Factorial ANOVA
Repeated-Measures ANOVA

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CPSY501
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Please download:
- ***treatment5.sav***
- ***MusicData.sav***

For next week, please read articles:
- ***Myers&Hayes 06***
- ***Horowitz 07***

TRINITY WESTERN UNIVERSITY

Outline for Today

- ANCOVA
  - Covariate or predictor?
- Factorial ANOVA
  - Running in SPSS and interpreting output
  - Follow-up: main effects
  - Follow-up: interactions and simple effects
  - Assumptions
- Repeated-Measures ANOVA
  - Assumptions (sphericity)
  - Follow-up: post-hoc comparisons

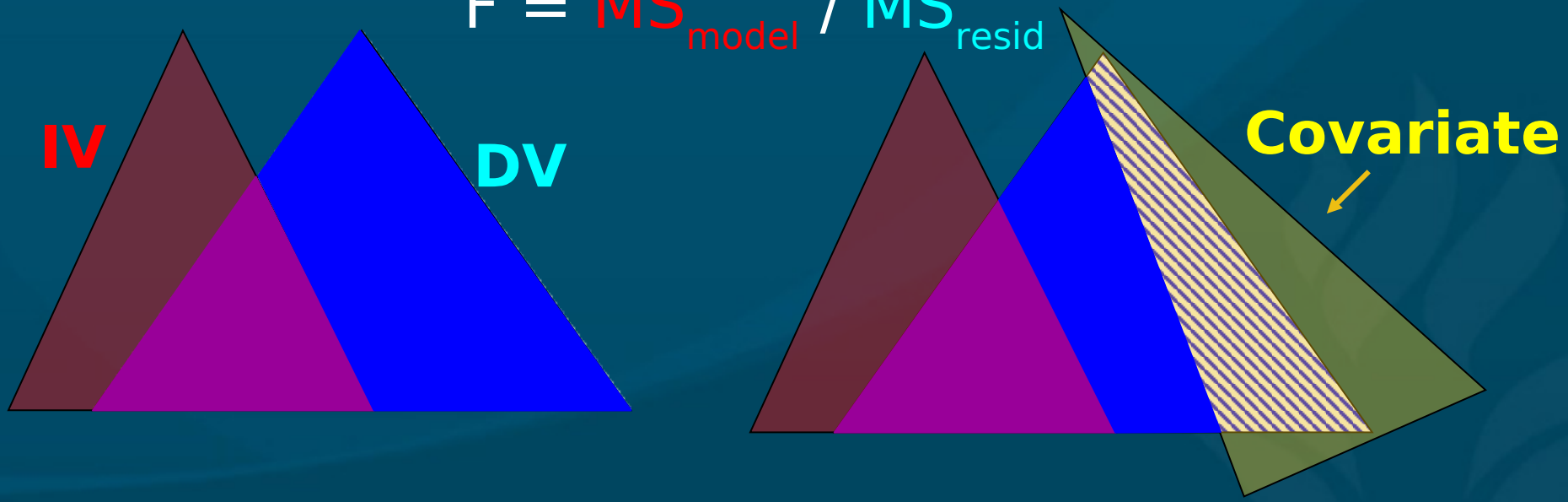
Introduction to ANCOVA

- Covariates are continuous "predictor" variables used as "control" factors to help power
- Covariates may be promoted to IVs if conceptually linked to other IVs or to the DV
- ANCOVA factors out the portion of variance in the DV that is accounted for by the covariates
  - Affects both MS_{model} and $MS_{residual}$
- Caution is required when covariates are correlated with IVs – creating conceptual links

Using ANCOVA in Research

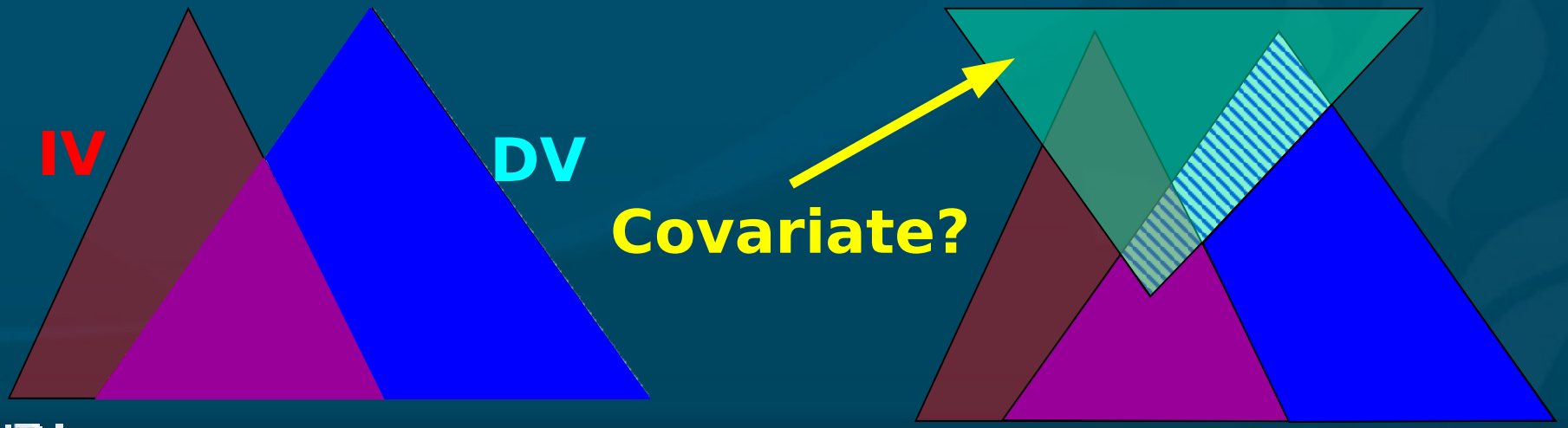
- Reduction of error variance: Including covariate(s) related to the DV in the model accounts for some within-group error variance, thus reducing MS_{resid} and increasing the *F*-ratio.

$$F = MS_{model} / MS_{resid}$$



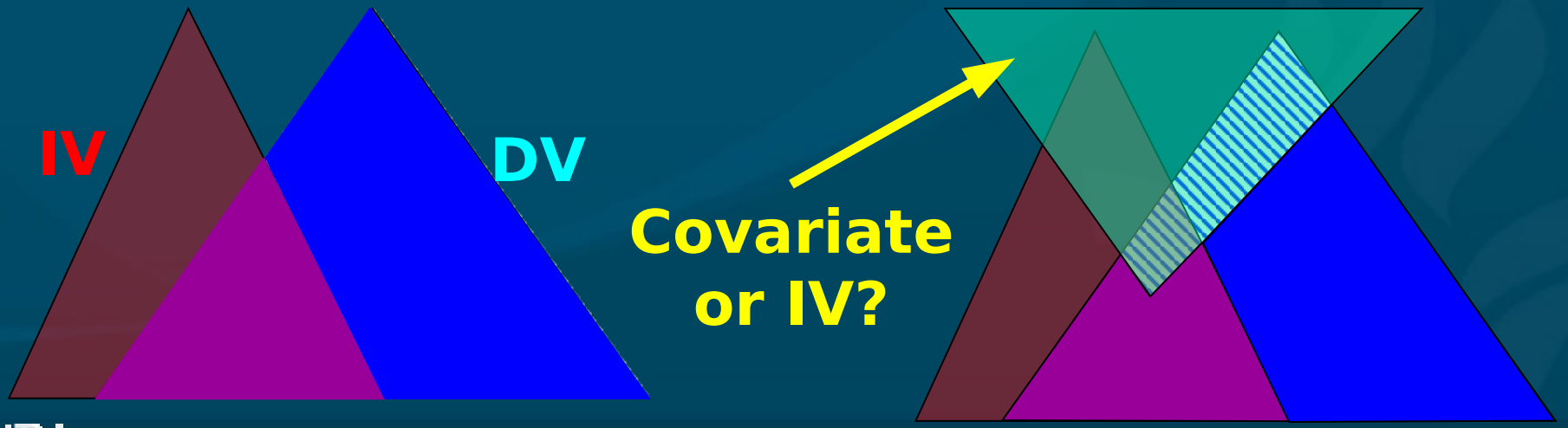
ANCOVA: Confounding Vars

- "Confounding" variables:
  External variables that may systematically influence an experimental manipulation.
- They can be identified through theory
- Control for them by entering them as covariates (though this may or may not improve *F*-ratio)



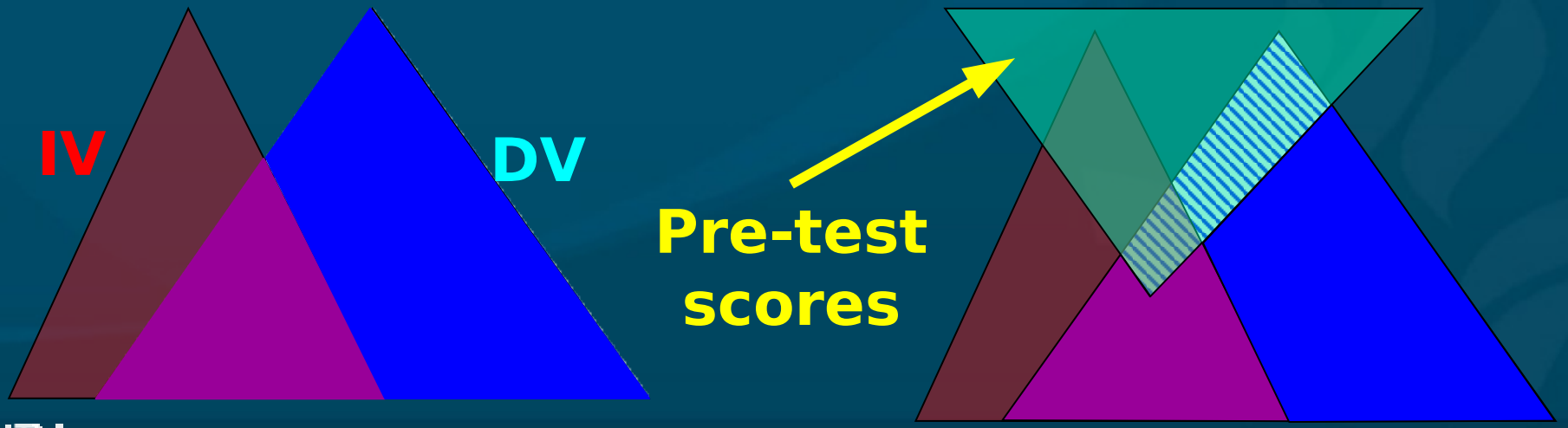
Covariates vs. Predictors

- If a covariate is 'linked' conceptually / theoretically with another IV or with the DV, then treat the covariate as an IV.
  - It could potentially be a moderator
- Any interactions or interpretable IV-Cov correlations then become part of the analysis.



ANCOVA in Therapy Research

- In therapy studies, different treatment groups often have different pre-treatment scores
  - How to compare treatments when the starting points are different?
- Solution: When in doubt, treat pre-treatment scores as another IV, not as a covariate.



Assumptions of ANCOVA

- Parametricity of DV (as with regular ANOVA)
- Homogeneity of regression slopes:
  - Regression of the DV on the Cov is the same for all groups
  - i.e., Cov is not a moderator
  - Test for interactions between IVs & Cov
- Conceptual independence of Cov & IVs
  - So that the shared variance is “external” to our RQ

ANCOVA: SPSS

- Analyze → General Linear Model → Univariate
  - Add variables to "Covariates" box
- Reporting: "Controlling/accounting for the influence of <Cov>, the effect of <IV> on <DV> is / is not significant, $F(df_{IV}, df_{error}) = \_\_\_, p = \_\_\_$."

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Intro to Factorial ANOVA

- ANOVA with multiple "between-subjects" IVs
- Describe number of categories/groups per IV:
  - "5 x 4 x 4 design" means 3 IVs, with 5 values (groups), 4 values, 4 values each
- Each cell is a combination of categories:
  - 5 x 4 x 4 = 80 cells
  - Each participant goes in exactly one cell, and is measured only once on the DV
  - Cells are assumed to be independent
  - "Balanced": cell sizes all equal

Why Factorial ANOVA?

- Why not just do One-way on each IV?
  - IVs may have shared variance
  - Interaction effects (moderation)!
- Main effects: effect of just one IV (One-way)
- Two-way interaction: Effects of one IV change depending on value of another IV (moderator)
- 3-way and higher interactions exist, too
- Higher-order effects supercede low-order ones: interpret the highest significant interaction
- Graphs may be needed to understand them

Factorial ANOVA in SPSS

- First check assumptions (see later slides)
- Analyze → GLM → Univariate
  - Enter all IVs together in "Fixed Factor(s)"
  - Model: "Full Factorial" (default)
    (checks for all main effects & interactions)
  - Options: Effect size & Homogeneity tests,
    Descriptives (and later, marginal means)
- Examine each effect in the model separately
- treatment5.sav: IVs: Treatment Type, Gender
  - DV: just depression at outcome for now

Interpreting Output: Treatment5

There were significant effects for treatment type, $F\ (2, 21) = 21.14$, $p < .001$, $\eta^2 = .668$, and gender, $F\ (1, 21) = 14.69$, $p = .001$, $\eta^2 = .412$, but no significant interaction, $F\ (2, 21) = 0.15$, $p > .05$, $\eta^2 = .014$

Tests of Between-Subjects Effects

Dependent Variable: depression level at outcome of therapy

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	55.796(a)	5	11.159	11.431	.000	.731
Intercept	317.400	1	317.400	325.141	.000	.939
Gender	**14.341**	**1**	**14.341**	**14.691**	**.001**	**.412**
Treatmnt	**41.277**	**2**	**20.638**	**21.142**	**.000**	**.668**
Gender * Treatmnt	**.283**	**2**	**.142**	**.145**	**.866**	**.014**
Error	20.500	21	.976			
Total	383.000	27				
Corrected Total	76.296	26				

a R Squared = .731 (Adjusted R Squared = .667)

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Follow-up Analysis: Main effects

- If there are significant main effects:
  - Analyze → GLM → Univariate → Post-hoc
  - Post-hoc tests as in one-way ANOVA
  - SPSS does post-hoc for each IV separately (i.e., as if doing multiple one-way ANOVAs)
- Report means and SDs for each category of each significant IV (Options: Descriptives)
- Or report marginal means for "unique effects" (Options: Estimated Marginal Means) (more on this momentarily)

Post-hoc: Treatment5

- Post-hoc on main effect for Treatment Type:
  - Levene's is not significant, so can choose a post-hoc test that assumes equal variance: e.g., Tukey's HSD
- No post-hocs needed for Gender – why?

- Output (see next slide):
  - The Wait List control group has significantly higher depression levels at post-treatment
  - (can graph means to visualize)

Multiple Comparisons

Dependent Variable: depression levels at outcome of therapy

	(I) Treatment Type	(J) Treatment Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
Tukey HSD	CBT	CBT					
		Church-based support group	-1.12	.454	.055	-2.27	.02
		WL Control	-3.03(*)	.469	.000	-4.21	-1.84
	Church-based support group	CBT	1.12	.454	.055	-.02	2.27
		Church-based support group					
		WL Control	-1.90(*)	.480	.002	-3.11	-.69
	WL Control	CBT	3.03(*)	.469	.000	1.84	4.21
		Church-based support group	1.90(*)	.480	.002	.69	3.11
		WL Control					

Based on observed means.

* The mean difference is significant at the .05 level.

Estimated Marginal Means

- Estimate of group means in the population rather than the sample, accounting for effects of all other IVs and any covariates.
- Analyze → GLM → Univariate → Options:
- Move IVs and interactions to "Display means"
  - Select "Compare main effects"
  - Select multiple comparisons adjustment
- Can be used to obtain estimated means for:
  - (a) each group within an IV, and
  - (b) each cell/sub-group within an interaction

Actual vs. Estimated Means

- If instead we want to plot the actual sample group means, just use:
- Graph → Line → Multiple → Define:
  - Enter DV in Lines Represent menu, as "Other Statistic"
  - Enter IVs as "Category Axis" and "Define Lines By"
- Usually, the estimated marginal means are close to the actual sample means

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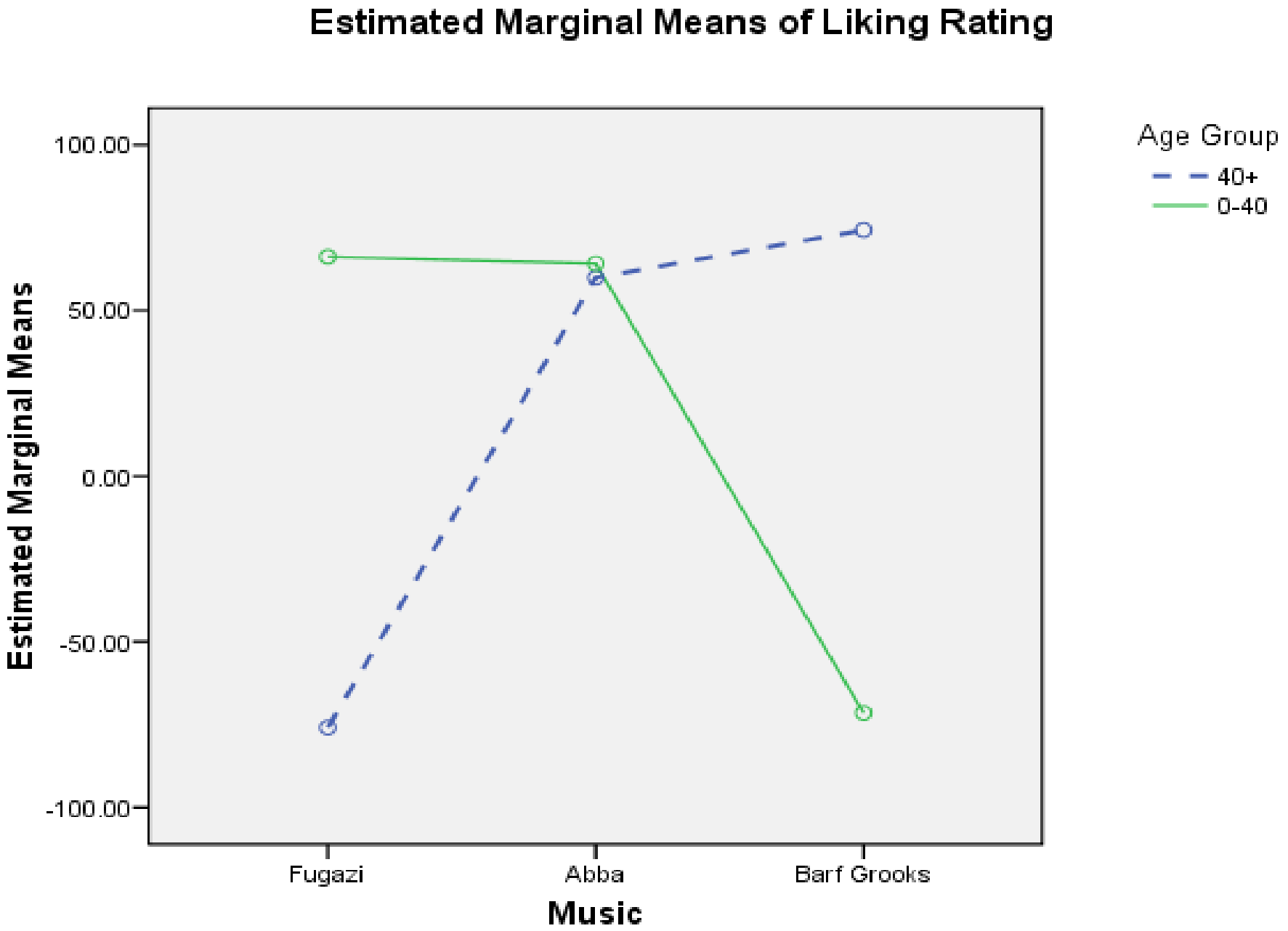
Graphing Interactions

- For significant interactions: Graph the interaction to understand its effects:
  - Analyze → GLM → Univariate → Plots
  - SPSS plots estimated marginal means
- The IV with the most groups usually goes into "Horizontal axis" (if makes sense conceptually)
- For 3-way interactions, use "Separate plots".
- More complex interactions require more work

Interactions Ex.: MusicData

- Dataset: MusicData.sav
- DV: Liking (scale)
- IV: Age (categorical: 0-40 vs. 40+)
- IV: Music (cat.: Fugazi, Abba, Barf Grooks)

- Run a 2x3 factorial ANOVA
  - Any significant interactions & main effects?
  - Plot the interaction of Age x Music


Estimated Marginal Means of Liking Rating
Estimated Marginal Means
100.00
50.00
0.00
-50.00
-100.00
Fugazi
Abba
Barf Grooks
Music
Age Group
40+
0-40

Follow-up: Simple Effects

- If BOTH interaction and main effects are significant, report both but
  - Interpret the main effects primarily "in light of" the interaction
- How do we further understand effects?
- Simple effect: look at the effect of certain IVs, with the other IVs fixed at certain levels
  - e.g., do the old like "Barf Grooks" more than the young do? (fix Music = "Barf Grooks")
- May need advanced SPSS syntax tools to do

Simple effects: MusicData

- Data → Split file → “Compare groups”: Music
  - Beware loss of power anytime we split data, due to small cell sizes
- Run an ANOVA for each group in Music:
  - GLM → Univariate: Liking vs. Age
  - Options: Effect size, Levene's tests, etc.
- Analogous to 3 *t*–tests for age:
  one *t*-test for each music group

Non-significant Interactions

- If the interaction is not significant, we might not have moderation. Either:
  - Leave it in the model (may have some minor influence, should be acknowledged), or
  - Remove it and re-run ANOVA (may improve the *F*-ratios)
- Analyze → GLM → Univariate → Model → Custom
  - Change Build Term to "Main effects"
  - Move all IVs into "Model", but omit the non-significant interaction term

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ANOVA: Parametricity

- Interval-level DV, categorical IVs
- Independent scores: look at study design
- Normal DV: run K-S & S-W tests (per-cell)
- Homogeneity of variances:
  - Levene's tests for each IV
  - Really, need homogeneity across all cells
- Use the same strategies for
  (a) increasing robustness and
  (b) dealing with violations of assumptions
  as you would in one-way ANOVA

Assumptions: Practise

- Dataset: treatment5.sav
- DV: depression score at follow-up (scale)
- IV: Treatment (categorical: CBT vs. CSG vs. WL)
- IV: Age (scale, but treat as categorical)

- What assumptions are violated?
- For each violation, what should we do?
- After assessing the assumptions, run the Factorial ANOVA and interpret the results.

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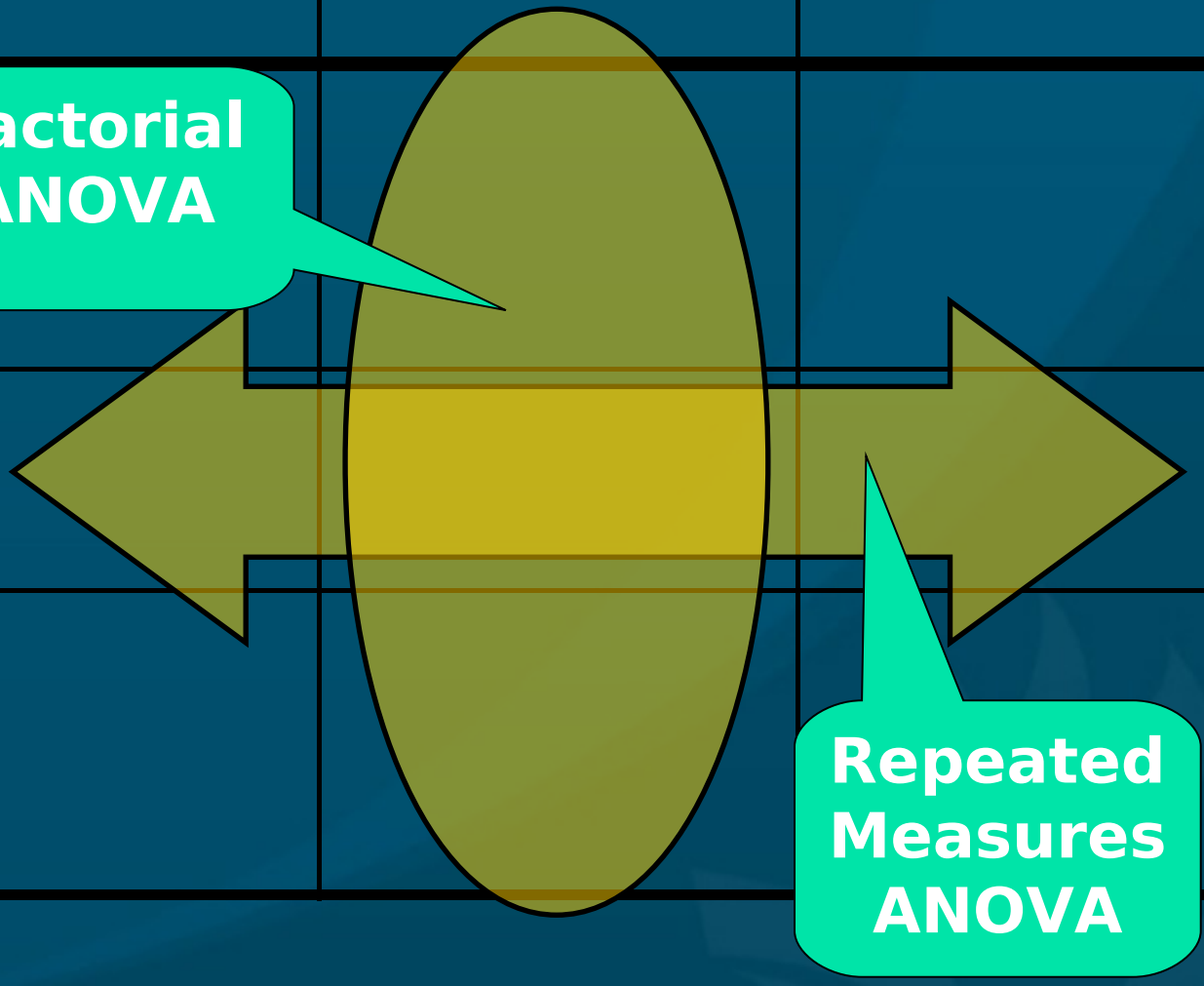
TREATMENT RESEARCH DESIGN	Pre-Test	Post-Test	Follow-up
Cognitive-Behavioural Therapy			
Church-Based Support Group			
Wait List control group			



Between- vs. Within- Subjects

- Between-Subjects Factor/IV:
  Different sets of participants in each group
  - e.g., an experimental manipulation is done between different individuals
  - One-way and Factorial ANOVA
- Within-Subjects Factor/IV: The same set of participants contribute scores to each cell
  - e.g., the experimental manipulation is done within the same individuals
  - Repeated-Measures ANOVA

RM Example: Treatment5

- DV: Depressive symptoms
  - (healing = decrease in reported symptoms)
- IV1: Treatment group
  - CBT: Cognitive-behavioural therapy
  - CSG: Church-based support group
  - WL: Wait-list control
- IV2: Time (pre-, post-, follow-up)
- There are several research questions we could ask that fit different aspects of this data set

Treatment5: Research Qs

- Do treatment groups differ after treatment?
  - One-way ANOVA (only at post-treatment)
- Do people "get better" while they are waiting to start counselling (on the wait-list)?
  - RM ANOVA (only WL control, over time)
- Do people in the study get better over time?
  - RM ANOVA (all participants over time)
- Does active treatment (CBT, CBSG) decrease depressive symptoms over time more than WL?
  - Mixed-design ANOVA
    (Treatment effect over time)

Repeated-Measures ANOVA

- One group of participants, experiencing all levels of the IV: each person is measured multiple times on the DV.
  - Scores are not independent of each other!
- RM is often used for:
  - (a) developmental change (over time)
  - (b) therapy / intervention (e.g., pre vs. post)
  - Also for other kinds of dependent scores (e.g., parent-child)

Why Use RM ANOVA?

- Advantages:
  - Improve power: cut background variability
  - Reduce MS-Error: same people in each cell
  - Smaller sample size required
- Disadvantages:
  - Assumption of sphericity is hard to attain
  - Individual variability is “ignored” rather than directly modelled: may reduce generalizability of results
- Use RM when you have within-subjects factors

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Assumptions of RM ANOVA

- Parametricity: (a) interval-level DV, (b) normal DV, (c) homogeneity of variances.
  - But not independence of scores!
- Sphericity: homogeneity of variances of pairwise differences between levels of the within-subjects factor
  - Test: if Mauchly's W ≈ 1, we are okay
  - If the within-subjects factors has only 2 cells, then W=1, so no significance test is needed.

Treatment5: 3-level RM

- Analyze → GLM → Repeated Measures
  - "Within-Subject Factor Name": Time
  - "Number of Levels": 3, press "Add"
- Define: identify specific levels of the "within-subjects variable": order matters!
- For now, don't put in treatment groups yet (Look at overall pattern across all groups)
- Options: Effect size
- Plots: "Time" is usually the horizontal axis
- Look through the output for Time only!

Check Assumptions: Sphericity

"The assumption of sphericity was violated, Mauchly's $W = .648$, $\chi^2(2, N = 30) = 12.16$, $p = .002$."

- If violated, use Epsilon (Greenhouse-Geisser) to adjust *F*-score (see later)
- Scored from 0 to 1, with 1 = perfect sphericity

Mauchly's Test of Sphericity

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
CHANGE	.648	12.154	2	.002	.740	.770	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

If Sphericity Is Satisfied:

- Report *F*-ratio, *df*, *p*, and effect size from the line with Sphericity Assumed
- APA style: "$F(2, 58) = 111.5$, $p < .001$, $\eta^2 = .794$"
- If the omnibus ANOVA is significant, identify specific group differences using follow-up tests

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	262.422	**2**	131.211	**111.514**	**.000**	**.794**
	Greenhouse-Geisser	262.422	1.479	177.414	111.514	.000	.794
	Huynh-Feldt	262.422	1.540	170.435	111.514	.000	.794
	Lower-bound	262.422	1.000	262.422	111.514	.000	.794
Error(time)	Sphericity Assumed	68.244	**58**	1.177			
	Greenhouse-Geisser	68.244	42.895	1.591			
	Huynh-Feldt	68.244	44.652	1.528			
	Lower-bound	68.244	29.000	2.353			

If Sphericity Is Violated:

- *F*-ratio and ANOVA results may be distorted
- Consider multi-level modelling instead (but it requires much larger sample size), or
- Consider multivariate *F*-ratio results (MANOVA):
  - But it loses power compared to RM ANOVA
  - Need Greenhouse-Geisser epsilon ≤ .75
  - Need sample size ≥ 10 + (# "within" cells)
  - Report, e.g.: "Wilk's $\lambda = .157$, $F(2, 28) = 75.18$, $p < .001$, $\eta^2 = .843$"

Sphericity Violated: Adjust df

- Use Greenhouse-Geisser epsilon if ≤ .75:
  - If > .75, you may use the more optimistic Huynh-Feldt epsilon
  - Multiply df by epsilon and update *F* and *p*
  - This is given in the output tables
- If the adjusted *F*-ratio is significant, proceed to follow-up tests as needed
- Report: e.g., "Greenhouse-Geisser adjusted $F(1.48, 42.9) = 111.51$, $p < .001$, $\eta^2 = .794$"

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Follow-up analysis: post-hoc

- If the overall RM ANOVA is significant, explore differences between specific cells/times:
  - Analyze → GLM → Repeated Measures: Define → Options:
  - Estimated Marginal Means: move RM factor to "Display means for"
  - Select "Compare Main Effects", use "Confidence interval adjust.": Bonferroni
- Plot the effects over time:
  - Plots → IV in "Horizontal axis" → Add
  - Or try error bar plots

Post hoc comparisons, cont.

- Note: the Post-Hoc button applies only to between-subjects factors
  - Hence not applicable here: we only have one IV (Time) and it is within-subjects
- Interpret the output:
  - Bonferroni results show that the mean Pre-test scores are significantly higher than the mean Post-test & Follow-up scores
  - But the Post-test & Follow-up scores are not significantly different
  - (see "Pairwise Comparisons", "Estimates")

Practise: “Looks & Charisma”

- Dataset: Field-Looks_Charis.sav (from textbook)
- How does “attractiveness” change over time?
- How does “charisma” change over time?
- Combine both IVs in a factorial RM analysis (using both IVs)
- Attending to sphericity issues, interpret the results
- Conduct follow-up tests to see which kinds of people are evaluated more (and less) positively