Where we are…

#	Date	Read (5th)	Due	Area	Lecture Topic	Lab #	Lab Assignment	T Lab	R Lab
1	Tue Aug 26			*Orientation*	Welcome & Orientation	-			
2	Thu Aug 28	1.1 to 1.4			Basic Terms	-		-	-
3	Tue Sep 2	2.1 & 2.5			Measurement Issues	1	Levels / Age 3x	1	-
4	Thu Sep 4	3.1			Data Reduction	2	Heaven & Hell		1, 2
5	Tue Sep 9	-	HW1	*Description*	Display & Analysis (Shapes & SPSS)	3	Total Miles	2, 3	
6	Thu Sep 11	3.2 & 3.5			Central Tendency	4	CT		3, 4
7	Tue Sep 16	3.3 & 3.4			Dispersion	5	Dispersion	4, 5	
8	Thu Sep 18	3.7			Indices & Data Cleaning	6	Music index		5, 6
9	Tue Sep 23	4.2		*Inference*	Probability & Z Scores	7	Standardizing Scores	6, 7	
10	Thu Sep 25	4.3	HW2		Zs & Ps	8	Table A		7, 8
11	Tue Sep 30	3.6 & 5.1			Parameters & Pt Estimation	9	Distances	8, 9	
12	Thu Oct 2	2.2 to 2.4 & 4.3			Sampling (Issues, Methods, Effects)	10	Sampling		9, 10
13	Tue Oct 7	4.4 to 4.6			The Central Limit Theorem	11-EC	CLT/World (EC)	10, 11*	
14	Thu Oct 9	5.3		*Estimation*	Confidence Intervals	12	CI for Intervals		11*, 12
15	Tue Oct 14		HW3		CIs for Proportions	13	CI for Proportions	12, 13	
16	Thu Oct 16	6.1 & 6.4			Hypotesting & Zs	14	Writing Hypotheses		13, 14
17	Tue Oct 21				Hypotesting for Large ns	15	Two Tests	14, 15	
18	Thu Oct 23	6.3 & 6.8	HW4		The "t" test, for small ns	16	CI & Test Ages		15, 16
19	Tue Oct 28	5.4			Sample Size Estimation	17	Estimating n Needed	16, 17	
20	Thu Oct 30	7.1, 7.3, & 10.1		*Covariation*	Differences in Means	18	Comparing Means		17, 18
21	Tue Nov 4	7.2	HW5		Differences in Proportions	19	Comparing Proportions	18, 19	
22	Thu Nov 6	12.1			**Analysis of Variance**	20, 21-EC	ANOVA (+ MODELS EC)		19, 20, 21*
	Tue Nov 11				(Veteran's Day)				
23	Thu Nov 13	9.4 & 9.5			**Scatterplots & Correlation**	22	Grade Correlations		22
24	Tue Nov 18	9.1 to 9.3	HW6		**Regression**	23	Regression Lab	20,21*,22,23	
25	Thu Nov 20	10.2 & 11.1			**Multiple Regression**	24-EC	Multiple Reg (EC)		23, 24*
26	Tue Nov 25	8.1	HW7	*Association*	**Crosstabulations**	25	TBA (any)	24*, 25	
	Thu Nov 27				(Thanksgiving)				
27	Tue Dec 2	8.2 & p.233			**Dependence**	26, 27-EC	TBA (SCU) (& 27-EC)	26, 27*	
28	Thu Dec 4	pp.238 to 243	HW8		**Association**	28-EC	Measures of Assoc (EC)		25,26,27*,28
x	Dec 9				(no lecture - work session only)			28*	
x	Dec 11				(no lecture - work session only)				
x	Dec 18	-	HW9		(no meetings - deadline only - 10am, firm!)				

Review so Far

- **We're being scientific, yo –**
  - Careful and systematic about using data to test claims
- **Measurements Matter, no cap -**
  - Interval vs. Categorical (Nominal or Ordinal) > means/props.
- **Focus is on distances/differences – big diffs are fire!**
  - Sampling error, Std. Deviation, Standard Error
  - Keystone is the Z Score (where Math140 ends?), esp. 1.96
- **The rest of the class (& all science) derives from that**
  - Subtract 2 numbers to assess how different they are
  - The more different they are, the more confident we are in Ha
  - Everything is about statistical *tests*…

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Analysis of Variance

(Varianssianalyssi in Finland)

Summary of Analysis Procedures

1. **Univariate** (including inference to a pop.)
2. Univariate analysis for **subsamples**
3. Bivariate analysis **from univariate** data (diff. of means or proportions)

	NOMINAL IV	ORDINAL IV	INTERVAL DV
NOMINAL DV	***7. Crosstabs*** Size: % diff by column Test: chi-square PRE: lambda, tau	*Equal differences?* *← No Yes →*	**6. Special Regression** (discriminant or logistic)
ORDINAL DV	*If nothing multivariate, use crosstabs or anova; otherwise, use ordinal regression*	**8. Linear association** Nonparametric tests Gamma, tau b, Somer's d	*Equal increments & uniform distribution?* *← No Yes*
INTERVAL DV	***3. Diff of Means/Props.*** ***4. ANOVA*** More than 2 groups F test Eta squared	*Equal differences?* *← No Yes →*	**5. Regression** Slope b T or F Correlation, R^2

Outline for Today…

- **Overview of Statistical Tests**
- **Introduction to ANOVA**
  - The F Test: A Ratio of Variances
  - WSS & BSS
- **Example, w/ Hypotheses & Data**
  - Calculations (inc. Mean Squared Errors)
  - Conclusions & Source Table
- **Three-Part Demo in SPSS**
- **Two Labs**
  - Required: Using F to Test Models ☺
  - Extra Credit: Everything through F ☺ ☺

Tests Overview: When to Use Which

- **Each test = a tool for a particular instance**
  - **T-test:** interval DV; IV has two categories
  - **ANOVA:** interval DV; IV has 2 or more categories
  - **Correlation/Regression:** DV & IV both interval
  - **Chi-Square:** DV and IV both nominal or ordinal
    - But that's later, and has issues so additional tests (gamma, lambda, *et al.*)
    - ~~Median Test in book~~
- **But each (esp outcome) is basically the same:**
  - Compare the sample data to the null hypothesis – how different?
  - Get a p value and interpret it (risk of being wrong if you reject the null)
  - Reject (or can't reject) null, but *more importantly*…
  - Support (or can't support) the alternative hypothesis

Tests Variances Formula Example Demo Lab

Intro to ANOVA: >2 Groups in the IV

- **Could use T-tests (Diff Means) for each pair**
  - E.g. compare Family A&B, A&C, and B&C
  - But sampling error occurs with each comparison
    - Inflated probability of Type I error (falsely rejecting null)
    - Each comparison increases discrepency, =*additive error*
    - Larger S.E.→smaller test stat.→larger p→harder to reject null
- **3 advantages to the ANOVA alternative**
  - Compares means *indirectly*, with variances
    - Uses "F" distribution, instead of "t" distribution
  - Compares two or more groups (if 2, then $F = t^2$)
  - F is an "omnibus test", overall test of the "model"

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Tests Variances Formula Example Demo Lab

Notes for Calculation of F

- Recall Variance
  - = sum of squared deviations from the mean

$$\sum \frac{(Y_i - \overline{Y})^2}{n-1}$$

- WSS & BSS are variations on that idea
  - WSS just compares the group variances
  - BSS compares each group to the "grand mean"

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Tests Variances Formula Example Demo Lab

F test & Two Kinds of Variance

- F = ratio of two kinds of variances
  - Between-group Sum of Squares (BSS; aka Systematic variance)
    - Hope to show that groups are <u>different</u> from each other
    - Therefore want differences *between* groups to be <u>large</u>
      - Want the group means to be very different, as before, but also…
  - Within-group Sum of Squares (WSS; aka Random variance)
    - Want to conceive of each group as <u>consistently</u> unique
    - Therefore want differences *within* groups to be <u>small</u>
      - Observations should be similar to each other, i.e. close to the mean

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Tests Variances Formula Example Demo Lab

Notation for Calculating F

$$\textbf{Mean for each group} = \overline{Y} = \frac{\sum Y}{n}$$

$$\textbf{Grand mean} = \overline{\overline{Y}}_{m=3} = \frac{\overline{Y}_1 + \overline{Y}_2 + \overline{Y}_3}{n_1 + n_2 + n_3}\,*$$

* Sample sizes: n_1 for sample 1, n_2 for sample 2, etc.

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Tests Variances Formula Example Demo Lab

What Variances do we want?

- **Idea is to compare WSS to BSS**
  - Want "within group variance" to be small
    - want to say that strata are unique
    - want to say that the groups are clearly distinguishabbe
  - To support Ha (that there is a difference), want more variance between groups and less within each
- Think about a simple example for now…
  - Heights of men vs women in the class

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Tests Variances Formula Example Demo Lab

The Technical Formulas

- WSS = sum of the group variances

$$\sum_{j=1}^{n_1}(Y_{1j} - \overline{Y}_1)^2 + \sum_{j=1}^{n_2}(Y_{2j} - \overline{Y}_2)^2 + \sum_{j=1}^{n_3}(Y_{3j} - \overline{Y}_3)^2$$

- BSS = the average deviation, for all cases, from the grand mean **(I.e. the mean of all the cases, in all groups combined)**

$$\sum_{i=1}^{3} n_i(\overline{Y}_i - \overline{\overline{Y}})^2 = n_1(\overline{Y}_1 - \overline{\overline{Y}})^2 + n_2(\overline{Y}_2 - \overline{\overline{Y}})^2 + n_3(\overline{Y}_3 - \overline{\overline{Y}})^2$$

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ANOVA Example: Hypotheses

- Research Q: **Does family size vary w/ ethnicity?**
- Research hypothesis (H_A): **The number of children ever born to a woman, *on average*, differs between Chinese, Hispanic, & Hutterite groups.**

$$H_A : \mu_1 \neq \mu_2 \neq \mu_3$$

- Null hypothesis (H_0): **The number of children ever born to a woman is, *on average*, the same for Chinese, Hispanic, & Hutterite groups.**

$$H_0 : \mu_1 = \mu_2 = \mu_3$$

ANOVA Example: Data

- **6 samples of women from 3 ethnicities, w/ # of children:**

Chinese		Hutterite		Hispanic	
Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
1	0	10	2	5	0
1	0	10	2	5	0
2	1	11	5	5	10
2	1	11	15	5	10
2	2	12	18		
3	4	12	24		
3	6				
14 / 7 = 2	14 / 7 = 2	66 / 6 = 11	66 / 6 = 11	20 / 4 = 5	20 / 4 = 5

- **Within each culture, the two sample means are the same (2, 11, or 5) but the variances are different – Sample 1 is less dispersed than Sample 2**

ANOVA Example: Lower WSS

- Sample 1's:
  - The means (2, 11, and 5) are very different so the variance between the groups (BSS) seems high.

    … AND …
  - The observations within each group are all close to the mean for that group, so variance within groups (WSS) seems low.

Chinese	Hutterite	Hispanic
Sample 1	Sample 1	Sample 1
1	10	5
1	10	5
2	11	5
2	11	5
2	12	
3	12	
3		
14 / 7 = 2	66 / 6 = 11	20 / 4 = 5

ANOVA Example: Higher WSS

- Sample 2's:
  - The means (2, 11, and 5) are still very different so the variance between the groups (BSS) seems high.

    … BUT …
  - The observations within each group are very different, deviating far from the means for each – harder to say the groups really differ, within groups (WSS) seems high.

Chinese	Hutterite	Hispanic
Sample 2	Sample 2	Sample 2
0	2	0
0	2	0
1	5	10
1	15	10
2	18	
4	24	
6		
14 / 7 = 2	66 / 6 = 11	20 / 4 = 5

ANOVA Example: Calc. WSS

- Research hypothesis (H_A): The number of children born to a woman differs by ethnicity.

Chinese			Hutterite			Hispanic		
Y	(Y-Mean)	(Y-Mean)^2	Y	(Y-Mean)	(Y-Mean)^2	Y	(Y-Mean)	(Y-Mean)^2
0	-2	4	2	-9	81	0	-5	25
0	-2	4	2	-9	81	0	-5	25
1	-1	1	5	-6	36	10	5	25
1	-1	1	15	4	16	10	5	25
2	0	0	18	7	49			
4	2	4	24	13	169			
6	4	16						
Mean=2		Sum=30	Mean=11		Sum=432	Mean=5		Sum=100

WSS = 30 + 100 + 432 = 562

ANOVA Example: Calc. BSS

- Grand mean =

  (0+0+1+1+2+4+6)+(0+0+10+10)+(2+2+5+15+18+24) / 17

  = 100 / 17 = 5.882
- BSS =

  $= n_1(\text{Mean-Grand})^2 + n_2(\text{Mean-Grand})^2 + n_3(\text{Mean-Grand})^2$

  $= 7*(2 - 5.882)^2 \quad + \quad 4*(5 - 5.882)^2 \quad + \quad 6*(11 - 5.882)^2$

  = 7*(15.070) + 4*(0.778) + 6*(26.194)

  = 105.490 + 3.112 + 157.164

  = 265.766

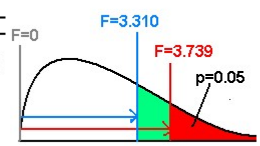
ANOVA Example: df's & MSE

- BSS degrees of freedom = m – 1
  - m = # of groups (here, 3: Chinese, Hispanic, & Hutterite)
  - So, df_{BSS} = m – 1 = 3 – 1 = 2
- WSS degrees of freedom = *N* - m
  - *N* = sample size (here, $n_1 + n_2 + n_3 = 7 + 4 + 6 = 17$)
  - So, df_{WSS} = *N* – m = 17 – 3 = 14
- F Uses "mean squared error"
  - MSE = sum of squares / degrees of freedom
  - F = (BSS / m - 1) / (WSS / *N* - m) = MSE_{BSS} / MSE_{WSS}
  - = (265.766 / 2) / (562 / 14) = 132.883 / 40.143 = 3.310

ANOVA Example: F Values

- Calculated F = 3.310
- Tabular F =3.739 *(3.74 in Table C, p.671)*

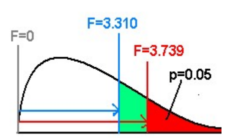
df denom	P	df for Numerator 1	2
1	.05	161.447	199.500
	.01	4052.176	4999.492
⋮			
14	.05	4.600	3.739
	.01	8.862	6.515
	.001	17.143	11.779



ANOVA Example: Finale

- Interpretation:

  If the null (that the group means are the same) is true, probability of obtaining an F larger than the one observed is greater than .05 (green, too!), which is too large.



- Conclusion:

  Given a p-value > .05, we fail to reject the null. Therefore, we do not have sufficient evidence to support our hypothesis that the number of children ever born to women differs by ethnicity.

ANOVA: SPSS "Source table"

- Look for this:

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	265.765	2	132.882	3.310	.066
Within Groups	562.000	14	40.143		
Total	827.765	16			

- Again, SPSS provides an "exact" p value (the estimated area under the curve to the right of the calculated F) so you don't need Appendix D (or anything else) to get a "tabular" F
- Also, SPSS gives the "Total Sum of Squares", (TSS = BSS+WSS), representing all of the variation from the means

ANOVA: Three SPSS Examples

- **ANALYZE – COMPARE MEANS – ONE-WAY ANOVA**
- Example 1 (AnovaEG1.sav)
  - Data from above
  - Basic ANOVA output
- Example 2 (AnovaEG2.sav)
  - Number of children by Rural/Urban – show $F=t^2$
- Example 3 (AnovaEG3.sav)
  - Tomatoes – does final height vary w/ fertilizer brand?
  - Choose "Options…" & click box by "Descriptive"
  - Choose "Options…" & click box by "Means Plot"

Required Group Lab: F-Testing Models

I'll emphasize this in labs moreso than lecture. If you aren't doing labs in breakouts, touch base with me!!

- Research Q: How are abortion attitudes distributed?
- Get AnovaGE2.sav from the website
- I've created an index (**ABTOT**) of abortion attitudes
  - Histogram was discussed in an earlier lecture
  - Measures **number of instances (of 6) in which respondent is *opposed*** to abortion
  - Higher values = more pro-life/anti-abortion; Lower values = more pro-choice
- Conduct "F-tests" (ANOVAs) to assess whether gender or education (*two possible factors* in explaining ABTOT) better predicts whether someone approves of abortion overall
  - That's two *separate* ANOVAs – one w/ each *factor*
  - Remember: Only reject if the p value is LESS than 0.05!
  - Also, click "Options" and choose both "Descriptives" and "Means Plot"
- Submit the two F values and their p values, interpret each result, make a statement about these two possible "independent variables", **& describe the means plot** for each

Extra Credit Lab: Everything to F

- Research Q: Do those who watch a variety of TV genres also listen to more kinds of music?
- Get AnovaGE1.sav from the website
- Create ("compute") an index of how many TV genres respondents watch (TVTOT, like RSHOWS)
- Remove the student who watches none of these genres (hint: declare that student as "missing")
- Create ("recode") a dichotomous variable (TVTOT2) for those who watch only 1 genre, vs. more than 1
- Conduct a "t-test" - does MUSIC vary by TVTOT2?
- Conduct an "F-test" (ANOVA) – does it now?
- Submit the t & its p, F & its p, and interpret results