Developmental Review 33 (2013) 29–57

Contents lists available at SciVerse ScienceDirect

Developmental Review

journal homepage: www.elsevier.com/locate/dr

The construct of psychophysiological reactivity: Statistical and psychometric issues

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ARTICLE INFO

Article history:
Received 1 February 2012
Revised 18 October 2012
Available online 16 November 2012

Keywords:
Psychophysiology
Reactivity
Measurement of change
Difference score
Residual score
Latent variable modeling

ABSTRACT

The purpose of this paper is to review major statistical and psychometric issues impacting the study of psychophysiological reactivity and discuss their implications for applied developmental researchers. We first cover traditional approaches such as the observed difference score (DS) and the observed residual score (RS), including a review of classic and recent research on their reliability and validity from two related bodies of work: the measurement of change and the Law of Initial Values. Second, we review several types of latent variable modeling in this context: latent difference score (LDS) models, latent residual score (LRS) models, latent state-trait (LST) models, and latent growth curve (LGC) models. Finally, we provide broad guidelines for applied researchers broken down by key stages of a psychophysiological project: study planning, data analysis, and reporting of results. Our recommendations highlight the need for (1) increased attention to the ubiquitous nature of measurement error in observed variables and the importance of employing latent variable models when possible, and (2) increased specification of theories relating to the construct of reactivity, especially in regards to the distinction between baseline arousal and change over time in broader systems of variables.

Introduction

Recent years have seen a proliferation of research studies that aim to link processes of children's adaptation across multiple levels of analysis, with a focus on integrating psychophysiological assess-

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0273-2297/$ - see front matter
http://dx.doi.org/10.1016/j.dr.2012.10.002

ments into the study of developmental psychology (e.g., Beauchaine, 2001; Curtis & Cicchetti, 2003; Obradović, 2012). Analytically, there is substantial interest in connecting youth's physiological responses to stressors/challenges to both behavioral outcomes as well as environmental influences. Although this research draws from decades of psychophysiological research in adults, it lacks consistency in conceptualizing and measuring indices of youth physiological responsivity. The goal of the present paper is to review the strengths and weaknesses of different approaches to the reduction and analysis of physiological data, in the hope of motivating better tests and refinement of existing developmental theories as well as more precise conceptualization of developmental changes in stress responsivity. In particular, we discuss statistical and psychometric issues that have relevance for researchers seeking connections between psychophysiological variables and other constructs of interest.

Following a brief introduction to the collection of psychophysiological data, the first half of this paper focuses on psychometric issues related to traditional measures of reactivity: the observed difference score and the observed residual score. This section draws on sources from the broad measurement of change as well as the psychophysiological Law of Initial Values, literatures with both a rich history (e.g., Heath & Oken, 1965; Wilder, 1931) and considerable recent revival (e.g., May & Hittner, 2010; Zimmerman, 2009). Since many of the publications discussing these topics are not in journals widely read by applied developmental psychologists, we hope that our review will provide developmental researchers with not only increased appreciation for the complex issues involved in such data reduction, but also practical guidance for research situations favoring a particular score. A recurring theme in this discussion is the ubiquitous yet unmeasured presence of error in observed scores.

The second half of this paper reviews newer, promising approaches to the analysis of reactivity data: latent difference score modeling, latent residual score modeling, latent growth curve modeling, and latent state-trait modeling. These methods offer great promise for the testing and refinement of developmental theory. Yet, with few exceptions, applications of these approaches remain rare in youth psychophysiology research; thus, we hope that our review will encourage the increased adoption and testing of these powerful analytic techniques. To that end, we provide sample programming syntax in Mplus (Muthén & Muthén, 1998–2010) for each of the discussed models in the Appendix (syntax partly adapted from Brown, Croudace, & Heron, 2011). We end our review with a set of general research recommendations.

Psychophysiological reactivity

We restrict our review primarily to statistical issues in studies that derive a single physiological reactivity score. To help ground our discussion, consider that such study paradigms often employ measures of the autonomic nervous system (ANS), a fast-acting physiological stress response system (Berntson, Quigley, & Lozano, 2007; Obradović, 2012). The ANS has traditionally been divided into two primary branches, the sympathetic and parasympathetic; the former initiates physiological arousal (termed the "fight-or-flight" response) and the latter restores homeostasis (termed the "rest-and-digest" response). Common markers of sympathetic ANS activity include cardiac pre-ejection period (PEP) and skin conductance level (SCL), whereas common markers of parasympathetic ANS activity include respiratory sinus arrhythmia (RSA), derived from polyvagal theory (Porges, 2001, 2007). However, the two ANS branches do not necessarily operate in a simple reciprocal manner, with co-activation and co-inhibition both possible. Although in recent years researchers have started to examine how the two systems jointly relate to developmental processes (Del Giudice, Hinnant, Ellis, & El-Sheikh, 2012), the majority of developmental research still focuses on a single measure of ANS activity at a time.

Although quite common, single-score operationalization is admittedly simplistic. In contrast, Berntson, Cacioppo, and Quigley (1991) outline a comprehensive theory of autonomic control that details various modes of SNS and PNS response, taken together. Among other points, Berntson et al. (1991) stress the importance of working towards independent assessment and manipulation of the SNS and PNS. The complexity of these and other psychophysiological systems has also been