Supplementary PROCESS Documentation

This document is an addendum to Appendix A of *Introduction to Mediation, Moderation, and Conditional Process Analysis* that describes options and output added to PROCESS since the printing of the book in May 2013. Whenever a new feature is added to PROCESS the version number is changed. This supplementary documentation is cumulative. All features described as additions to earlier releases can be found in later releases as well. This document was produced and uploaded to *www.processmacro.org* on June 28, 2016.

Decimal Place Precision in Output

(Version 2.10)

PROCESS generates numerical output to four decimals places of resolution. This can be changed with the *dec* argument when using the `decimals` option. This argument is set to `F10.4` by default, meaning numbers in the output will contain up to ten characters, with four of these to the right of the decimal. In this argument, `Fa.b` sets the number of characters allocated to numbers to *a* and the number of decimal places to display to the right of the decimal point to *b*. For example, `decimals=F12.6` specifies twelve characters with six to the right of the decimal place. In the *dec* argument, `a` should be larger than `b`.

In the SAS version of PROCESS, the "F" should be left off the *dec* argument. For example, to set 12 characters for numbers with six after the decimal, use `decimals=12.6`.

Additional Johnson-Neyman Output

(Version 2.10)

When the Johnson-Neyman technique is used, the PROCESS output in this release includes a table at the top that provides information about the

percent of cases in the data with values of the moderator above ("% above") or below ("% below") the points of transition in significance identified using the JN method. For example, output such as

```
Moderator value(s) defining Johnson-Neyman significance region(s)
     Value    % below    % above
    3.5087     1.5504    98.4496
    4.9753    44.1860    55.8140
```

reflects that in the data, only 1.55% of the cases have a value of moderator less than 3.5087, whereas 98.45% of the cases have a value of the moderator larger than 3.5087. Similarly, 44.19% of the cases have a value of moderator less than 4.9753 and 55.81% of the cases have a value of the moderator larger than 4.9753.

Models 75 and 76
(Version 2.10)

Two new conditional process models are added to PROCESS that specify two moderators of the $X \rightarrow M$, $M \rightarrow Y$, and/or $X \rightarrow Y$ paths. See the conceptual and statistical diagrams in the model templates document available through the web page for *Introduction to Mediation, Moderation, and Conditional Process Analysis* at *www.afhayes.com*.

Index of Moderated Mediation
(Version 2.10)

For some models, the indirect effect of X on Y through mediator M_i can be expressed as a linear function of the single moderator in the model. The slope of the line relating the indirect effect to the moderator is the "index of moderated mediation" described in Hayes (2015). The table below formalizes how this index is constructed in terms of the model coefficients from the statistical model as diagrammed in the model templates section of this Appendix. An inference as to whether this index of moderated mediation is statistically different from zero is a formal test of moderation of the indirect effect by the moderator in the model. PROCESS automatically produces this index of moderated mediation through each mediator in the model as well as bootstrap confidence interval for inference. The index of moderated mediation and the bootstrap confidence interval produced by PROCESS is an automatic implementation of the formal test of moderated mediation described in sections 12.3 and 12.4.

PROCESS Model	Index of Moderated Mediation
7 and 8	$(a_{3i}b_i)\delta$
14	$(a_i b_{3i})\delta$
15	$(a_i b_{2i})\delta$
58 (dichotomous W only)	$[a_{1i}b_{3i} + a_{3i}b_{1i} + a_{3i}b_{3i}(2W_{low} + \delta)]\delta$
59 (dichotomous W only)	$[a_{1i}b_{2i} + a_{3i}b_{1i} + a_{3i}b_{2i}(2W_{low} + \delta)]\delta$
74	$a_i c'_{2i}$

Unless the moderator is a dichotomous variable, δ is set to one, yielding an index of moderated mediation that is the slope of the line relating the size of the conditional indirect effect of X on Y through M_i to the moderator. When the moderator is a dichotomous variable, δ is set to the difference between the two values of the moderator coding the two groups, so as to produce an index that is equal to the difference between the two conditional indirect effects. This mathematical transformation does not affect the resulting inference using a bootstrap confidence interval.

The index of moderated mediation is provided for models 58 and 59 only if the moderator is dichotomous. When the moderator is not a dichotomous variable in these models, the function relating the indirect effect to the moderator is not a line and the method described in Hayes (2015) cannot be used. In the expression for the index of moderated mediation of these two models, W_{low} is the smaller of the two values used to code groups.

Because there is only one indirect effect in Model 74 when the moderator is dichotomous, the index of moderated mediation is produced in Model 74 output only when the moderator is not dichotomous.

Covariance Matrix of Regression Coefficients
(Version 2.11)

PROCESS will display the variance-covariance matrices for the regression coefficients in each part of the model by specifying **covcoeff=1** in the PROCESS command line. By default, the variance-covariance is not produced in the output.

Comparing Conditional Effects in Moderation Analysis
(Version 2.12)

In models with only a moderation component (models 1, 2, and 3), two conditional effects of *X* on *Y* can be formally compared with a statistical test. In model 1, evidence of moderation of *X*'s effect on *Y* by *M* leads to the corresponding claim that any two conditional effects of *X* on *Y* for different values of *M* are different from each other. But in models 2 and 3, one can choose different values of the two moderators and ask whether the conditional effect of *X* on *Y* differs between two groups defined by different values of the moderators. This requires the use of the `contrast` option, setting its argument to 1 (i.e., `contrast=1`), combined with the `mmodval` and/or `wmodval` options. For instructions, see Hayes (2014).

Mediation Analysis in the Two-Condition Within-Subject Design
(Version 2.12)

In a two-condition within-subjects design, a mediator and consequent variable are each measured twice, once in each of two conditions that represent the antecedent variable *X*. Montoya and Hayes (in press) discuss the estimation of direct, indirect, and total effects of *X* in such a design along with bootstrap confidence intervals for inference about the indirect effect. PROCESS can conduct such an analysis with the use of the `ws` option in model 4, setting its argument to 1 (i.e., `ws=1`). For instructions and example code, see Montoya and Hayes (in press). The `ws` option is available only for model 4 (i.e., the simple and parallel multiple mediator models).

Long Variable Names in PROCESS for SPSS
(Version 2.13 and 2.15)

Prior to version 2.13, PROCESS for SPSS allowed long variable names but did not recognize characters after the eighth. This could produce inaccurate output when the user includes two variables in a model that are not unique in the first eight characters. With the release of version 2.13, the SPSS version of PROCESS no longer accepts variable names longer than eight characters. If any of the variables in the model have names that are longer than eight characters, PROCESS will terminate and request the offending variable name(s) be shortened.

With the release of version 2.15, this restriction is lifted with the addition of the **longname** option, setting its argument to 1. (i.e., **longname=1**). Use this option only when all the variable names in the data file are unique in the first eight characters.

Effect Size in Mediation-Only Models with Covariates
(Version 2.13)

With the release of version 2.13, PROCESS will produce point and bootstrap interval estimates of several measures of effect size for indirect effects in models 4, 5 and 6 when covariates are included in the models of both M and Y (the default **covmy=0** option). In a model with one or more covariates, the definitions of several of the effect size measures for indirect effects discussed in section 6.3 are modified. Define SD_{X^+} and SD_{Y^+} as the the standard error of estimate (i.e., the square root of the mean squared residual) when X and Y, respectively, are estimated from only from the covariates (and, if the cluster option is used, from dummy variables coding the clustering variable). The partially standardized indirect effect is then defined as

$$ab_{ps} = \frac{ab}{SD_{Y^+}}$$

and the completely standardized indirect effect is defined as

$$ab_{cs} = \frac{SD_{X^+}(ab)}{SD_{Y^+}} = SD_{X^+}(ab_{ps})$$

Thus, these two measures gauge the indirect effect relative to variation in Y and (for the completely standardized indirect effect) X not accounted for by the covariate(s).

When one or more covariates are included in the model of Y, the total effect of X is no longer the regression weight for X in a model of Y that includes only X (denoted c throughout Chapters 4 and 5). As a result, the ratio of the indirect to the total effect, P_M, is no longer ab/c but, rather, the more general

$$P_M = \frac{ab}{c' + ab}$$

The denominator of P_M above is the regression weight for X in a model estimating Y from X and the covariate(s) (and cluster variable dummies when the **cluster** option is used) but not the mediator(s).

The effect size measures described by Fairchild et al. (2009) (variance in Y explained by the indirect effect) as well as κ^2 (Preacher & Kelley, 2011)

have not been generalized to models with covariates and so PROCESS suppresses their printing in this case. No effect size measures are generated in models in which the covariates are restricted to the models of M only (**covmy=1**) or Y only (**covmy=2**).

Multicategorical Focal Predictor or Moderator in Model 1
(Version 2.14)

With the release of version 2.14, PROCESS will accept a multicategorical variable for the focal predictor (X) or moderator (M) in model 1. In model 1 (and *only* model 1), the **mcx** and **mcm** options specify that X or M is a multicategorical variable, meaning that the variable listed in *xvar* or *mvlist* contains numerical codes that designate membership in one of three or more groups. PROCESS automatically implements four coding systems for groups, with the system to be used designated using the arguments 1, 2, 3, or 4. For example, **mcx=2** tells PROCESS that *xvar* is a multicategorical variable and to use sequential coding for groups, and **mcm=1** specifies the moderator *mvlist* as a multicategorical variable and to use simple indicator (a.k.a "dummy variable") coding to represent groups.

For a multicategorical variable with k groups, PROCESS automatically constructs $k-1$ variables $D_1, D_2, \ldots, D_{k-1}$ and adds them to the model along with necessary products to specify the interaction. In addition, an omnibus test of interaction between *xvar* and *mvlist* is provided in the form of an F-ratio based on $k-1$ and $df_{residual}$ degrees of freedom. Either *xvar* or *mvlist* can be specified as multicategorical, but not both. That is, the **mcx** and **mcm** options cannot be used simultaneously.

These $k-1$ D variables are constructed using one of four coding systems, depending on the argument given to **mcx** or **mcm**. Acceptable arguments are 1 for dummy coding (the default), 2 for sequential coding, 3 for Helmert coding, and 4 for effect coding. The variables representing the codes are in the output as D1, D2, and so forth, and a table mapping categories to codes is provided at the top of the output. The examples below assume that the variable called "cond" represents four groups coded in the data with the numbers 1, 3, 4, and 6.

When the argument for **mcx** or **mcm** is set to 1, simple indicator coding is used with the group coded with the smallest numerical code treated as the reference category. The indicator codes will correspond to groups as coded in *xvar* or *mvlist* in ascending sequential order. For example, **mcx=1** implements the coding system below:

cond	D_1	D_2	D_3
1	0	0	0
3	1	0	0
4	0	1	0
6	0	0	1

There is no option in PROCESS for changing which group is treated as the reference. If you want to designate a different group as the reference group, recode *xvar* or *mvlist* prior to using PROCESS so that the reference group you desire is coded with the numerically smallest code.

When the argument for **mcx** or **mcm** is set to 2, sequential coding is used. Sequential coding allows for the comparison of group *j* to the group one ordinal position higher on the categorical variable. PROCESS will assume that the ascending ordinality of the multicategorical variable corresponds to the ascending sequence of arbitrary numerical coded in *xvar* or *mvlist*. For example, **mcx=2** implements the coding system below:

cond	D_1	D_2	D_3
1	0	0	0
3	1	0	0
4	1	1	0
6	1	1	1

When the argument for **mcx** or **mcm** is set to 3, Helmert coding is used. Helmert coding allows for the comparison of group *j* to all groups ordinally higher on the categorical variable. PROCESS will assume that the ascending ordinality of the multicategorical variable corresponds to the ascending sequence of arbitrary numerical coded in *xvar* or *mvlist*. Helmert coding is also useful for setting up certain orthogonal contrasts for a nominal multicategorical variable. For example, **mcx=3** implements the coding system below:

cond	D_1	D_2	D_3
1	−3/4	0	0
3	1/4	−2/3	0
4	1/4	1/3	−1/2
6	1/4	1/3	1/2

When the argument for **mcx** or **mcm** is set to 4, effect coding is used, with group with the smallest numerical code left out of the coding scheme. The dummy variables correspond to groups in ascending sequential order in the coding of the multicategorical variable. For example, **mcx=4** implements the coding system below:

COND	D_1	D_2	D_3
1	−1	−1	−1
3	1	0	0
4	0	1	0
6	0	0	1

A variable specified as multicategorical cannot contain more than 9 categories. PROCESS discerns the number of categories using the number of unique numerical codes in the variable specified as multicategorical. The Johnson-Neyman method is not available for probing an interaction when is specified as *xvar* multicategorical, nor is the **cluster** option available.

The **mcx** and **mcm** options have an effect only when specifying model 1. For any other model, they are ignored.

For a discussion of moderation analysis with a multicategorical focal predictor or moderator, see Darlington and Hayes (2017).

Heteroscedasticity-Consistent Inference
(Version 2.14)

Version 2.14 of PROCESS offers a test of the difference in R^2 due to interactions in model 1, 2, and 3 that does not assume homoscedasticity. It relies on the same computational procedures that generate the HC3 standard error estimator. This test is provided automatically when use of the HC3 standard error is requested with option **hc3=1**. See Hayes and Cai (2007).

Multicategorical *X* in Mediation Models
(Version 2.15)

In model 4, *xvar* can be specified as a multicategorical variable using the `mcx` option discussed in the section above titled "Multicategorical Focal Predictor or Moderator in Model 1". This option is not available for any other model that contains a mediation component. The `contrast`, `effsize`, and `cluster` options are not available in model 4 when *xvar* is specified as multicategorical. For a discussion of multicategorical independent variables in mediation analysis, see Hayes and Preacher (2014).

Indices of Partial, Conditional, and Moderated Moderated Mediation
(Version 2.16)

In release 2.16, PROCESS generates tests of partial, conditional, and moderated moderated mediation as described in Hayes (2016). These are available for models 9–13, 16–22, 28, and 29.

Number of Bootstrap Samples
(Version 2.16)

With the release of version 2.16, the default number of bootstrap samples for the construction of bootstrap confidence intervals is 5,000.

Disabling of Preacher and Kelley's kappa-squared
(Version 2.16)

PROCESS version 2.16 no longer produces Preacher and Kelley's kappa-squared as a measure of effect size for the indirect effect. This feature in earlier releases was disabled in version 2.16 in response to a recent article by Wen and Fan (2015, *Psychological Methods*) pointing out computational errors in its derivation.

References

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