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Measuring the development of inhibitory control: The challenge of heterotypic continuity

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ABSTRACT

Inhibitory control is thought to demonstrate heterotypic continuity, in other words, continuity in its purpose or function but changes in its behavioral manifestation over time. This creates major methodological challenges for studying the development of inhibitory control in childhood including construct validity, developmental appropriateness and sensitivity of measures, and longitudinal factorial invariance. We meta-analyzed 198 studies using measures of inhibitory control, a key aspect of self-regulation, to estimate age ranges of usefulness for each measure. The inhibitory control measures showed limited age ranges of usefulness owing to ceiling/floor effects. Tasks were useful, on average, for a developmental span of less than 3 years. This suggests that measuring inhibitory control over longer spans of development may require use of different measures at different time points, seeking to measure heterotypic continuity. We suggest ways to study the development of inhibitory control, with overlapping measurement in a structural equation modeling framework and tests of longitudinal factorial or measurement invariance. However, as valuable as this would be for the area, we also point

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out that establishing longitudinal factorial invariance is neither sufficient nor necessary for examining developmental change. Any study of developmental change should be guided by theory and construct validity, aiming toward a better empirical and theoretical approach to the selection and combination of measures.

Inhibitory control, "the ability to inhibit responses to irrelevant stimuli while pursuing a cognitively represented goal" (Carlson & Moses, 2001, p. 1033), is a key construct in the domain of self-regulation (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996). Self-regulation is a broad construct encompassing physiological, attentional, cognitive, emotional, and behavioral regulatory processes that promote adaptive or goal-directed behavior (Berger, 2011; Calkins & Fox, 2002). Self-regulation and inhibitory control measures have been associated with many important adjustment outcomes, including school readiness (Blair, 2002), health (Moffitt et al., 2011), and psychopathology (Dale & Baumeister, 1999), including in longitudinal studies (e.g., Brocki, Nyberg, Thorell, & Bohlin, 2007). Studies of self-regulation in children often include batteries of behavioral tasks thought to assess executive functioning, executive control, inhibitory control, response inhibition, behavioral regulation, and effortful control, among others (Carlson, 2005; Carlson & Moses, 2001; Kochanska, Murray, & Harlan, 2000). Despite the different terms used for similar measures, the different self-regulation constructs primarily reflect differences in research tradition rather than construct differences (Zhou, Chen, & Main, 2012). It has been difficult to achieve conceptual clarity among the different self-regulation constructs (McClelland & Cameron, 2012). The present review focuses on issues in measurement of inhibitory control, a key component of self-regulation across many research traditions, in longitudinal research. It is important to consider how to measure the development of inhibitory control because of the widespread use of inhibitory control measures in early childhood and its relevance to the development of psychopathology.

Inhibitory control, also referred to as response inhibition, is one of the separable cognitive processes thought to comprise the construct of executive function. In the past, inhibitory control was thought to emerge only in middle to late childhood, corresponding with improvements in the child's ability to execute complex, higher-order integrative tasks (Welsh, Friedman, & Spieker, 2006). However, response inhibition, in its most basic form, is present in the first year of life including the inhibition of neonatal reflexes and the inhibition of predominant behavioral reaching responses (Diamond, 1990), and more robustly in the preschool years. The vast majority of research on the development of inhibitory control often focuses on development from early childhood to adolescence (Durston et al., 2002; Williams, Ponesse, Schachar, Logan, & Tannock, 1999), with behavioral measures of inhibitory control demonstrating dramatic improvement over this time span (Welsh et al., 2006; Williams et al., 1999). The age at which performance on inhibitory control tasks reaches adult levels depends largely upon task complexity and difficulty, with performance on some basic tasks reaching adult levels in early childhood, while performance on other tasks, which require the integration of multiple executive functions, continues to improve until adolescence (for a review, see Garon, Bryson, & Smith, 2008).

Executive function has been defined as "goal-directed cognitive control of thought, action, and emotion" (Zelazo et al., 2013, p. 16). In adults, executive function is thought to be a multi-dimensional construct comprised of separable cognitive processes including response inhibition, working memory, and cognitive flexibility (Miyake et al., 2000). However, it is less clear whether such a factor structure characterizes executive function in early childhood, with some studies suggesting that executive function is best represented as a single, unitary construct in early childhood (Fuhs & Day, 2011; Shing, Lindenberger, Diamond, Li, & Davidson, 2010; Wiebe, Espy, & Charak, 2008; Wiebe et al., 2011; Willoughby, Blair, Wirth, & Greenberg, 2010; Willoughby, Wirth, & Blair, 2012) that likely fractures into a multi-dimensional construct in later childhood, with other studies suggesting that a multi-dimensional factor structure similar to adults is present in early childhood (Lee, Bull, & Ho, 2013; Lee et al., 2012; Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012).