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Editorial Perspective: Integrating exploratory and competitive–confirmatory approaches to testing person × environment interactions

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Students of child development and of psychopathology have long been interested in how person characteristics (e.g. genotype, temperament) might moderate the effect of environmental exposures (e.g. harsh parenting, negative life events) on development. Historically, most such research on person × environment interaction has been guided by diathesis-stress thinking, which stipulates that some individuals, due to their personal characteristics, are more susceptible to the adverse effects of contextual risk than are others (but do not function differently under supportive or even benign conditions). More recently, the differential-susceptibility framework has emerged as an alternative way of conceptualizing person × environment interactions (Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2007). It stipulates that the very person characteristics that make some more 'vulnerable' to adversity also makes them more likely to benefit from contextual support and enrichment, thereby implying that such individuals are more developmentally plastic, 'for better and for worse'.

Although it remains the case that empirical work continues to provide evidence consistent with the diathesis-stress framework, much recent research has also proven consistent with differential-susceptibility theorizing (for review, see Belsky & Pluess, 2013). Perhaps, even more compelling than results of observational studies, including meta-analyses of such (van IJzendoorn, Belsky, & Bakermans-Kranenburg, 2012), are those of randomized-control trials. There is repeated indication from such work that the anticipated benefits of intervention efforts are restricted to or most pronounced in the case of children or adolescents carrying what diathesis-stress thinkers have long considered 'risk' factors, thereby indicating that they also operate as 'opportunity' factors (e.g. Bakermans-Kranenburg & Van IJzendoorn, 2015).

In an effort to advance research illuminating the form of person × environment interactions in observational work, Belsky, Pluess, and Widaman (2013) contrasted, in this journal, two ways of evaluating such interactions. Whereas the traditional approach involved post hoc evaluation, initially involving an *exploratory* test of the interaction between person and environmental predictors, usually in a regression model, while requiring a significant interaction before 'probing' its form, the second approach abandoned exploratory analysis entirely. Indeed, it involved the a priori testing of competing models (see also Widaman et al., 2012).

The impetus for the new, a priori testing approach was the realization that slopes in person × environment interactions predicted under diathesis-stress theorizing might be identical to those under differential susceptibility. What differed across these theoretical positions was not the predicted slopes, but the placement of the *crossover point* in the interaction. If the crossover point was near the middle of the environmental variable – so that the interaction conformed to a 'for better or for worse' pattern –results were more consistent with differential-susceptibility predictions; conversely, if the crossover point was near the most positive point in the environmental measurement, then results were more consistent with diathesis-stress conjectures.

Given the theoretical significance of the placement of the crossover point, the competitive and confirmatory model testing approach which we advanced uses a re-parameterization of the regression model that makes the crossover point a parameter to be estimated. Having both a point estimate and, given its standard error, an interval estimate of the crossover point should lead to more informed judgments by investigators regarding whether results are more consistent with predictions under diathesis stress or differential susceptibility than was likely under traditional, exploratory model fitting.

Since the publication of the competitive and confirmatory model testing approach, it has been employed in many studies, sometimes providing evidence consistent with diathesis-stress theorizing and sometimes with differential-susceptibility thinking. At the same time, investigations of person × environment interaction have often mixed and matched these approaches, requiring first evidence of a significant interaction in an exploratory regression analysis before proceeding to implement the analytic steps central to the competitive and confirmatory model testing framework—despite that these post hoc and a priori approaches were considered mutually exclusive alternatives by Belsky et al. (2013) and Widaman et al. (2012). The purpose of

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this editorial is to modify our standing on mixed approaches, making clear that we now embrace the use of a mixed approach—but one that differs in important ways from the mixing and matching that has been employed to date.

Currently, those who implement the mixed approach require that the first, exploratory phase of analysis yields a conventionally significant interaction term ($p < .05$) before proceeding to the second, competitive and confirmatory model testing stage of analysis. In other words, the test of significance of the interaction between person and environment predictors functions as a 'screen' for proceeding to the second stage. We regard this criterion as too strong for the same reason that we originally eschewed it in advancing the competitive and confirmatory model testing approach: Being exploratory in character, the first stage presumes that there are no hypotheses about the form of the interaction being evaluated, thereby reducing the statistical power to detect such when, as so clearly evident in the second stage of analysis, competing hypotheses are central to the inquiry.

In our new mixed approach, we encourage researchers first to fit a standard statistical model as they would under the traditional exploratory approach to evaluating person × environment interactions and then to follow up with the competitive and confirmatory model testing if this appears to be feasible. If one uses multiple regression, the first, exploratory step would involve a statistical model that includes, at minimum, both person and environment main effects and the person × environment product term that represents the interaction. Two results from this initial, exploratory analysis are of considerable utility in deciding whether to proceed to implement the competitive and confirmatory model testing approach – the magnitudes of the F ratio for the interaction and of the parameter estimates for the predictors in the equation.

The magnitude of the F ratio for the interaction can provide evidence that the model testing approach is feasible. The latter approach utilizes iterative, nonlinear numerical optimization methods to estimate model parameters. If the F ratio for the interaction is very near 0.0, then slopes for an interaction will be almost parallel, and this causes no estimation problems in the exploratory approach. But, in such a case, any iterative, nonlinear estimation routine will be ill-conditioned, leading to problems such as lack of convergence and improper parameter estimates or standard errors. In the first, exploratory approach, an F ratio >1.0 may have a p-value of .10 or .20 but does indicate that more trend than error is being fit, and we regard this as a much better criterion for moving to the competitive and confirmatory testing step than requiring that the interaction be significant at $p < .05$. But an $F > 1.0$ should not be considered a hard-and-fast criterion, rather one to be approximated. When discussing p values, Rosnow and Rosenthal (1989) opined that '... surely, God loves the .06 nearly as much as the .05'. Extending this to F ratios and paraphrasing these scholars, we think that, surely, She loves an $F = 0.95$ nearly as much as an $F = 1.05$. Still, as the F ratio for the interaction approaches zero, this poses severe estimation problems for the competitive and confirmatory model testing approach and suggests, given an absence of interaction, that neither differential-susceptibility nor diathesis-stress predictions would be confirmed by the data, thereby by making second-stage model testing an ill-considered venture.

The magnitude of parameter estimates is a second benefit derived from the initial, exploratory step. We have fielded many questions from researchers interested in the competitive and confirmatory model testing approach seeking advice on start values. Iterative, nonlinear estimation methods require the researcher to supply start values for parameter estimates. If an iterative method fails to converge, whether the fault lies in the inadequacy of the model for the given data or in poor start values can be difficult to determine. Both Aiken and West (1991) and Widaman et al. (2012) discussed how to obtain an estimate of the crossover point from parameter estimates from an exploratory model; and Widaman et al. (2012) addressed how start values for other estimates in the re-parameterized equation can be developed. Good start values increase the likelihood of convergence of the estimation procedure to a solution with acceptable estimates, and lack of convergence to an acceptable solution implies that the fault is probably due more to inapplicability of the model for the data than to poor start values.

To summarize, empirical studies using our original competitive and confirmatory model testing approach to investigating person × environment interactions has convinced us of the utility of adopting a two-stage analytic strategy. But as we have hopefully made clear, we believe that the best way to proceed to further efforts to evaluate competing theoretical models is to eschew the statistical significance requirement of the first, exploratory stage, relying instead on the magnitude of the F ratio. As theoretically minded developmental scholars, we remain convinced that pitting alternative models against each other advances scientific inquiry more so than does continuing a practice of just running exploratory analyses and thereafter probing significant person × environment interactions, acting as if the work undertaken was not informed by any conceptual framework. So, let the model fitting commence.

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