2xkxQ Example: "Regression Slope Differences" Type Analysis

The purpose of this study was to examine the relationships of exam review attendance, practice item difficulty and number of practices with exam performance. Practice difficulty was a 3-condition variable - practice problems were either about the same difficulty as the exam problems (=1), they were easier than the exam problems (=2), or they were more difficult than the exam problems (=3). Different sections of the course were randomly assigned to receive the three difficulty levels. The schedule showed the class meeting during which the exam review would occur & student's attendance was recorded. The number of online practice problems each participant completed before taking the exam were also recorded. The dependent variable was performance on an examination.

We can describe these data as either a 3-predictor multiple regression (with dummy-coded categorical variables and a quantitative variable), or as a 2x3 factorial design with a quantitative covariate.

Either way, we should examine whether the interactions among the predictors add any explanatory power to the model.

If we describe these data as a factorial ANCOVA, then including the interactions between the IVs and the covariate would be tests of the homogeneity of regression slope assumption.

Inspection of the group means shows that there is considerable confounding by number of practices across the groups. Not only that, but the pattern of the confounding is complex, suggesting that there will be interactions including number of practices, and so, the regression slope homogeneity assumption is unlikely to hold.

Report

Mean

practgrp	atndrev	numpract	testperf
same	no	4.2000	60.0000
	yes	8.8333	80.0000
	Total	5.9375	67.5000
easier	no	2.7000	60.0000
	yes	7.1111	43.3333
	Total	4.7895	52.1053
harder	no	3.4000	44.0000
	yes	7.3333	82.2222
	Total	5.2632	62.1053
Total	no	3.4333	54.6667
	yes	7.6250	67.0833
	Total	5.2963	60.1852

Descriptive Statistics

|	N	Minimum	Maximum	Mean	Std. Deviation
testperf	54	30.00	100.00	60.1852	17.96125
numpract	54	1.00	10.00	5.2963	2.75838
Valid N (listwise)	54				

Here is a plot of the raw data.

You can see that we have a definite data pattern here – something more complex than the usual slightly tilted ovoid.

It is difficult to anticipate what pattern we will find, especially without knowing what combination of conditions each dot comes from.

But there is definitely a cross-over looking pattern here.

This sort of pattern often goes with finding substantial interactions within the complex desian.
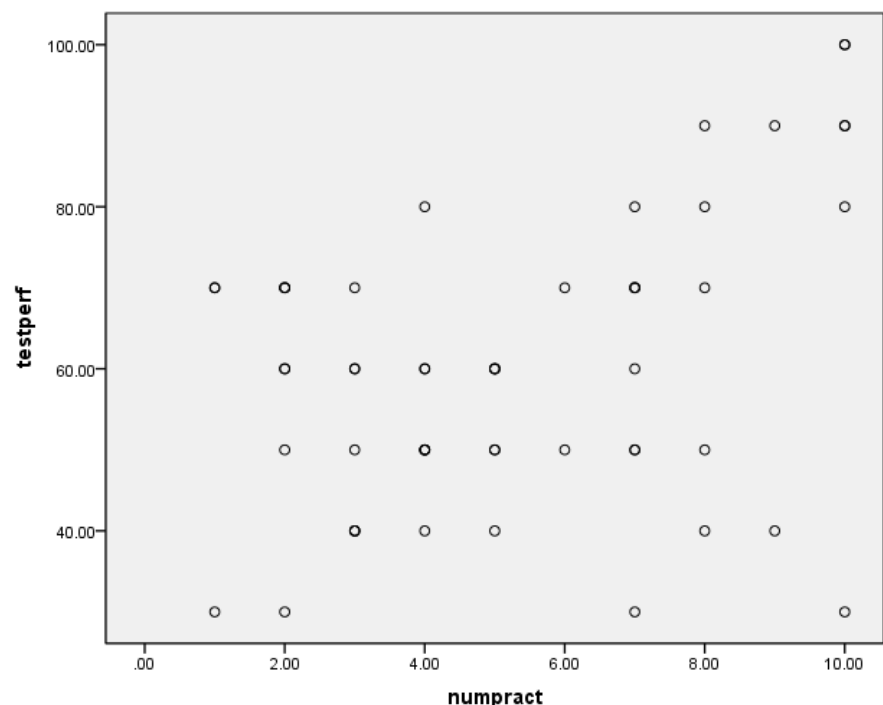
Data Preparation

Here is the syntax to dummy-code the categorical variables, mean-center the quantitative variable, and construct the various interactioins

* pract_s0e1 compares same=1=>0 with easier = 2 => 1.
if (practgrp = 1) pract_s0e1 = 0.
if (practgrp = 2) pract_s0e1 = 1.
if (practgrp = 3) pract_s0e1 = 0.

Practice Difficulty has 3 conditions → 2 dummy codes will be needed.

*pract_s0h1 compare same=1=>0 with harder=3=>1.
if (practgrp = 1) pract_s0h1 = 0.
if (practgrp = 2) pract_s0h1 = 0.
if (practgrp = 3) pract_s0h1 = 1.

* atndrev_n0y1 no=1=>0   yes=2=>1.
if (atndrev = 1) atndrev_n0y1 = 0.
if (atndrev = 2) atndrev_n0y1 = 1.

Review Attendance is binary → 1 dummy code will be needed

* mean center number of practices.
compute pract_mcen = numpract - 5.296.

We'll need to mean-center the number of practices

*practice group x review attendance interaction - takes 2.
compute pract_rev_int1 = pract_s0e1 * atndrev_n0y1.
compute pract_rev_int2 = pract_s0h1 * atndrev_n0y1.

The interaction of practice difficulty and review attendance requires 2 interaction codes → the product of the review attendance dummy code with each of the practice difficulty dummy codes, in turn

*practice group x number practices interaction - takes 2.
compute pract_npract_int1 = pract_s0e1 * pract_mcen.
compute pract_npract_int2 = pract_s0h1 * pract_mcen.

The interaction of practice difficulty and number of practices will require 2 interaction codes → the product of the mean-centered number of practices and each or the practice difficulty dummy codes, in turm.

* review attendance x number practices interaction.
compute rev_npract_int = atndrev_n0y1 * pract_mcen.

The interaction of review attendance and number pracities will require just one interaction code → the product of the review attendance dummy code and the mean-centered number practices.

* 3-way interaction - takes 2.
compute pract_rev_npract_3way1 = pract_s0e1 * atndrev_n0y1 * pract_mcen.

compute pract_rev_npract_3way2 = pract_s0h1 * atndrev_n0y1 * pract_mcen.

exe.

The 3-way interaction will require 2 interaction codes → the product of each of the 2 practice difficulty x review attendance codes with the centered number of practices

SPSS Results

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.933[a]	.870	.835	7.28671

a. Predictors: (Constant), pract_rev_npract_3way2, pract_npract_int1, pract_s0e1, pract_s0h1, atndrev_n0y1, rev_npract_int, pract_rev_int2, pract_mcen, pract_npract_int2, pract_rev_npract_3way1, pract_rev_int1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14868.108	11	1351.646	25.457	.000[a]
	Residual	2230.040	42	53.096		
	Total	17098.148	53			

a. Predictors: (Constant), pract_rev_npract_3way2, pract_npract_int1, pract_s0e1, pract_s0h1, atndrev_n0y1, rev_npract_int, pract_rev_int2, pract_mcen, pract_npract_int2, pract_rev_npract_3way1, pract_rev_int1
b. Dependent Variable: testperf

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	58.938	2.558		23.037	.000
	pract_mcen	-.969	1.014	-.149	-.955	.345
	atndrev_n0y1	1.039	9.519	.029	.109	.914
	pract_s0e1	-18.247	6.436	-.490	-2.835	.007
	pract_s0h1	-1.245	5.011	-.033	-.248	.805
	rev_npract_int	6.629	2.653	.625	2.499	.016
	pract_npract_int1	-6.469	2.327	-.565	-2.779	.008
	pract_npract_int2	8.191	2.172	.697	3.772	.001
	pract_rev_int1	6.625	11.791	.139	.562	.577
	pract_rev_int2	12.548	11.009	.263	1.140	.261
	pract_rev_npract_3way1	-1.958	3.708	-.103	-.528	.600
	pract_rev_npract_3way2	-8.481	3.493	-.531	-2.428	.020

a. Dependent Variable: testperf

constant — those in the "same difficulty – did not attend review" condition who completed 5.296 practices have an average performance of 58.938%

pract_mcen — for those in the "same difficulty – did not attend review" condition, performance decreased by -.969 for each additional practice completed

antdrev_n0y1 — among those with same difficulty practices and who completed 5.296 practices, those who attended the review scored 1.039% better than those who did not

rev_npract_int — for those in the "same difficulty – did attend review" condition, performance increased by 5.660 (-.969 + 6.629) for each additional practice completed

| pract_s0e1	among those who did not attend the review and completed 5.296 practices, those with easy practices scored 18.247% poorer than those with same difficulty practices
pract_npract_int1	or those in the "easy difficulty – did not attend review" condition, performance decreased by 7.438 (.969 + –6.469) for each additional practice completed
pract_s0h1	among those who did not attend the review and completed 5.296 practices, those with hard practices scored 1.245% poorer than those with same difficulty practices
pract_npract_int2	for those in the "hard difficulty – did not attend review" condition, performance increased by 7.222 (-.969 + 8.191) for each additional practice completed
pract_rev_int1	for those with easy difficulty practices who completed 5.296 practices, those who attended the review performed 7.665% better than those who did not attend the review (1.039 + 6.625 -- the simple effect of attending for same difficulty + how much the se of attending for easy difficulty differs)
pract_rev_npract_3way1	for those in the "easy difficulty –did attend review" condition, performance decreased by -2.767 for each additional practice completed (-.969 + 6.629 – 6.469 + -1.958 – the slope for the same-no attend group & how the slope is different for those who had the review & how the slope was different for those who had the easy practices & how the slope differs when both attendance and practice difficulty change simultaneously
pract_rev_int2	for those with hard difficulty practices who completed 5.296 practices, those who attended the review performed 13.587% better than those who did not attend the review (1.039 + 12.548 -- the simple effect of attending for same difficulty + how much the se of attending for hard difficulty differs)
pract_rev_npract_3way2	for those in the "hard difficulty –did attend review" condition, performance increased by -5.370 for each additional practice completed (-.969 + 6.629 + 8.191 +-8.481 – the slope for the same-no attend group & how the slope is different for those who had the review & how the slope was different for those who had the hard practices & how the slope differs when both attendance and practice difficulty change simultaneously

All the information in the regression weights is captured in the simple testperf – number of practices regression models for each of the six conditions of the practice difficulty x review attendance design …

			(slope	* X) +		height
Not Attend	---------------	Same	-0.969	* X	+	58.938
Not Attend	---------------	Easier	-7.438	* X	+	40.691
Not Attend	---------------	Harder	7.222	* X	+	57.693
Attended	- - - - - -	Same	5.66	* X	+	59.977
Attended	- - - - - -	Easier	-2.767	* X	+	48.355
Attended	- - - - - -	Harder	5.37	* X	+	71.28

… and the corresponding plot of the model.
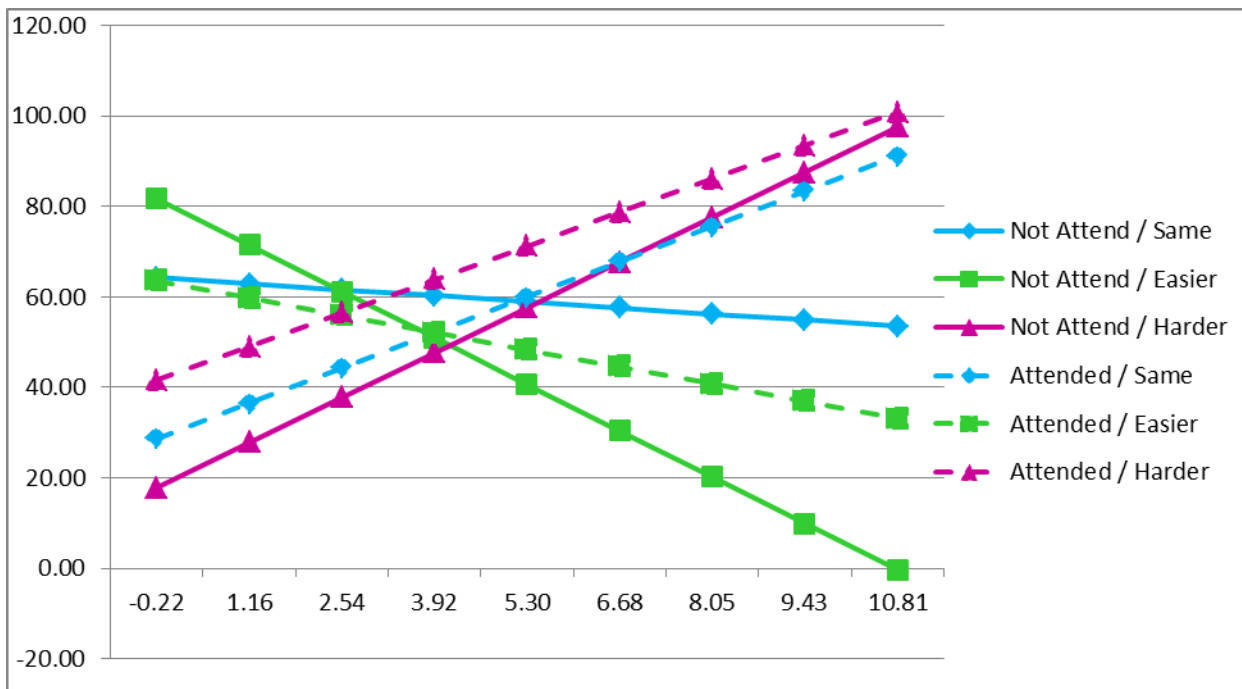
While complex, there are some import aspects to the pattern of the data.

Hard practices & attend review, hard practices & not attend review, and same difficulty practices & attend review all show a practice improvement effect   The test performance differences among the 3 conditions are larger at low amounts of practice, with little apparent difference at larger amounts of practice.

Same difficulty practices & not attend show no practice effect.

Easy difficulty practices & not attend and easy practices &attend both show a practice decrement effect, though the effect is less pronounced for those who attend. It seems that doing lots of the easy practices creates a misplaced confidence, that is somewhat offset by attending the review.

Finally – notice anything?   Here's a hint..

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
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This model fit the data very well (R^2 = .84), but still there are y' values far below the testperf minimum of 30!!

Why? Remember that we only fit a linear model to these data! There must be some nonliniearity to these data, to account for the "too low" y' values.