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Identifying unique components of preschool children's self-regulatory skills using executive function tasks and continuous performance tests

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ABSTRACT

Continuous Performance Tests (CPTs) are proposed to measure attention and inhibitory control (IC). The purpose of this study was to examine the extent to which performance on the CPT overlaps with measures of executive functioning (EF) skills (i.e., IC and working memory [WM]). A sample of 279 preschoolers (Age, $M = 55.86$, $SD = 4.00$) were administered three CPTs as well as measures of IC, WM, and early academic achievement. For each child, a teacher completed a behavioral-rating measure. Results indicated that omission and commission errors on the CPT were distinct from EF skills and each other. These findings have implications for understanding the overlap between attention and EF and for the use of low target-frequency CPTs with preschoolers.

Inhibitory control (IC), working memory (WM), and attention are regulatory processes that are crucial to the development of academic and social skills in preschool children (Blair & Razza, 2007; Kochanska, Murray, & Harlan, 2000). An understanding of the relations between these processes is complicated by the multitude of measures used to assess these constructs as well as the multifaceted nature of these measures. There are a variety of direct measures that can be used to assess IC (Grass–Snow task; Carlson & Moses, 2001) and WM (Listening Recall; Pickering & Gathercole, 2001). The continuous performance test (CPT; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956) is a cognitive task that has been used as a measure of aspects of attention (Berwid et al., 2005), IC (Bodnar, Prahme, Cutting, Denckla, & Mahone, 2007), and hyperactivity/impulsivity (H/I; Barkley, 1991). Although the ambiguity regarding the specific constructs measured by the CPT has been acknowledged in the literature (Riccio, Reynolds, & Lowe, 2001), less research has been specifically designed (using multiple indicators) to examine directly the extent to which the constructs measured by the CPT overlap with other measures of self-regulation. The primary purpose of this study was to examine the degree to which measures of IC and WM and indices of attention and H/I from CPTs represent similar or different constructs. We also aimed to examine the joint and unique relations between these direct measures of regulatory processes and preschool children's academic performance and classroom behaviors.

Self-regulatory processes

Executive functioning (EF) is an important part of self-regulatory behavior that refers to the control of thoughts and action needed for future-oriented and goal-directed behaviors (Welsh, Pennington, & Groisser, 1991). A variety of theories have been proposed as explanations of the cognitive mechanism that underlies complex tasks requiring intentional allocation of attention resources (i.e. "frontal lobe or executive tasks" Miyake et al., 2000, p. 50). Most such theories propose the existence of multiple components that overlap to varying degrees. IC is a specific component of EF that is defined as the ability to inhibit prepotent thoughts or actions in favor of subdominant thoughts or actions, typically in the context of goal-directed behavior (Blair, Zelazo, & Greenberg, 2005; Rothbart & Bates, 2006). WM is another component of EF that is defined as the active use (i.e., manipulation or updating with regard to sensory input) of information held in memory. Although simple recall is necessary to perform a WM task, WM is distinguished from simple memory span by more complicated processes that build on recall, making information available in support of the performance

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of complex tasks. Attention is a multi-faceted system that is closely linked to aspects of EF (Derryberry & Rothbart, 1997). Generally, attention is the process of focusing awareness on certain aspects of internal and external stimuli. Regulation of attention refers to the ability to control this focus and avoid distraction from competing, irrelevant stimuli. In summary, WM, IC, and attention are closely linked processes that contribute to complex self-regulatory behaviors.

IC and WM

IC and WM are two of the most commonly studied components of EF. WM and IC have been reported to be related but separable constructs in both adults (Miyake et al., 2000) and school-age children (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003). By definition, IC tasks require the performance of a non-predisposed response, or the withholding of a response, in a context in which a mutually exclusive predisposed response exists. The essential feature of IC tasks is that a rule must be held in memory and used first to overcome a predisposition toward one response and finally to refrain from performing a response or to perform a non-predisposed response. Therefore, it could be argued that the capacity to maintain an active representation of task rules through WM plays an important role in the performance of IC tasks.

Findings from studies of the dimensionality of EF task performance among preschool children are less consistent than those from studies of the dimensionality of EF among school-age children. For example, results of exploratory factor analytic studies (Welsh, Nix, Blair, Bierman, & Nelson, 2010) demonstrate adequate fit using single-factor models to account for performance on a variety of EF tasks. Further, results of several confirmatory factor analytic studies of data from preschool samples (Wiebe et al., 2011; Willoughby, Blair, Wirth, & Greenberg, 2010) demonstrate that combining WM and IC factors into a single dimension does not decrease model fit, suggesting the absence of a boundary between factors. In contrast, results from two recent studies with preschool children (Lerner & Lonigan, 2014; Schoemaker et al., 2012) demonstrated that WM and IC were separable but correlated constructs. It is not yet clear if methodological differences or age differences explain differences in findings across studies.

Attention and executive processes

Attention is a regulatory process that is strongly associated with other self-regulatory processes. Attention is related to WM (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005) in that poorer WM is associated with poorer attention skills (Gathercole et al., 2008). Both parent-rated attention and direct measures of attention have been shown to be associated with IC in early childhood (Reck & Hund, 2011). However, attention is a multi-faceted construct the components of which may differ in their relations to executive processes. There are executive forms of attention (Eisenberg, Smith, Sadovsky, & Spinrad, 2004; Posner & Rothbart, 1998) that relate to the ability to attend to relevant aspects of stimuli and ignore irrelevant aspects. One aspect of attention, attention shifting, is a specific component of EF and refers to the ability to shift flexibly across mental-sets (e.g., switching from one task to another, switching from one set of rules to another, Miyake et al., 2000). There are also simpler components of attention such as sustained attention and vigilance that focus on the ability to remain alert for a target over time. Although almost all cognitive tasks require a degree of attention, it is not always clear what specific aspects of attention they measure.

The CPT

The overlap between definitions and descriptions of IC, WM, and attention makes determining the extent to which each is uniquely measured by performance on a given task difficult. This is particularly true of multi-faceted tasks such as the CPT, which is widely accepted as a measure of attention and also has been used as a measure of IC (Berry, 2012; Bodnar et al., 2007). During this task, children view a stimulus sequence on a screen, respond to target stimuli, and withhold responses to non-target stimuli. There are two primary error types derived from CPT performance: commission errors and omission errors. Commission errors occur when a child responds to a non-target stimulus. Commission errors are typically presumed to represent levels of hyperactivity (Barkley, 1991) but also have been characterized as measuring impulsivity (Rodriguez-Jimenez et al., 2006) and IC (Berry, 2012; Brooks et al., 2006). Omission errors occur when a child fails to respond to a target stimulus and are typically presumed to measure attention (Berwid et al., 2005; Bodnar et al., 2007); however, the specific component of attention presumed to be measured by the CPT differs across studies and may, for example, include attentional control (Sulik et al., 2010), sustained attention (Rosvold et al., 1956), or vigilance (Gualtieri & Johnson, 2006). Although, the different terms used to characterize omission and commission errors are certainly related, they are not necessarily interchangeable. Thus, there is a need for a better developed understanding of the specific constructs measured by different aspects of performance on the CPT.

There are multiple versions of the CPT that vary in stimulus presentation. Versions of the CPT used with younger children typically use images of common objects rather than letters, numbers, or other symbols as stimuli and have slower stimulus presentation rates than do CPTs used with older children and adults. CPTs also can vary in terms of target frequency and the specific rules regarding when to respond. The CPT used in the present study is based on the traditional CPT paradigm designed by Rosvold et al. (1956) which has a low target-frequency and requires children to respond only when a target it displayed. More recent commercially available versions of the task, such as the Conners (1985) require the child to respond to all stimuli *except* the target stimuli, resulting in more frequent responding. Both versions of the CPT have been accepted as measures of attention. However, because responding may not be considered a prepotent response in the traditional low target-frequency versions of the CPT, it has been argued that the traditional CPT does not necessarily assess IC (Egeland & Kovalik-Gran, 2010).

Self-regulatory processes, early academic skills, and problem behaviors

There is evidence that attention problems are associated with academic development in research with school-age (McClelland, Acock, & Morrison, 2006) and preschool-age (Walcott, Scheemaker, & Bielski, 2010) populations. Much of the research linking inattention to academic skills has been conducted using teacher and parent ratings of inattention (Galéra, Melchior, Chastang, Bouvard, & Fombonne, 2009; Lonigan et al., 1999). There is also research reporting relations between performance on direct measures of inattention, such as the CPT, and academic performance (Lam & Beale, 1991; Sims & Lonigan, 2013). Inattention may lead to academic difficulties because it interferes with active engagement in academic-related activities such as listening to instructions, completing school work efficiently, and participating in classroom discussions that promote learning (Loe & Feldman, 2007; Mash & Barkley, 2003). Inattention also may influence the development of academic skills because of its relation to executive processes such