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.afhayes.com* on February 27, 2015.

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 $X \to M$, $M \to Y$, and/or $X \to Y$ 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	$(a_ib_{3i})\delta$
15	$(a_ib_{2i})\delta$
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	$a_ic'_{2i}$

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).

Long Variable Names in PROCESS for SPSS

(Version 2.13)

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.

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**).

References

Hayes, A. F. (2015). An index and test of linear moderated mediation. *Multivariate Behavioral Research*, *50*, 1-22.

Hayes, A. F. (2014). *Comparing conditional effects in moderated multiple regression: Implementation using PROCESS for SPSS and SAS*. White paper downloadable from http://www.afhayes.com/public/comparingslopes.pdf