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ON USING REGRESSION COEFFICIENTS TO INTERPRET MODERATOR EFFECTS[1]

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In moderated multiple regression analysis, several researchers have relied totally or partially on the sign associated with the regression weight of the cross-product term xz to interpret a moderator effect. This study examined a common convention used in such interpretations. First through logical exposition, and then through the use of a Monte Carlo approach to simulate various moderator conditions, it was found that this convention may lead to incorrect inferences regarding interaction effects. Alternative procedures for interpreting moderator effects are recommended.

MODERATED regression analysis has been used in behavioral science research for some three decades (Saunders, 1956). This technique assesses the influence of a third variable, called a moderator (z), on the relationship between two other variables (x and y). A moderator effect exists when the relationship between the predictor variable x and criterion variable y is conditional on the value of z. In

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developing this technique, Saunders (1956) noted that a moderator effect will evidence itself as an interaction between x and z. Procedurally, this calls for treating the appropriate product-variable, xz, as a new predictor in a standard multiple regression equation. The form of this modification is $\hat{y} = a + b_1x + b_2z + b_3\,xz$, where a is a constant and b_1, b_2 and b_3 are regression weights. Statistical properties of moderated regression analysis have been closely examined (e.g., Dunlap and Kemery, 1988; Evans, 1985). Less attention has been devoted to associated issues of interpretation, with noteworthy exceptions being Arnold (1982) and Stone and Hollenbeck (1989).

The purpose of the present study was to examine a convention that has been used to describe interaction effects within moderated regression frameworks. A statistically significant cross-product term in moderated regression indicates an interaction between a moderator and an independent variable in explaining variance in the dependent variable. One way to understand this interaction is by plotting lines corresponding to regression equations associated with different moderator values (Cohen and Cohen, 1983). Arbitrarily high and low moderator values are used so that the plotted lines contrast sufficiently enough to depict the nature of the interaction.

Of interest in the present study is a second method used in describing moderator effects. This method involves inspecting the sign associated with the xz regression weight, b_3. An examination of several applied psychology and organizational psychology journals confirms the use of this second method in areas where moderator designs are popular. A number of studies appear to have relied on the sign of b_3 to interpret the nature of a moderator effect (e.g., Konar-Goldband, Rice, and Monkarsh, 1979; McKinley, Cheng, and Schick, 1986; Tharenou and Harker, 1982, 1984; Wiggins, 1973). These studies either have stated that b_3 was used or have listed b_3s and made interpretations without referring to another interpretational technique.

Other studies have partially used this information for interpretational purposes. Such studies have discussed the sign of b_3 in an interpretational context, but have also relied on plots or other procedures to examine moderator effects (e.g., Abdel-Halim, 1980; Bhagat, 1982; Cheng, 1984; Fry, Kerr and Lee, 1986; Oldham and Fried, 1987; Podsakoff, Todor, and Schuler, 1983; Schriesheim, 1980; Schriesheim and DeNisi, 1981; Skaret and Bruning, 1986). (The substantive interpretations appearing in cited studies are not at issue with respect to the focus of the current study. The studies are cited simply to provide evidence that the interpretational approach in question is used.)

Interpretations based on b_3 assume that its sign identifies z values, usually a range of high or low values, for which predictability is greater. In this instance, predictability refers to how accurately the predictor x explains variation in the criterion y. A common interpretational rule regarding the sign of b_3 is that a positive sign denotes that only high values of z are associated with predictability, whereas a negative sign denotes that only low values of z are associated with predictability (e.g., Abdel-Halim, 1980; Bhagat, 1982; McKinley et al., 1986; Skaret and Bruning, 1986; Tharenou and Harker, 1982, 1984; Wiggins, 1973). Of course, if b_3 is not significantly different from zero, no moderator effect exists.

Indiscriminate use of this rule (hereafter termed the Signed Coefficient Rule—SCR) could result in some interpretive ambiguity. This point may be illustrated by using a study by Ganster, Fusilier, and Mayes (1986) who, in examining the role of social support in the experience of stress at work, found statistical evidence that social support moderated the effect of certain stressors on life and job dissatisfaction. In their Table 4, with job dissatisfaction as the criterion and lack of variability as the predictor, the b_3 value for supervisor support was positive (.24), whereas the b_3 value for friends support was negative (−.31). Interpreting the sign of b_3 in accordance with the SCR would suggest that high moderator values should yield greater predictability in the former case and lower moderator values should yield greater predictability in the latter case. However, the regression plots in Figures 3 and 4 of the study by Ganster et al. (1986) show that high moderator values are associated with more valid prediction in both cases. Figure 1 of this same article depicts a disordinal interaction in which both low and high moderator values correspond with improved prediction. Interestingly though, the presence of a positive b_3 value (.27) associated with this plot suggests that only one range of moderator values provides predictability.

Clearly, other factors must be considered in using the sign of b_3 to interpret interactions. This requirement can be understood by considering the interactive equation:

$$\hat{y} = b_0 + b_1 x + b_2 z + b_3 xz. \tag{1}$$

This equation can be rewritten as

$$\hat{y} = (b_0 + b_2 z) + (b_1 + b_3 z)x \tag{2}$$

and, therefore

$$\hat{y} = b_0{}^* + b_1{}^* x \tag{3}$$

where $b_0{}^*$ is the sum of b_0 and b_2z, and $b_1{}^*$ is the sum of b_1 and b_3z. In other words, $\hat{y}$ is a linear function of x, and this function changes depending on the value of z. The actual sign of b_3 *in isolation* does not provide any information regarding the value of $b_1{}^*$. Depending on the sign and magnitude of b_1, $b_1{}^*$ may be negative, positive, or zero. To illustrate this logical analysis, a series of computer simulations was conducted to examine the interpretational value of the sign of b_3 under a controlled range of moderator conditions.

Method

A discrete moderator was used for illustrational purposes. Such a moderator may be described as involving two subgroups within which the relationship between an independent (x) and dependent (y) variable differs. Whereas an infinite number of relationships may be considered with a continuous moderator, a discrete moderator limits the number of relationships compared to two. This choice permits clear depiction of the effect that subgroup differences in relationships between x and y have on b_3. With regard to published moderator research, this study is analogous to those investigating differential predictability across samples defined along categorical lines (e.g., gender, race).

Monte Carlo Simulation

A program was written to generate simulated pairs of random normal deviates in accordance with two arbitrarily specified subgroup ($n = 50$) population correlation values. Kemery, Mossholder, and Roth (1987) have presented specific details of the method used for data generation. For example, if the population correlation (ρ) between x and y was .40 in the first group and $-.20$ in the second, the program generated pairs of random normal scores based on $\rho = .40$ for the first group and on $\rho = -.20$ for the second group. The moderator variable, group membership (z), was coded "1" for group one and "0" for group two. From the generated x and z scores, a cross-product term (xz) was computed for each simulated subject. An intercorrelation matrix for y, x, z, and xz was calculated using the generated scores. A formula based on multiple regression procedures in Nunnally (1967) was derived to compute β_3 from this matrix; its accuracy was verified against SPSS^x regression results. Beta weights were calculated rather than regression coefficients (b_3) because of computational ease. As the sign of β_3 and b_3 are always the same, influences concerning the sign of β_3 apply to the sign of b_3 as well.

To demonstrate contingencies in interpreting the sign associated with β_3, a series of scenarios was constructed where within-group correlations between x and y differed strongly, moderately, very little, or not at all. A β_3 value was then computed for each scenario. Scenarios were constructed in which ρ for the first subgroup was held constant at .40, while the ρ for the second subgroup was varied from .40 to $-.40$, in decrements of .10. In all, nine scenarios were constructed. Within each of the scenarios, 100 simulations were run. In a second part of this demonstration, specific scenarios were constructed to highlight complications in interpreting the sign of β_3.

Results and Discussion

For brevity, results for only five of the scenarios from the first part of the study are reported. Data for all nine scenarios may be obtained from the first author. Table 1 presents the mean, minimum value, maximum value, standard deviation, and standard error of the β_3s derived for each of the five scenarios. That standard deviations (*SD*) across the different scenarios are roughly equal as are the standard errors (SE) attests to the effect of random sampling around the specified subgroup parameters. The range between minimum and maximum β_3 values is relatively constant across the scenarios.

Of pertinence to the study are the values for β_3 as ρ for the second subgroup was decreased. Table 1 indicates the sign of β_3 does not change and that β_3 grows larger as the difference between subgroup

TABLE 1
Descriptive Statistics for β_3: Values from Five Scenarios

First Subgroup $\rho = .4$		Cross-product Beta Weight (β_3)				
	Second Subgroup					
Scenario	ρ	*Mean*	*Minimum*	*Maximum*	*SD*	*SE*
1	.3	.070	−.213	.408	.120	.012
2	.2	.123	−.164	.423	.130	.013
3	0	.280	−.035	.631	.138	.014
4	−.2	.445	.108	.693	.116	.012
5	−.4	.589	.243	.898	.127	.013

Note. The moderator = 1 for the first subgroup and = 0 for the second subgroup.
SD = standard deviation, SE = standard error.

ρ's increases. It can easily be shown that the absolute value of β_3 corresponds to the *magnitude* of the relative difference between the y on x regressions of the two subgroups (Arnold, 1982). However, it is not so readily apparent that the sign of β_3 does not necessarily indicate the *nature* of the slope differences. For example, when the ρ for subgroup 1 is .4 and the ρ of subgroup 2 is $-.4$ (a circumstance signifying population relationships of equal magnitude or predictability), the sign of β_3 is still positive. An interpretation based solely on the sign of β_3, as suggested by the SCR, would indicate that one subgroup is more predictable than other. Obviously, this inference is incorrect.

It is instructive to consider what happens to β_3 when the sign of ρ in the first subgroup is changed to $-.40$ and ρ for the second subgroup is set equal to 0. This scenario is comparable to that shown in Table 1 where ρ for the first subgroup is .40. The results for β_3 are as follows: mean $= -.28$, minimum $= -.611$, maximum $= .051$, $SD = .133$, and $SE = 0.13$. In an absolute sense, these values are similar to those in Table 1, row 3. However, although the first subgroup remains the most predictable, the sign associated with β_3 is reversed. This outcome contradicts the notion that by itself, the sign associated with β_3 reveals which subgroup is more predictable.

In moderated regression analysis, β_3 is actually a partial regression coefficient, which reflects the fact that other variables in the equation have been statistically controlled in deriving the coefficient. As an interaction must be considered in the context of independent and moderator variables (Stone and Hollenbeck, 1989), an attempt was made to determine how these two variables might influence interpretations of β_3. Because of the way in which data were generated in the simulations, the moderator variable (i.e., group membership code) is uncorrelated with the dependent variable. Thus, only for the independent variable (β_1) could this issue be considered. To examine its influence on interpretations of β_3, the independent variable was entered first in a stepwise moderated regression model (followed by the moderator variable and cross-product term, respectively). The β_1 value is the standardized weight assigned to the independent variable *at this step*. It should be noted that this value is equivalent to the correlation between the independent and dependent variables.

Three pairs of scenarios, representing different types of moderator conditions, were arbitrarily selected to illustrate connections between the signs of β_1 and β_3. All scenarios were computed in the same manner as those in Table 1. Table 2a represents a condition where subgroup ρ's are both positive. In this condition the sign of β_3

TABLE 2
β_3 and β_1 for Arbitrary Subgroup ρ Values

	First Subgroup ρ	Second Subgroup ρ	β_3	β_1
(a)	.7	.2	.34	.44
	.2	.7	−.37	.44
(b)	−.7	.2	−.62	−.25
	−.2	−.7	.33	−.43
(c)	.3	−.2	.39	.04
	−.2	.2	−.28	.01

Note. The moderator = 1 for the first subgroup and = 0 for the second subgroup.

appears to indicate subgroup predictability in accordance with the SCR. However, unlike the case of these special scenarios, subgroup ρ's are not known. As the purpose of moderated regression is to investigate potential differences in subgroup predictability, it is inappropriate to presume *a priori* anything about subgroup predictability.

In the next pair of scenarios (Table 2b), negative ρ's are introduced and β_1 becomes negative. In this condition, using the SCR would result in an incorrect interpretation of the interaction. The subgroup with the largest ρ, −.7, is the one that is most predictable even though the SCR interpretation of β_3 suggests that exactly the opposite outcome is true. In each Table 2b scenario, the sign of β_1 is negative—a circumstance indicating a negative correlation between the independent and dependent variables. At least in this context (i.e., $r_{yz} = 0$), when the sign of β_1 is negative, the SCR has to be reversed.

Further complications arise when the independent variable is unrelated to the dependent variable, as in the case of disordinal interaction. Such a condition is shown in Table 2c. When ρ for a subgroup is effectively equal in size but opposite in sign as the ρ for the other subgroup, β_1 tends toward zero. It can be readily seen in this condition that the SCR incorrectly suggests predictability is higher for one subgroup than for the other. Line 5 of Table 1 provides another example of such a condition.

These results support the conclusion from the previously presented logical analysis that the sign of β_3 is not sufficient for interpreting moderator effects. At the very least, the pattern of intercorrelations among dependent, independent, and moderator variables has to be taken into account lest incorrect inferences be made. It is recommended that the SCR not be used to interpret moderated regression interactions. Perhaps, this demonstration will encourage researchers to use other interpretational techniques. Whether in conjunction with discrete or continuous moderators, it is suggested that a better alternative is to use plotting techniques (e.g., Cohen and Cohen, 1983). An equally attractive procedure would be to examine the moderated regression equation across a range of moderator values to discern the effect on the estimated criterion variable (e.g., Champoux and Peters, 1987).

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