Stat 13, Intro. to Statistical Methods for the Life and Health Sciences.

1. Finishing up the bicycles and commute times and SIDS and Back to Sleep examples.
2. Comparing 2 means, breastfeeding and intelligence example.
3. Paired data and studying with music example.
4. Simulation approach with paired data and baseball example.

Read ch7.

Bring a PENCIL and CALCULATOR and any books or notes you want to the midterm and final.

HW3 is due Tue. 4.CE.10, 5.3.28, 6.1.17, and 6.3.14.

In 5.3.28d, use the theory-based formula. You do not need to use an applet.

The midterm will be on ch1-7.

http://www.stat.ucla.edu/~frederic/13/sum17 .

Bicycling to Work

- We cannot generalize beyond Groves and his two bikes.
- A limitation is that this study is not ***double-blind***
  - The researcher and the subject (which happened to be the same person here) were not blind to which treatment was being used.
  - Dr. Groves knew which bike he was riding, and this might have affected his state of mind or his choices while riding. How?

- SIDS. Davies (1985) found that in Hong Kong, where the custom was for children to sleep on their backs, the rates of SIDS were very low.
- 1992: Back to Sleep began in the United States.

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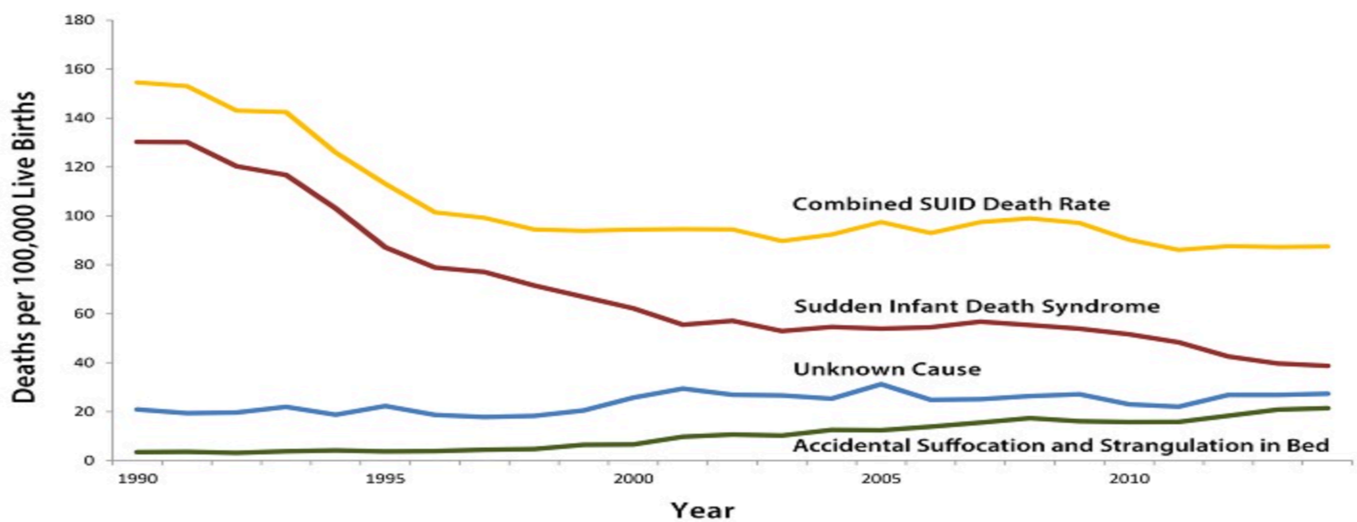
Trends in Sudden Unexpected Infant Death by Cause, 1990-2014



Abbreviation: SUID, sudden unexpected infant death.

SOURCE: CDC/NCHS, National Vital Statistics System, Compressed Mortality File.

Breastfeeding and Intelligence

Example 6.3

Breastfeeding and Intelligence

- A 1999 study in *Pediatrics* examined if children who were breastfed during infancy differed from bottle-fed.
- 323 children recruited at birth in 1980-81 from four Western Michigan hospitals.
- Researchers deemed the participants representative of the community in social class, maternal education, age, marital status, and sex of infant.
- Children were followed-up at age 4 and assessed using the General Cognitive Index (GCI)
  - A measure of the child's intellectual functioning
- Researchers surveyed parents and recorded if the child had been breastfed during infancy.

Breastfeeding and Intelligence

- Explanatory and response variables.
  - **Explanatory variable:** Whether the baby was breastfed. (Categorical)
  - **Response variable:** Baby's GCI at age 4. (Quantitative)

- Is this an experiment or an observational study?
- Can cause-and-effect conclusions be drawn in this study?

Breastfeeding and Intelligence

- **Null hypothesis:** There is no relationship between breastfeeding during infancy and GCI at age 4.
- **Alternative hypothesis:** There is a relationship between breastfeeding during infancy and GCI at age 4.

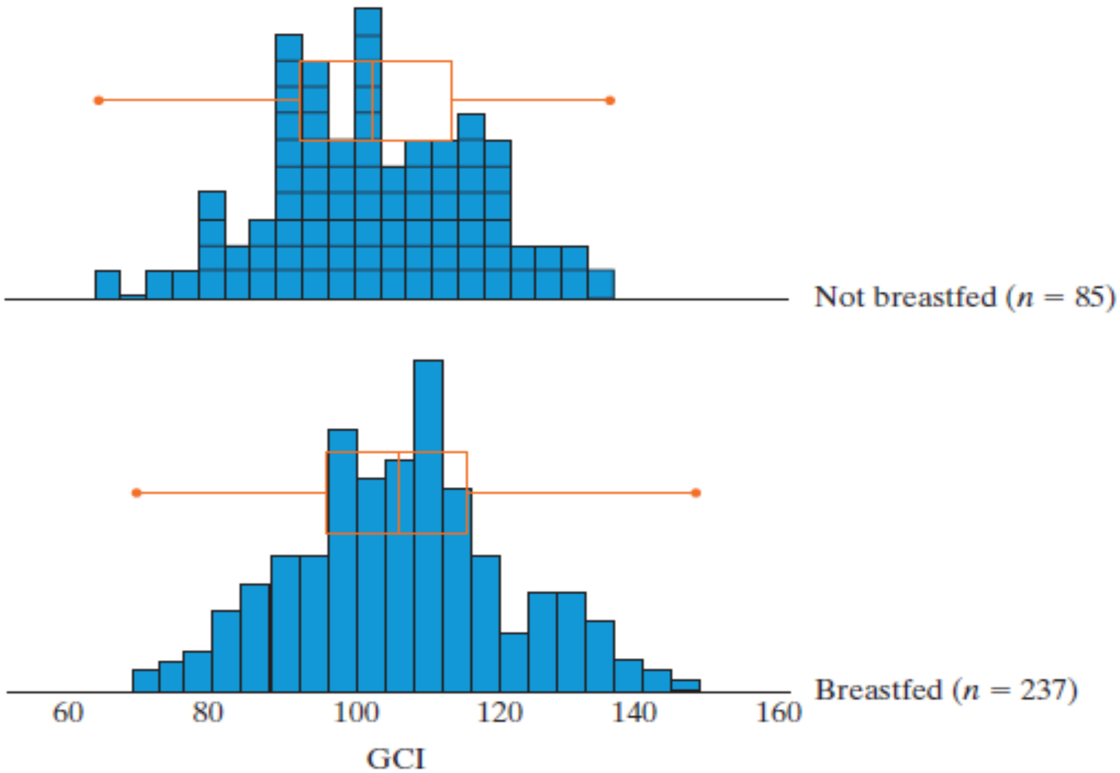
Breastfeeding and Intelligence

- $\mu_{breastfed}$ = Average GCI at age 4 for breastfed children
- μ_{not} = Average GCI at age 4 for children not breastfed

- **H_0:** $\mu_{breastfed} = \mu_{not}$
- **H_a:** $\mu_{breastfed} \neq \mu_{not}$

Breastfeeding and Intelligence

Group	Sample size, n	Sample mean	Sample SD
Breastfed	237	105.3	14.5
Not BF	85	100.9	14.0



Breastfeeding and Intelligence

The difference in means was 4.4.

- If breastfeeding is not related to GCI at age 4:
  - Is it **possible** a difference this large could happen by chance alone? Yes
  - Is it **plausible (believable, fairly likely)** a difference this large could happen by chance alone?
    - We can investigate this with simulations.
    - Alternatively, we can use theory-based methods.

T-statistic

- To use theory-based methods when comparing multiple means, the t-statistic is often used.
- It is simply the number of standard deviations our statistic is above or below the mean under the null hypothesis.
- $t = \frac{statistic - hypothesized\ value}{SE} = \frac{\bar{x}_1 - \bar{x}_2 - 0}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$
- Here, t = $\frac{105.3 - 100.9}{\sqrt{(\frac{14.5^2}{237} + \frac{14.0^2}{85})}} = 2.46.$
- p-value ~ 1.4 or 1.5%. [2 * (1-pnorm(2.46))], or use pt.

Breastfeeding and Intelligence

Meaning of the p-value:

- If breastfeeding were not related to GCI at age 4, then the probability of observing a difference of 4.4 or more or -4.4 or less just by chance is about 1.4%.

- A 95% CI can also be obtained using the t-distribution. The SE is $\sqrt{(\frac{14.5^2}{237} + \frac{14.0^2}{85})}$ = 1.79. So the margin of error is multiplier x SE.

Breastfeeding and Intelligence

- The SE is $\sqrt{(\frac{14.5^2}{237} + \frac{14.0^2}{85})}$ = 1.79. The margin of error is multiplier x SE.
- The multiplier should technically be obtained using the t distribution, but for large sample sizes you get almost the same multiplier with t and normal. Use 1.96 for a 95% CI to get 4.40 +/- 1.96 x 1.79 = 4.40 +/- 3.51 = (0.89, 7.91).
- The book uses 2 instead of 1.96, and the applet uses 1.9756 from the t-distribution. Just use 1.96 for this class.

Breastfeeding and Intelligence

- We have strong evidence against the null hypothesis and can conclude the association between breastfeeding and intelligence here is statistically significant.
- Breastfed babies have statistically significantly higher average GCI scores at age 4.
- We can see this in both the small p-value (0.015) and the confidence interval that says the mean GCI for breastfed babies is 0.89 to 7.91 points higher than that for non-breastfed babies.

Breastfeeding and Intelligence

- To what larger population(s) would you be comfortable generalizing these results?
  - The participants were all children born in Western Michigan.
  - This limits the population to whom we can generalize these results.

Breastfeeding and Intelligence

- Can you conclude that breastfeeding improves average GCI at age 4?
  - No. The study was not a randomized experiment.
  - We cannot conclude a cause-and-effect relationship.
- There might be alternative explanations for the significant difference in average GCI values.
- What might some confounding factors be?

Breastfeeding and Intelligence

- Can you conclude that breastfeeding improves average GCI at age 4?
  - No. The study was not a randomized experiment.
  - We cannot conclude a cause-and-effect relationship.
- There might be alternative explanations for the significant difference in average GCI values.
  - Maybe better educated mothers are more likely to breastfeed their children
  - Maybe mothers that breastfeed spend more time with their children and interact with them more.
  - Some mothers who do not breastfeed are less healthy or their babies have weaker appetites and this might slow down development in general.

Breastfeeding and Intelligence

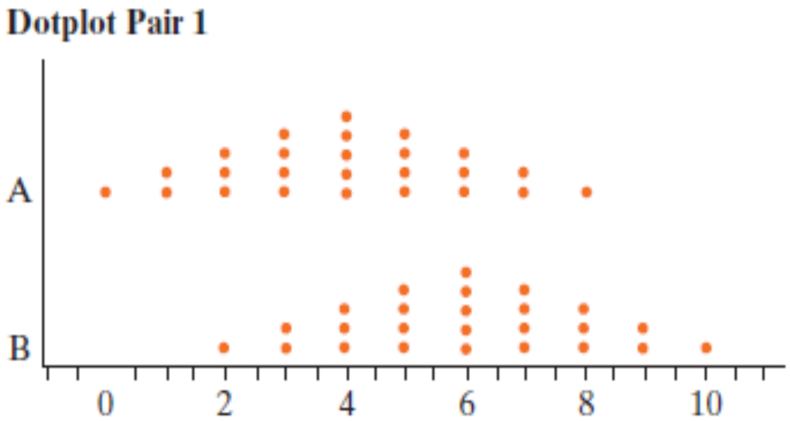
- Could you design a study that allows drawing a cause-and-effect conclusion?
  - We would have to run an experiment using random assignment to determine which mothers breastfeed and which would not. (It would be impossible to double-blind.)
  - Random assignment roughly balances out all other variables.
- Is it feasible/ethical to conduct such a study?

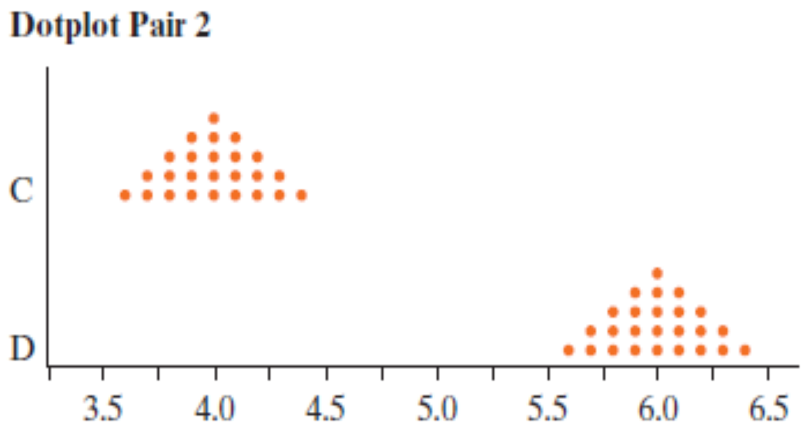
Strength of Evidence

- We already know:
  - As sample size increases, the strength of evidence increases.
  - Just as with proportions, as the sample means move farther apart, the strength of evidence increases.

More Strength of Evidence

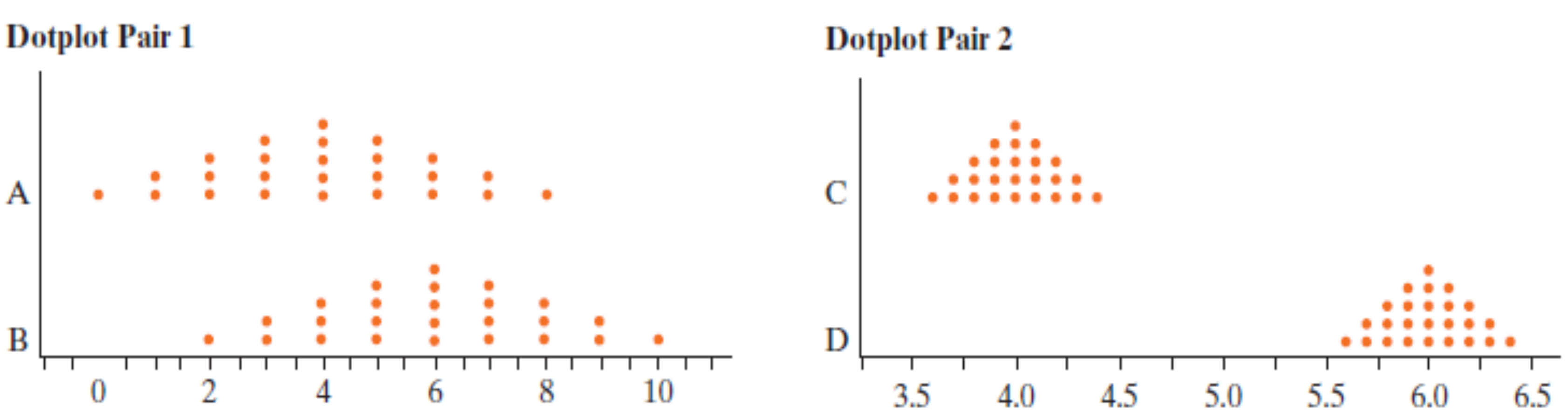
- If the means are the same distance apart, but the standard deviations change, then the strength of evidence changes too.
- Which gives stronger evidence against the null?





More Strength of Evidence

- If the means are the same distance apart, but the standard deviations change, then the strength of evidence changes too.
- Which gives stronger evidence against the null?



- Smaller SDs lead to stronger evidence against the null.

Effects on Width of Confidence Intervals

- Just as before:
  - As sample size increases, confidence interval widths tend to decrease.
  - As confidence level increases, confidence interval widths increase.
  - The difference in means will not affect the width (margin of error) but will affect the center of the CI.
- As we saw with a single mean, as the SDs of the samples increase, the width of the confidence interval will increase.

3. t versus normal and assumptions.

Why do we sometimes use the t distribution and sometimes the normal distribution in testing and confidence intervals?

The central limit theorem states that, for any iid random variables X_1, ..., X_n with mean μ and SD σ, $(\bar{x}$ - μ) ÷ (σ/√n) -> standard normal, as n -> ∞.

iid means independent and identically distributed, like draws from the same large population.

standard means mean 0 and SD 1.

3. t versus normal and assumptions.

CLT: $(\bar{x}$ - μ) ÷ (σ/√n) -> standard normal.

If Z is std. normal, then P(|Z| < 1.96) = 95%.

So, if n is large, then

P(|$(\bar{x}$ - μ) ÷ (σ/√n)| < 1.96) ~ 95%.

Mult. by (σ/√n) and get

P(|$\bar{x}$ - μ| < 1.96 σ/√n) ~ 95%.

P(μ $-$ $\bar{x}$ is in the range 0 +/- 1.96 σ/√n) ~ 95%.

P(μ is in the range $\bar{x}$ +/- 1.96 σ/√n) ~ 95%.

This all assumes n is large. What if n is small?

3. t versus normal and assumptions.

CLT: ($\bar{x}$ - μ) ÷ (σ/√n) -> standard normal.

What about if n is small?

A property of the normal distribution is that the sum of independent normals is also normal, and from this it follows that if $X_1, ..., X_n$ are iid and normal, then ($\bar{x}$ - μ) ÷ (σ/√n) is standard normal.

So again P(μ is in the range $\bar{x}$ +/- 1.96 σ/√n) = 95%.

This assumes you know σ. What if σ is unknown?

3. t versus normal and assumptions.

Suppose $X_1, \ldots, X_n$ are iid with mean μ and SD σ.

CLT: $(\bar{x} - \mu) \div (\sigma/\sqrt{n})$ ~ std. normal.

If $X_1, \ldots, X_n$ are normal, then $(\bar{x} - \mu)\div(\sigma/\sqrt{n})$ is std. normal.

σ is the SD of the population from which $X_1, \ldots, X_n$ are drawn. s is the SD of the sample, $X_1, \ldots, X_n$.

Gosset (1908) showed that replacing σ with s,

if $X_1, \ldots, X_n$ are normal, then $(\bar{x} - \mu)\div(s/\sqrt{n})$ is t distributed.

So we need the multiplier from the t distribution.

3. t versus normal and assumptions.

To sum up,

if the observations are iid and n is large, then

P(μ is in the range $\bar{x}$ +/- 1.96 σ/√n) ~ 95%.

If the observations are iid and normal, then

P(μ is in the range $\bar{x}$ +/- 1.96 σ/√n) ~ 95%.

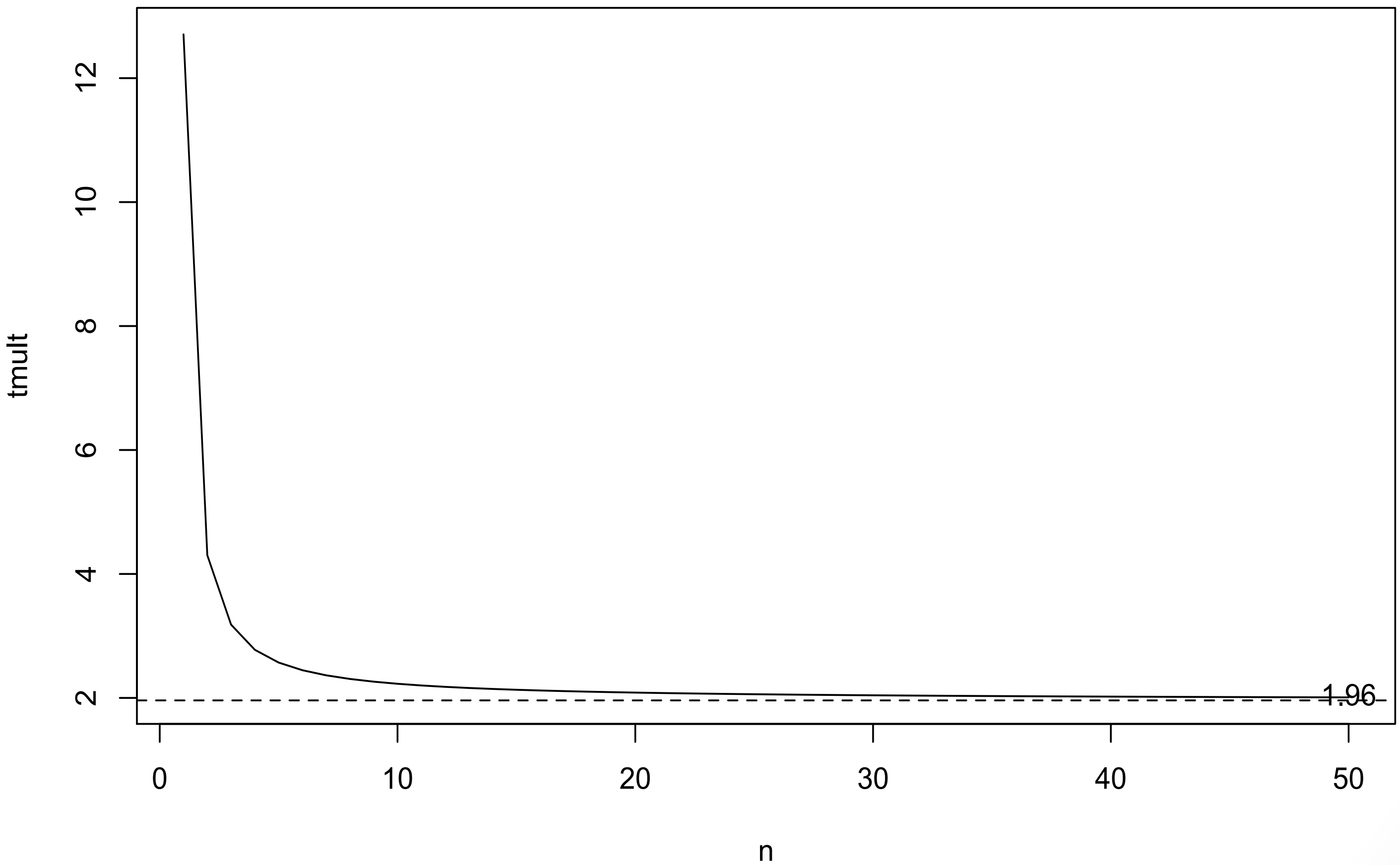
If the obs. are iid and normal and σ is unknown, then

P(μ is in the range $\bar{x}$ +/- t_{mult} s/√n) ~ 95%.

where t_{mult} is the multiplier from the t distribution.

This multiplier depends on n.

3. t versus normal and assumptions.



4. When to use which formula.

a. 1 sample numerical data, iid observations, want a 95% CI for μ.

- If n is large and σ is known, use $\bar{x}$ +/- 1.96 σ/√n.
- If n is small, draws are normal, and σ is known, use $\bar{x}$ +/- 1.96 σ/√n.
- If n is small, draws are normal, and σ is unknown, use $\bar{x}$ +/- t_{mult} s/√n.
- If n is large and σ is unknown, t_{mult} ~ 1.96, so we can use $\bar{x}$ +/- 1.96 s/√n.

n ≥ 30 is often considered large enough to use 1.96.

In practice, we typically do not know the draws are normal, but if the distribution looks roughly symmetrical without enormous outliers, the t formula may be reasonable.

b. 1 sample binary data, iid observations, want a 95% CI for π.

View the data as 0 or 1, so sample percentage p = $\bar{x}$, and

s = √[p(1-p)], σ = √[π(1−π)].

4. When to use which formula.

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- If n is small, draws ~ normal, and σ is unknown, use $\bar{x}$ +/- t_{mult} s/√n.
- If n is large and σ is unknown, t_{mult} ~ 1.96, so we can use $\bar{x}$ +/- 1.96 s/√n.

b. 1 sample binary data, iid observations, want a 95% CI for π.

View the data as 0 or 1, so sample percentage p = $\bar{x}$, and

s = √[p(1-p)], σ = √[π(1–π)].

If n is large and π is unknown, use $\bar{x}$ +/- 1.96 s/√n.

Here large n means ≥ 10 of each type in the sample.

4. When to use which formula.

What if n is small and the draws are not normal, and you want a theory-based test or CI?

How should you find the t multiplier for a CI or a p-value using the t-statistic, when n is small?

These are questions outside the scope of this course, but some techniques have been developed, such as the bootstrap, which are sometimes useful in these situations.

4. When to use which formula.

c. Numerical data from 2 samples, iid observations, want a 95% CI for μ_1 - μ_2.

If n is large and σ is unknown, use $\bar{x}_1$ - $\bar{x}_2$+/- 1.96 $\sqrt{\frac{s_1^2}{n_1}+\frac{s_2^2}{n_2}}$.

As with one sample, if σ_1 is known, replace s_1 with σ_1, and the same for σ_2. And as with one sample, if σ_1 and σ_2 are unknown, the sample sizes are small, and the distributions are roughly normal, then use t_{mult} instead of 1.96. If the sample sizes are small, the distributions are normal, and σ_1 and σ_2 are known, then use 1.96.

d. Binary data from 2 samples, iid observations, want a 95% CI for π_1 - π_2.

same as in c above, with $p_1 = \bar{x}_1$, $s_1 = \sqrt{[p_1 (1-p_1)]}$, $\sigma_1 = \sqrt{[\pi_1 (1-\pi_1)]}$.

Large for binary data means sample has ≥ 10 of each type.

4. Causation and prediction.

Note that for prediction, you sometimes do not care about confounding factors.

* Forecasting wildfire activity using temperature.

Warmer weather may directly cause wildfires via increased ease of ignition, or due to confounding with people chooseing to go camping in warmer weather. It does not really matter for the purpose of merely *predicting* how many wildfires will occur in the coming month.

* The same goes for predicting lifespan, or liver disease rates, etc., using smoking as a predictor variable.

5. CIs and tests.

Suppose we are comparing death rates in a treatment group and a control group. We observe a difference of 10.2%, do a test, and find a p-value of 8%.

Does this mean the 95%-CI for the difference in death rates between the two groups would contain zero?

CIs and tests.

Suppose we are comparing blood pressures in a treatment group and a control group. We observe a difference of 10.2 mm, do a 2-sided test, and find a p-value of 3%.

Would the 95%-CI for the difference in blood pressures between the two groups contain zero?

CIs and tests.

Suppose we are comparing blood pressures in a treatment group and a control group. We observe a difference of 10.2 mm, do a 2-sided test, and find a p-value of 3%.

Would the 95%-CI for the difference in blood pressures between the two groups contain zero or not?

No. It would not contain zero.

For what confidence level would the CI just barely contain 0?

97%.

CIs and tests.

The p-value is 3%. A 97%-CI would just contain zero.

```
                    Ho
         (          95%        )       (          95%-CI       )
------------------------------------------------------------------
                     |                           |
                     0                        10.2mm

                    Ho
(                   97%                        )
                     (                    97%-CI                  )
------------------------------------------------------------------
                     |                           |
                     0                        10.2mm
```

6. Review list.

1. Meaning of SD.
2. Parameters and statistics.
3. Z statistic for proportions.
4. Simulation and meaning of pvalues.
5. SE for proportions.
6. What influences pvalues.
7. CLT and validity conditions for tests.
8. 1-sided and 2-sided tests.
9. Reject the null vs. accept the alternative.
10. Sampling and bias.
11. Significance level.
12. Type I, type II errors, and power.
13. CIs for a proportion.
14. CIs for a mean.
15. Margin of error.
16. Practical significance.
17. Confounding.
18. Observational studies and experiments.
19. Random sampling and random assignment.
20. Two proportion CIs and testing.
21. IQR and 5 number summaries.
22. CIs for 2 means and testing.
23. Placebo effect, adherer bias, and nonresponse bias.
24. Prediction and causation.

7. Example problems.

Some good hw problems from the book are 1.2.18, 1.2.19, 1.2.20, 1.3.17, 1.5.18, 2.1.38, 2.2.6, 2.2.24, 2.3.3, 2.3.25, 3.2.11, 3.2.12, 3.3.8, 3.3.19, 3.3.22, 3.5.23, 4.1.14, 4.1.18, 5.2.2, 5.2.10, 5.2.24, 5.3.11, 5.3.21, 5.3.24, 6.2.23, 6.3.1, 6.3.12, 6.3.22, 6.3.23.

Example problems.

NCIS was the top-rated tv show in 2014. It was 3rd in 2016 and is now 5th in 2017.

A study finds that in a certain city, people who watch NCIS are much more likely to die than people who do not watch NCIS. Can we conclude that NCIS is a dangerous tv show to watch?

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No. Age is a confounding factor. The median age of a viewer is 61 years old.

- 1. Suppose the population of American adults has a mean systolic blood pressure of 120 mm Hg and an SD of 20 mm Hg. You take a simple random sample of 100 American adults. Which of the following is true?
- A typical adult's blood pressure would differ from 120 by about **20** mm Hg, and a typical sample of size 100 would have a sample mean that differs from 120 by about **2** mm Hg.
- A typical adult's blood pressure would differ from 120 by about **20** mm Hg, and a typical sample of size 100 would have a sample mean that differs from 120 by about **20** mm Hg.
- A typical adult's blood pressure would differ from 120 by about **2** mm Hg, and a typical sample of size 100 would have a sample mean that differs from 120 by about **0.2** mm Hg.
- A typical adult's blood pressure would differ from 120 by about **20** mm Hg, and a typical sample of size 100 would have a sample mean that differs from 120 by about **0.2** mm Hg.

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- **A typical adult's blood pressure would differ from 120 by about 20 mm Hg, and a typical sample of size 100 would have a sample mean that differs from 120 by about 2 mm Hg.**
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- A typical adult's blood pressure would differ from 120 by about **2** mm Hg, and a typical sample of size 100 would have a sample mean that differs from 120 by about **0.2** mm Hg.
- A typical adult's blood pressure would differ from 120 by about **20** mm Hg, and a typical sample of size 100 would have a sample mean that differs from 120 by about **0.2** mm Hg.

Example problems.

- In the study on clofibrate, researchers found that 25% of patients in the clofibrate group who stopped taking clofibrate died within 5 years, compared to just 15% of those in the clofibrate group who continued to take it. Does this prove that clofibrate works?
- a. Yes. For middle aged men suffering from heart problems, taking clofibrate causes them to increase their chance of living 5 years by 10%.
- b. No. Adherers were healthier than non-adherers, even in the placebo group.
- c. No. The clofibrate group was younger than the placebo group.
- d. No. The study was not double-blind, and this likely influenced the results.

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Example problems.

Suppose you sample 100 UCLA students and 80 2nd graders and record their blood glucose levels. The mean at UCLA is 5.5 mmol/L, with an SD of 1.5, and the mean in 2nd grade is 7.5 mmol/L, with an SD of 2.2.

a. Find a 95%-CI for how much less an average UCLA student's blood glucose level is than an average 2nd grader.

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a. Find a 95%-CI for how much less an average UCLA student's blood glucose level is than an average 2nd grader.

$2.0 \pm 1.96\sqrt{1.5^2/100 + 2.2^2/80} = 2.0 \pm 0.564$.

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b. Is the difference observed between the mean blood glucose at UCLA and in 2nd grade statistically significant?

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b. Is the difference observed between the mean blood glucose at UCLA and in 2nd grade statistically significant?

Yes. The 95%-CI does not come close to containing 0.

Example problems.

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c. Is this an observational study or an experiment?

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Observational study.

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d. Does going to UCLA cause your blood glucose level to drop?

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Suppose you sample 100 UCLA students and 80 2nd graders and record their blood glucose levels. The mean at UCLA is 5.5 mmol/L, with an SD of 1.5, and the mean in 2nd grade is 7.5 mmol/L, with an SD of 2.2.

d. Does going to UCLA cause your blood glucose level to drop?

No. Age is a confounding factor. Young kids eat more candy.

Example problems.

Suppose you sample 100 UCLA students and 80 2nd graders and record their blood glucose levels. The mean at UCLA is 5.5 mmol/L, with an SD of 1.5, and the mean in 2nd grade is 7.5 mmol/L, with an SD of 2.2.

e. The mean blood glucose level of all 43,301 UCLA students is a

parameter random variable t-test

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f. If we took another sample of 100 UCLA students and 80 2nd graders, and used the difference in sample means to estimate the difference in population means, how much would it typically be off by?

Example problems.

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f. If we took another sample of 100 UCLA students and 80 2nd graders, and used the difference in sample means to estimate the difference in population means, how much would it typically be off by? $SE = \sqrt{(1.5^2/100 + 2.2^2/80)} = .288$ mmol/L

Example problems.

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g. How much does one UCLA student's blood glucose level typically differ from the mean of UCLA students?

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Suppose you sample 100 UCLA students and 80 2^{nd} graders and record their blood glucose levels. The mean at UCLA is 5.5 mmol/L, with an SD of 1.5, and the mean in 2^{nd} grade is 7.5 mmol/L, with an SD of 2.2.

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1.5 mmoL/L.

Example problems.

- Researchers take a simple random sample of Californians and a simple random sample of Texans to see who does more exercise. They find that the Californians spend 2.5 hours per week exercising on average and the Texans spend 2.0 hours per week exercising on average. The researchers do a 2-sided test on the difference between the two means and find a p-value of 2.3%. Which of the following would be true of 90% and 95% confidence intervals for the weekly mean exercising time for Californians minus the mean exercising time for Texans?
- a. Both the 90% CI and the 95% CI will contain zero.
- b. Neither the 90% CI nor the 95% CI will contain zero.
- c. The 95% CI will not contain zero, but the 90% CI might contain zero.
- d. The 95% CI will contain zero, but the 90% CI might not contain zero.

Example problems.

- Researchers take a simple random sample of Californians and a simple random sample of Texans to see who does more exercise. They find that the Californians spend 2.5 hours per week exercising on average and the Texans spend 2.0 hours per week exercising on average. The researchers do a 2-sided test on the difference between the two means and find a p-value of 2.3%. Which of the following would be true of 90% and 95% confidence intervals for the weekly mean exercising time for Californians minus the mean exercising time for Texans?
- a. Both the 90% CI and the 95% CI will contain zero.
- **b. Neither the 90% CI nor the 95% CI will contain zero.**
- c. The 95% CI will not contain zero, but the 90% CI might contain zero.
- d. The 95% CI will contain zero, but the 90% CI might not contain zero.