawn from random sampling studies, but not otherwise
  - **Simple random sampling** (SRS): A simple random sample of size n from a population is a subset of the population consisting of *n* members selected in such a way that every subset of size n is afforded the same chance of being selected.
- Random sampling ensures that all subpopulations are represented in the sample in roughly the same mix as in the overall population.
- Statistical inference procedures incorporate measures of uncertainty that describe that chance.

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Slide 52 Inferences to populations

NOTES:

Selecting a random sample

- Simple random sampling
- Stratified random sampling
- Multilevel sampling (e.g., Regions, Lakes, areas within lakes)
- Systematic sampling
  - Quadrat samples
  - Line transect samples: see Hayek & Buzas (1996)
- Random cluster sampling (selecting blocks or grids at random)
  - Lakes: Can adjust the probability of being sampled
- Adaptive cluster sampling (Thompson 1990),
- Variable probability sampling
  - EMAP

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Slide 53 Selecting a random sample

NOTES:

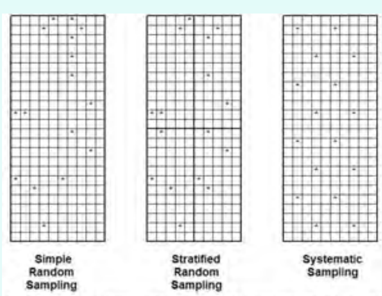
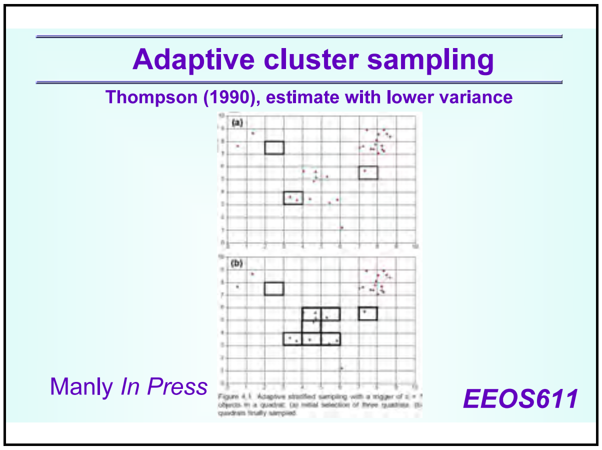


Figure 1.2 Comparison of simple random sampling, stratified random sampling and systematic sampling for plots in a rectangular study region, with chosen plots indicated by *.

Manly *In Press*

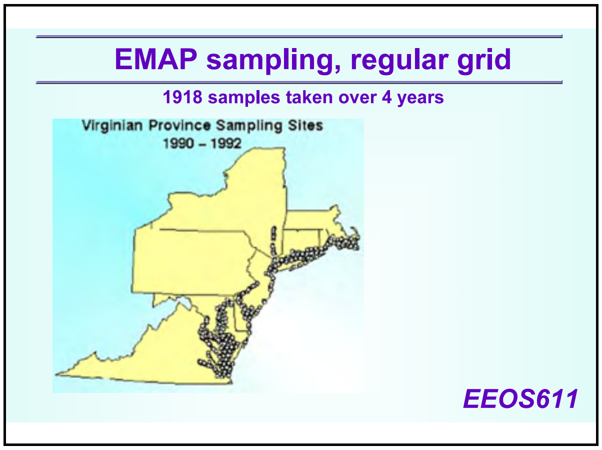
Slide 54

NOTES:



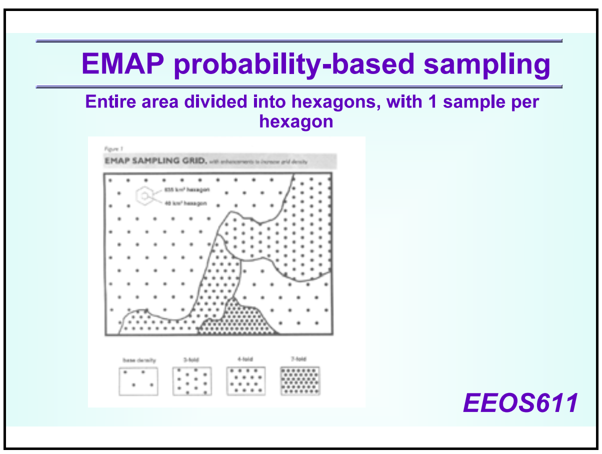
Slide 55 Adaptive cluster sampling

NOTES:



Slide 56 EMAP sampling, regular grid

NOTES:

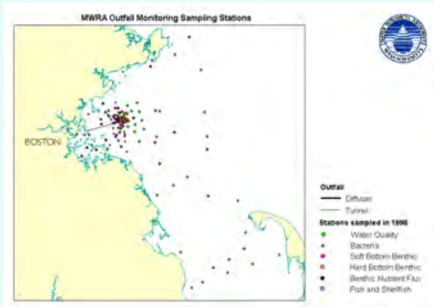


Slide 57 EMAP probability-based sampling

NOTES:

MA Bay sampling

Random locations, but many rocky stations deleted

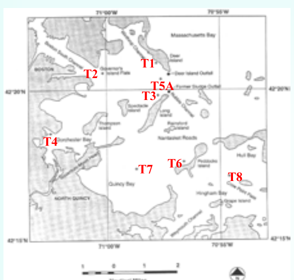


Slide 58 MA Bay sampling

NOTES:

Boston Harbor sampling

8 stations sampled since 1991: not selected randomly



No statistical inferences possible in a strict sense.

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Slide 59 Boston Harbor sampling

NOTES:

Statistical inference

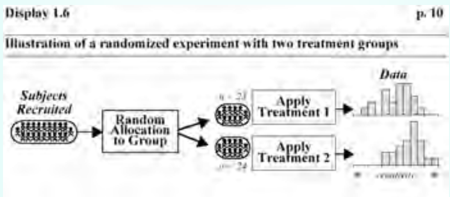
& Neyman-Pearson Hypothesis testing

Slide 60 Statistical inference

NOTES:

A probability model for randomized experiments

- The creativity study is an example
- An additive model: $Y^*=Y+\delta$



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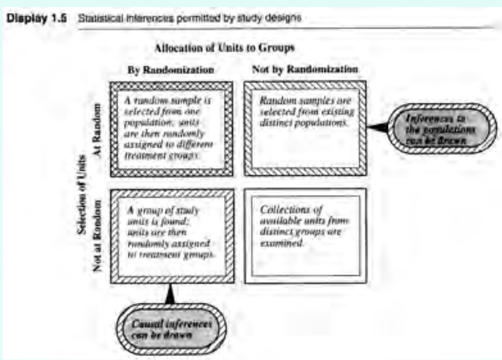
Slide 61 A probability model for randomized experiments

NOTES:



Slide 62

NOTES:

Null & alternate hypotheses

Page 10

- "Is there a treatment effect?" must be translated into a model that can be tested statistically $Y^*=Y+\delta$, where δ is the treatment effect
- Create a test statistic
  - Assume a creativity parameter δ
    - $\delta=0$ is the null hypothesis
    - $\delta\neq0$ is the alternate hypothesis
  - Randomization distribution of the test statistic
  - The p-value of the test, derived from the randomization assumption

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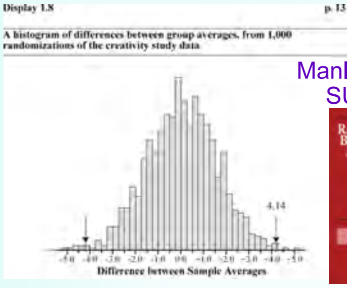
Slide 63 Null & alternate hypotheses

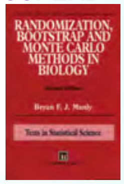
NOTES:

Randomization distribution

Can be done with Matlab & R, not SPSS



Manly's book is SUPERB!



Slide 64 Randomization distribution

NOTES:

Computing p values using randomization & Monte Carlo trials

- All possible permutations: not feasible for many studies
- Set the number of Monte Carlo simulations at about 4*1/(desired precision of the p value)
  - See: How many Monte Carlo Simulations Should You Run? HO13-MCTRIALS.pdf
- Or, approximate the randomization distribution with a normal or *t* distribution

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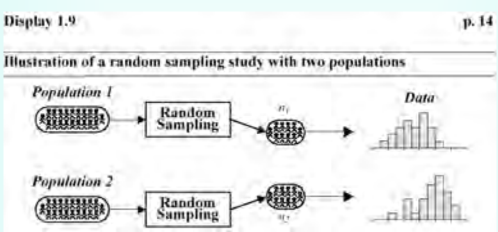
Slide 65 Computing p values using randomization & Monte Carlo trials

NOTES:

Measuring uncertainty in observational studies



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Slide 66 Measuring uncertainty in observational studies

NOTES:

Related issues

- Relative frequency histograms
- Stem and leaf diagrams: poor in SPSS
- Box plots, box-and-whisker plot
- Standard statistical terminology
  - A parameter, a feature of a probability model. Parameters indicated by Greek letters.
  - Statistic: any quantity that can be calculated from the observed data.
    - Mean in statistical sleuth is over the entire population: it is a parameter
    - Standard deviation
  - Experimental units: the things to which treatments are applied

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Slide 67 Related issues

NOTES: