Example of "Tracking" a Suppressor Effect in a Multiple Regression Model

In a multiple regression we looked at earlier we had found…

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.756[a]	.572	.563	.39752

a. Predictors: (Constant), Verbal subscore of GRE, Quantitative subscore of GRE, Analytic subscore of GRE

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	28.888	4	7.222	45.67	.000[a]
	Residual	21.351	135	.158		
	Total	50.239	139			

a. Predictors: (Constant), Verbal subscore of GRE, PROGRAM, Quantitative subscore of GRE, Analytic subscore of GRE

b. Dependent Variable: 1st year graduate gpa -- criterion variable

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	
		B	Std. Error	Beta	Sig.
1	(Constant)	-1.027	.454		.025
	PROGRAM	-6.561E-02	.070	-.055	.348
	Analytic subscore of GRE	6.749E-03	.001	.549	.000
	Quantitative subscore of GRE	3.374E-03	.000	.456	.000
	Verbal subscore of GRE	-2.353E-03	.001	-.243	.001

a. Dependent Variable: 1st year graduate gpa -- criterion variable

Take a look at the GRE Verbal subscale

- This is a kind of suppressor variable -- the significant simple r and the significant multiple regression b have opposite signs
- By itself GREV is positively correlated with gpa, but in the model higher GREV scores predict smaller gpa (other variables held constant)

What this model is telling is that "the part of Verbal GRE that is independent of Quant GRE & Analytic GRE and is negatively related to GPA".

Exploring a Suppressor Variable

The first thing to do is to look at the intercorrelations among the predictors.

Correlations

		1st year graduate gpa -- criterion variable	Analytic subscore of GRE	Quantitative subscore of GRE	Verbal subscore of GRE	PROGRAM
1st year graduate gpa -- criterion variable	Pearson Correlation	1	.643	.613	.277	-.186
	Sig. (2-tailed)	.	.000	.000	.001	.028
	N	140	140	140	140	140
Analytic subscore of GRE	Pearson Correlation	.643	1	.472	.539	-.178
	Sig. (2-tailed)	.000	.	.000	.000	.036
	N	140	140	140	140	140
Quantitative subscore of GRE	Pearson Correlation	.613	.472	1	.465	-.196
	Sig. (2-tailed)	.000	.000	.	.000	.020
	N	140	140	140	140	140
Verbal subscore of GRE	Pearson Correlation	.277	.539	.465	1	-.228
	Sig. (2-tailed)	.001	.000	.000	.	.007
	N	140	140	140	140	140

All the contributing variables have the signed correlation with gpa and GREV. But notice two things: 1) the collinearities among the three GRE predictors are very similar, but 2) the GREV correlation with GGPA is substantially lower than that of the other GRE predictors. This is a common correlation pattern when there is a suppressor effect. (Another common pattern is when the predictors have similarly sized correlations with the criterion, but one of the predictors is negatively correlated with the other predictors.)

The next thing to try is to simplify the model and figure out which variables have to be there for the GREV suppressor effect to happen. We'll start by dropping PROGRAM from the model, because it doesn't contribute to the model but is adding to the "collinearity mix".

Note: If there were several noncontributing predictors we wouldn't just dump them all. Rather we'd simplify the model a bit at a time (constantly checking if the suppressor effect is still there).

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.215	.408		-2.980	.003
	Analytic subscore of GRE	6.779E-03	.001	.551	7.907	.000
	Quantitative subscore of GRE	3.415E-03	.000	.462	6.962	.000
	Verbal subscore of GRE	-2.270E-03	.001	-.235	-3.382	.001

a. Dependent Variable: 1st year graduate gpa -- criterion variable

Now all the predictors are contributing with $R^2 = .538$, $p < .001$ -- the suppressor effect is still there!

What we do next is try different reduced models -- all including GREV -- to see what variables have to be present to get the suppressor effect. This is pretty simple in this example, but can get ugly with larger models.

Here's what we get for each of the 2-predictor models that include GREV (I've simplified the output a bit) …

GREQ & GREV

Model Summary

Model	R	R Square
1	.613[a]	.376

a. Predictors: (Constant), Verbal subscore of GRE, Quantitative subscore of GRE

Coefficients[a]

Model		Unstandardized Coefficients	Sig.
		B	
1	(Constant)	.739	.060
	Quantitative subscore of GRE	4.566E-03	.000
	Verbal subscore of GRE	-1.00E-04	.892

a. Dependent Variable: 1st year graduate gpa -- criterion variable

GREA & GREV

Model Summary

Model	R	R Square
1	.648[a]	.420

a. Predictors: (Constant), Analytic subscore of GRE, Verbal subscore of GRE

Coefficients[a]

Model		Unstandardized Coefficients	Sig.
		B	
1	(Constant)	-1.005	.035
	Verbal subscore of GRE	-9.42E-04	.210
	Analytic subscore of GRE	8.550E-03	.000

a. Dependent Variable: 1st year graduate gpa -- criterion variable

So, neither GREA or GREQ by itself produces the GREV suppressor effect. Each is sufficiently collinear with GREV (and the GREV - gpa correlation is weak enough) that when placed in a model with it, GREV has no unique contribution. However when both GREA and GREQ are present we get the GREV suppressor effect.

We might describe this suppressor effect as, "While GREV has a weak positive correlation with GGPA, once GREQ and GREA are taken into account, higher GREV scores predict lower GGPA."

Identifying Suppressor "Constructs"

We want to figure out (hypothesize) what "construct" is involved in the suppressor effect, and try to find a direct measure of it to explore the model and the suppressor effect further. This will usually require a deep knowledge of the variables and population under study, and (perhaps several) additional data sets including these hypothesized variables.

In this case we needed to figure out what is "the part of Verbal GRE that is independent of Quant GRE & Analytic GRE and is negatively related to GPA". The Verbal GRE is a set of multiple choice questions with most of the items being about ***verbal reasoning***. What, we asked ourselves is different about this verbal reasoning than the reasoning tested in the quantitative and analytic parts of the GRE? We had two hypotheses – vocabulary and writing skill – both of which can be limiting factors in grad school performance. So, the next fall we collected some additional data from each of our first-year graduate students: a measure of "advanced" psychological vocabulary, a measure of "vocabulary acquisition ability", a writing score obtained by applying a standard scoring rubric to the writing sample each student submitted along with their application, and an assessment of "technical writing ability".

We wanted to see if any of these related to "the part of Verbal GRE that is independent of Quant GRE & Analytic GRE and is related to GPA". So, we correlated each of the four with two measures for this sample, Grad GPA and "residual GREV" (this was obtained by predicting each person's GREV from their GREQ & GREA and then using the residual of that prediction, i.e., the part of GREV that is not related to GREA and GREQ).

Correlations

		advpsyc_vocab	vocab_aq	writng_sample	tech_writing
ggpa	Pearson Correlation	.462	.316	.271	.112
grev_residual	Pearson Correlation	.159	.145	.640	.071

The vocabulary measures have nice correlatiions with GGPA, but aren't related to the GREV_residual, so they are not the construct we are looking for. The techical writing measure isn't related to either GGPA nor the residual. However, the writing sample measure looks pretty good – strong correlation with the residual GREV & nice correlation with GGPA.

The next step is to try using the writing sample variable in place of GREV in the regression analysis. Fortunately, we were able to apply the writing ability rubric for many of the folks in the earlier data set and also add in the cases from the most recent cohort for this analysis.

This model, with $R^2 = .511$, $p < .001$, had about the same fit as when using GREV and had similar regression weights!

Coefficients[a]

Model		Unstandardized Coefficients	Standardized Coefficients		Correlations
		B	Beta	Sig.	Zero-order
1	(Constant)	-2.889		.000	
	grea	.007	.551	.000	.643
	greq	.004	.437	.000	.613
	writng_sample	-.046	-.316	.000	.271

a. Dependent Variable: ggpa

It looks like we've identified (or at least found a correlate of) the construct represented in the suppressor effect of the original model – "writing ability" seems to be "the part of Verbal GRE that is independent of Quant GRE & Analytic GRE and is negatively related to GPA".

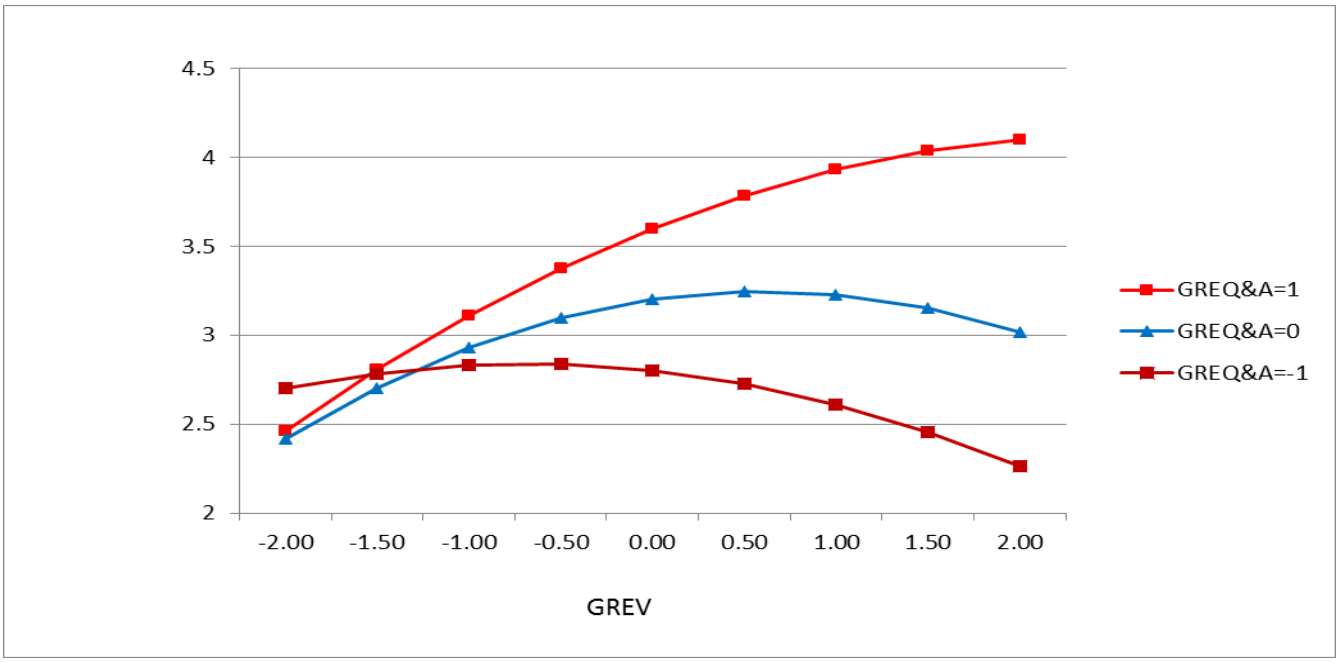
Notice however, that when using that variable – we still have a suppressor effect! Writing ability is positively correlated with GGPA, yet has a negative weight in this multiple regression model! So, we have an idea what to call the construct involved. What we still don't know is why this construct is positively correlated with GGPA yet negatively related in the multiple regression model – why are those with poorer writing skills expected to have the higher GPA?

Looking for "Underspecifications"

Sometimes a suppressor effect occurs because the model is "underspecified" and the variables in the model are trying to "make up for" the variables that were left out. When that happens, the regression weights sometimes "don't make sense". One particularly interesting variation of this is when one or more of the "main effects" don't make sense when their interaction has been left out of the model. In this case, we wanted to explore whether there might be a "missing" interaction. Specifically, we wanted to know whether there was an interaction between the information carried by the GREQ & GREA predictors and that carried by the GREV predictor.

To make things a bit easier, we aggregated GREA and GREQ into a single variable, using the beta weights to given them the proper relative contribution to predicting GGPA, and rescaled that aggregate into a Z-score (mean=0, std=1). We converted GREV into a Z-score and then computed the interaction as the product of the aggregated GREQ&A Z-score and the GREV Z-score. The two Z-scores and the interaction were put together into a multiple regression model. We also added into that model quadratic components of each main effect and the interaction.

Here is a plot of the resulting multiple regression model..



The "story" from this multple regression model is much more interesting (and far less puzzling) than the initial model that included the suppressor effect of GREV!

- As before, there is a positive main effect for GREQ & GREA -- those with higher GREQ&A (red line) generally have higher overall GGPAs then those with lower GREQ&A (maroon line).
- In this more complete model, there is also a positive main effect for GREV (rather than a suppressor-effect negative relationship) – those with higher GREV generally have higher overall GGPAs than those with lower GREV.
- There is a definate interaction of GREQ&A and GREV as they related to GGPA
    - For those with high GREQ&A – who are likely to be learning the material in the courses – better writing skills are associated with better GGPA
    - For those with intermediate GREQ&A – who are likely to be learning less of the material in the courses – better writing helps up to a point (about ½ Std above the mean GREV) and then the curve drops off
    - However, for those with low GREQ&A – who are likely to be struggling with the couse material– greater writing ability predicts lower GGPA (I suspect because their good writing reveals they haven't learned the material)

Now we have as a solid idea about why we got a suppressor effect in the in original model, as well as a much more complete picture of how GREQ, GREV & GREA relate to GGPA, and the information provided by both.

Last thing… One way to check up on our interpretations and hypotheses about "the part of Verbal GRE that is independent of Quant GRE & Analytic GRE and is negatively related to GPA" is to look at the same regression model, but substituting the writing sample measure for GREV. If we have understood what is represented by that residual and the associated suppressor effect, then the model with the writing sample should look much like the model with GREV.

Here's a plot of that model with the writing sample variable included in place of GREV.

The similarity of the two models suggests that the contribution of GREV to the model is related to how well that measure represents writing ability as it related to GGPA.