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Refining the Preschool Self-regulation Assessment for Use in Preschool Classrooms

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To aid in understanding preschoolers' self-regulation and refinement of measurement, we examined properties of a field-based assessment battery of preschooler's self-regulation, the Preschool Self-regulation Assessment (PSRA). The PSRA, which includes seven age-appropriate tasks that tap children's executive control, was administered to 313 preschoolers and then to 261 of these children approximately 3 months later. Teachers reported on children's school readiness (social competence and classroom adjustment) at the end of preschool and kindergarten years, and on academic success in kindergarten. PSRA tasks were examined for ceiling effects at 35–65 months; Pencil Tap, Balance Beam, Toy Wrap and Snack Delay were retained for lack of such effects. Confirmatory factor analyses showed two components at each time point – hot and cool executive control – and cross-time correlations showed significant stability of individual differences. Four-year-old girls and children of higher socioeconomic status outperformed 3-year-old boys and those at socioeconomic risk. Children, especially girls, scored higher on hot executive control. Finally, aspects of executive control differentially predicted teacher-reports of school readiness at both times of assessment, with age, gender and risk status controlled. These selected PSRA tasks, as a shortened battery, have potential for research and applied usage, and findings speak to theoretical understanding of preschoolers' self-regulation.

Young children's school readiness is defined as their mastery of certain basic skills or abilities, such as literacy, numeracy and social skills, which help ensure success in the new learning environment of formal schooling (Hair, Halle, Terry-Humen, Lavelle, & Calkins, 2006). Such readiness, or its lack, often sets children on a cycle of success or failure in both academic and social domains (McClelland, Acock, & Morrison, 2006).

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According to kindergarten teachers, self-regulation is another readiness skill needed for successful transition to school (Rimm-Kaufmann, Pianta, & Cox, 2001). It is not surprising that abilities in working memory, inhibitory control, attention and delay of gratification, for example, should aid the young child in the myriad challenging tasks facing them in the classroom.

In concert with these assertions, a growing body of work has emphasized the impact of children's self-regulatory skills on their social competence and academic success (Denham, Brown, & Domitrovich, 2010). For example, self-regulation is found to be related to preschoolers' social competence (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Blair, Granger, & Razza, 2005; Raver et al., 2011), as well as their early math ability and literacy (Altemeier, Abbott, & Berninger, 2008; Bierman et al., 2008; Blair & Razza, 2007; Espy et al., 2004; Ponitz, McClelland, Matthews, & Morrison, 2009; Pritchard & Woodward, 2011; Sesma, Mahone, Levine, Eason, & Cutting, 2009; Welsh, Nix, Blair, Bierman, & Nelson, 2010).

Given this increased interest in young children's self-regulation in relation to school readiness, a wide variety of assessment tools to measure preschoolers' self-regulation have been developed. These measures include structured and semi-structured assessments designed for laboratory use (e.g. Murray & Kochanska, 2002), naturalistic observations (e.g. Denham & Burton, 1996) and parent-report and teacher-report questionnaires (e.g. Rothbart, Ahadi, & Hershey, 1994).

Researchers are also adapting laboratory-based structured self-regulation tasks to form field-based assessment tools of preschoolers' self-regulation (Ponitz et al., 2008; Ponitz et al., 2009; Smith-Donald, Raver, Hayes, & Richardson, 2007). Compared with their laboratory counterparts, these tools are generally designed to require a shorter amount of training time to collect reliable data, with inexpensive and portable materials; at the same time, they include standard situations in which to assess self-regulation.

Such direct assessments have demonstrated construct validity and predicted social and academic outcomes with less potential for observer bias (Carlson, 2005; Ponitz et al., 2008). By directly assessing young children's self-regulation in field-based research settings, researchers can collect data on wider samples of children, such as low-income children, who may not participate in university research (Smith-Donald et al., 2007). These assessments, then, may be particularly ecologically valid, as well as accessible to groups for whom school readiness is very important. Thus, field-based self-regulation assessments have the potential to further our understanding of young children's normative development. These tools need to be clearly theoretically grounded, so that it is to definitional issues that we now turn.

Definition and Structure of Self-regulation

In the present study, our primary focus is to examine the properties of one field-based assessment tool, the Preschool Self-regulation Assessment (PSRA; Smith-Donald et al., 2007), to evaluate its usability for both research and applied purposes. Self-regulation refers to a broad construct representing the cognitive, motivational-affective, social and physiological processes that modulate attention, emotion and behaviour to a given situation/stimulus, for the purpose of pursuing a goal (Calkins & Howse, 2004; Posner & Rothbart, 2007).

Beyond these assertions, however, developmentalists have struggled to create one satisfactory definition of the construct (Carlson, 2005). For our purposes, current inquiry suggests that it may be fruitful to integrate neurobiological and behavioural evidence, and to specify as clearly as possible the distinctions that

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we consider most empirically defensible. In doing so, we draw from current literature and methods, but attempt to transcend theoretical demarcations that obfuscate rather than clarify.

We base our constructs on actual demands made on preschool children: entering the peer arena, independently responding to new adults (e.g. their teacher) and attempting new developmental tasks. All these new, increasingly expected, requirements tax the young child's developing self-regulatory systems. Cognitive and affective/motivational processes, supported as they are by cortical involvement, are implicated in what we term *executive control* (EC). Recent advances in both developmental psychobiological theorizing and research, and neuroimaging, suggest that two types of EC are distinguishable, both neurally and behaviourally, and that such distinctions can be important both theoretically and practically (Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011; Zelazo & Müller, 2002). Therefore, we consider that self-regulation includes cool executive control (CEC; more affectively neutral, slow acting and developing) and hot executive control (HEC; more reflexive, fast acting, early developing and under stimulus control; Willoughby et al., 2011).

Cool executive control and HEC are tightly related because of the central role played by the prefrontal cortex (PFC) in both. The PFC is responsible for higher-order cognitive processes, such as activating working memory, inhibiting prepotent responses while activating alternative, subdominant responses, and flexibly focusing or shifting attention (Garon, Bryson, & Smith, 2008).

Cool executive control encompasses a wide array of increasingly organized, flexible, goal-directed *cognitive* processes in response to relatively non-affective and novel situations, as well as complex cognitive tasks (Blair et al., 2005; Diamond, 2006). Children entering the new and potentially stressful school environment need CEC abilities to follow complex rules, flexibly respond to conflicting stimuli and purposefully shift or focus their attention (e.g. taking turns in games; playing ' Simon Says'; focusing on manipulating puzzle pieces without letting a playmate interrupt; disengaging from a task when the teacher says it is time to clean up). Not surprisingly then, CEC skills have been shown to predict early literacy skills (McClelland et al., 2007; Willoughby et al., 2011) and mediate intervention effects of research-based curricula implemented in Head Start programmes (Bierman et al., 2008).

Regulating cognitive and behavioural outcomes during learning activities, as indicated by competent CEC, is important, but young children also need to demonstrate self-regulation in which affective and motivational processes figure more prominently (e.g. not touching a toy that belongs to someone else; waiting patiently for one's teacher to provide drawing materials; refraining from becoming angry when tasks become difficult). This kind of self-regulation illustrates the second component of EC, HEC. Such processes involve orbitofrontal cortical, limbic, as well as PFC, control (Calkins & Marcovitch, 2010; Willoughby et al., 2011). The complexity of self-regulatory tasks requiring HEC necessitates a more intricate set of neural processes.

Thus HEC, guided by both emotional information from the limbic system and cortical 'braking' (and assisted by the bridging mechanism of the anterior cingulate cortex; Calkins & Marcovitch, 2010), enables children to regulate their anger and approach systems and purposefully deploy attention during emotional arousal (Rothbart & Bates, 2006). A decade-long programme of research provides exceptionally strong empirical evidence that the preschoolers' demonstration of one aspect of HEC, the ability to delay gratification, predicts a myriad of outcomes through adulthood (Eigsti et al., 2006). Regarding our focus on school readiness, preschoolers who are better able to control their impulses and balance their own self-defined needs

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with societal norms are considered more 'well-regulated' and ready to interact positively with both people and activities in the classroom (Blair & Razza, 2007; Rothbart & Jones, 1998).

Both subtypes of EC require consideration because of their somewhat varying source and functions, but much overlap between them would be expected. It remains to be seen, given a set of tasks showing good variability through a relatively wide age range when self-regulation is thought to be rapidly developing, whether we will see one unitary EC, or both CEC and HEC.

However, before we can answer this question, we must examine each PSRA task to measure its adequacy during this age range; for example, often even self-regulation tasks administered within a relatively narrow age range (e.g. preschool) are not uniform in difficulty (Best & Miller, 2010). Ceiling effects could render it difficult to find differences in self-regulation across ages and other theoretically important groupings of children, or relations of self-regulation with important outcomes, such as school readiness. Carlson (2005) found little evidence of ceiling effects across 3-year and younger 4-year-olds in several tasks analogous to those included in the PSRA; however, ceiling effects emerged as children approached 5 years of age.

Thus, the first goal of this study is to examine the CEC and HEC tasks at two time points separated by approximately 3 months (a period large enough to capture the emergence of developmental change seen in, e.g. Carlson, 2005, but not so small as to be prone to practice effects) and determine whether ceiling effects preclude using any of them. Given these results, discerning the structure of self-regulation describable by our measure is the second goal of the current study. Using this structure for tasks that measure self-regulation across the 3 to 5-year-old age range, as our third goal, we then examine test-retest reliability, necessary for any adequate measurement. These goals work together to evaluate the PSRA as a potentially useful measure.

Self-regulation and Child Characteristics

After establishing important initial parameters of the PSRA, we aim to examine how the measure reflects individual differences in self-regulation due to age, gender, or socioeconomic risk. Several cognitive processes involved in self-regulation (i.e. inhibitory control, working memory and attention) show dramatic development between ages of 3 and 5 years (Jones, Rothbart, & Posner, 2003; Welsh et al., 2010). Hence, researchers have found age-related differences on tasks measuring self-regulation (e.g. Bierman et al., 2008; Carlson, 2005; Carlson & Moses, 2001; Jones et al., 2003; Espy et al., 2004; Li-Grining, 2007); in general, older children are more adept at self-regulation tasks, often more strongly on CEC tasks, as compared with HEC tasks. We expect similar age differences because age trajectories differ across tasks (Carlson, 2005); however, we will examine such differences specifically on the tasks retained after ceiling effects analyses. Knowing age differences in self-regulation can have important measurement and developmental considerations (what tasks are appropriate for ages across the preschool range?) but also may be important in the applied sense, because it is important to hold appropriate expectations of preschoolers' self-regulation abilities.

Further, children growing up in poverty may experience stressful life events, low levels of social support and limited opportunities for guided exploration of the social and physical environment, resulting in likely developmental delays in

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CEC (Bierman et al., 2008; Li-Grining, 2007). We expect to find differences in both CEC and HEC according to socioeconomic risk; the extant literature does not allow for a more differentiated prediction, as most attention has been afforded to CEC. Pinpointing differences in the development of age-appropriate self-regulation in children varying in socioeconomic status (SES) can translate into foci for preschool programming.

Regarding gender, biological differences and gender-related socialization processes also may have an impact on development of self-regulation. For example, Carlson and Moses (2001) found that girls performed better than boys on inhibitory control (CEC) tasks. Ponitz et al. (2008) found that both girls and higher SES children achieved slightly higher behavioural self-regulation scores, similar in many ways to CEC tasks, than did boys and lower-SES children; Li-Grining (2007) found differences favouring preschool girls on delay of gratification (HEC) tasks. We expect to find that girls outperform boys on both CEC and HEC but more strongly for HEC. Discerning gender differences may help early childhood educators in targeting self-regulation programming to those most in need.

Finally, we have already noted that preschoolers' self-regulation is increasingly being found to relate to various indices of school readiness; in the current study involving the PSRA, we move beyond examining relations of CEC and HEC with social competence and academic success, to also include prediction of classroom adjustment (e.g. expressing positive attitudes toward learning, attention/persistence and willingness to try new tasks in school), a third important index of school readiness.

More specifically, we would expect that CEC would be especially related to academic success, and also to attention/persistence and motivation to learn, whereas HEC would be especially related to social competence, lack of anger and aggression, and positive attitudes in the classroom. That is, CEC would not only support preliteracy and numeracy, but also, via working memory, flexibly focusing or shifting attention, and inhibiting prepotent responses, play a role in how children are able to concentrate and remain focused on classroom tasks, as well as have the self-possession to face new tasks with zestful anticipation. In contrast, HEC, with the more affective component of delay of gratification, would figure in being sensitive to and cooperative with others, refraining from aggression and anger, and maintaining a positive, cheerful classroom demeanour.

The Present Study

The current investigation is particularly germane because of needs in applied developmental psychology; Isquith, Crawford, Espy, and Gioia (2005) note that the study of young children's self-regulation still needs evidence of reliability and validity of measurement. To reiterate our study aims, which are consonant with this call, (i) we examine each PSRA task's usability across the 3 to 5-year-old age range at two time points; (ii) after retaining those tasks, which do not exhibit prohibitive ceiling effects, we examine their structure and reliability; (iii) then we evaluate the resultant components' differences according to child characteristics (i.e. age, gender and socioeconomic risk status); (iv) finally, we describe prediction of teachers' reports on school readiness (classroom adjustment and academic success), across two periods. Our final results add to theoretical understanding of self-regulation, as well as to potential utility of this measure in both research and applied settings.

METHOD

Participants

This study was part of a larger longitudinal study focused on creating a portable assessment battery of preschoolers' social-emotional competence related to school readiness. Preschoolers enrolled in Head Start and private childcare centres in the greater Northern Virginia area participated. These centres were selected because of variability in race, ethnicity and income, as well as access to many children. Three hundred and thirteen children (173 private childcare, 140 Head Start) were administered the entire PSRA at Time 1 (T1) and were therefore included in the current analyses; 261 children were administered in the PSRA at Time 2 (T2). Age at T1 was used to distinguish two age groups (ages at beginning of the study were, for 3-year-olds: M = 41.5 months, *SD* = 3.9; for 4-year-olds: *M* = 53.6 months, *SD* = 3.6). Participants were 50.2% men, with a majority of children identified by their parent as either Caucasian or African–American (43.5% Caucasian, 36.1% African–American, 7.3% multi-racial, 2.6% Asian, 9.3% not reported and 1.3% other). No participant required the administration of the PSRA in a language other than English.

Because confidentiality agreements with participating centres precluded our asking families about their income directly, socioeconomic risk was broadly classified at T1 by children's enrollment in private child care centres versus Head Start. Thus, child's age, gender and risk status were used as demographic characteristics.

General Procedures

Children were administered in the PSRA twice – in the late fall to early spring (T1) and the late spring of the same year (T2). Assessments were conducted in quiet locations during the school day. Preschool teacher measures were collected at the end of the academic year (~T2). For each participating child in their classroom, teachers were paid $20 in compensation for the time used in completing the questionnaires. Children received stickers for participation. Children who were administered in the PSRA at T2 did not differ from those who were not on any T1 PSRA task and differed on only one demographic measure (i.e. race; children tested at T2 were more likely than those who were not Caucasian, χ^2 (N = 313, $df = 6) = 13.56$, $p < 0.05$).

Kindergarten teacher data were collected in the spring (T3), for the subsample of children ($N = 99$) who were still in the area and in schools that gave consent for research. These teachers were paid $25 per child because they completed more questionnaires; many are not the focus of this study. Kindergartners remaining in the study and those who could not be followed, did not differ on any measure or demographic characteristic, except for age and risk status, χ^2s ($N = 313$, 1) = 6.78 and 6.21, respectively, ps < 0.01 and 0.05, respectively. Younger children, who took longer to reach kindergarten (and thus had more time for parents to move away or become less familiar with the study), and those in private child care (who were more mobile than those in Head Start) were more likely to be lost in the study.

Child Measures

Preschool Self-regulation Assessment (Smith-Donald et al., 2007). The PSRA was utilized to capture strengths and weaknesses in preschoolers' self-regulation. The PSRA consists of seven structured tasks to tap CEC and HEC. As CEC tasks,

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three tasks requiring children to filter competing stimuli (Pencil Tap, Balance Beam, Tower Turn-Taking), originating from laboratory-based work (e.g. Murray & Kochanska, 2002), were included. Four delay tasks (Toy Wrap, Toy Wait, Snack Delay and Tongue Task) were used to assess HEC. The PSRA battery was administered by 12 trained and certified research assistants who live-coded latencies or performance levels for each task. Table 1 gives a more detailed summary of the PSRA tasks and how scores were computed (see also Smith-Donald et al. (2007)).

Inter-assessor reliability (intra-class correlation for continuous and Cohen's kappa for categorical variables) for the current data ranged between 0.81 on Toy Wait to 0.97 on Pencil Tap, showing good to excellent assessor agreements.

Teacher Measures

T2 and T3 classroom adjustment: Preschool Learning Behaviour Scale (PLBS: McDermott, Leigh, & Perry, 2002). The PLBS is a 29-item teacher rating instrument assessing preschool children's approaches to learning. Both preschool and kindergarten teachers rated children's observable behaviours occurring during classroom learning activities over the previous 2 months, on a 3-point Likert scale. The PLBS focuses on attentiveness, responses to novelty and correction, observed problem-solving strategy, flexibility, reflectivity, initiative, self-direction and cooperative learning. The instrument yields three reliable learning behaviour dimensions: (i) Competence Motivation (i.e. reluctant to tackle a new activity); (ii) Attention/Persistence (i.e. tries hard, but concentration soon fades and performance deteriorates); and (iii) Attitudes Toward Learning (i.e. does not achieve anything constructive when in a sulky mood).

Multi-method, multi-source validity analyses have substantiated PLBS dimensions for preschool children, with similar reliability estimates for both Caucasian and non-Caucasian children (Fantuzzo, Perry, & McDermott, 2004). In this study, the PLBS dimensions demonstrated good internal consistency (αs = 0.78–0.91 across T2 and T3).

T2 and T3 social competence: Social Competence and Behaviour Evaluation (SCBE-30: LaFreniere & Dumas, 1996). The 30-item version of the SCBE is designed to measure the social-emotional competence of 3 to 6-year-olds. We utilized teacher ratings of child behaviours such as 'easily frustrated' (Anger/Aggression scale) and 'comforts or assists children in difficulty' (Sensitivity/Cooperation scale). Both preschool and kindergarten teachers completed this measure.

Social Competence and Behaviour Evaluation-30 subscales demonstrated adequate to very high internal consistency (αs = 0.88–0.94 across T2 and T3; see also LaFreniere & Dumas, 1996). LaFreniere and Dumas demonstrated construct and convergent validity of the measure via associations between the SCBE and measures of anxiety/withdrawal and conduct disorder (see also Denham et al., 2003, for further evidence of SCBE-30's psychometric adequacy). Finally, the SCBE-30 is structurally equivalent across diverse demographic groups (LaFreniere et al., 2002).

T3 academic success: ECLS-K Academic Rating Scale. Kindergarten teachers completed the Academic Rating Scale (ARS, US Department of Education, National Center for Education Statistics, 2002–2005), which includes: (i) Language and Literacy (nine items, e.g. 'reads simple books independently'); (ii) General Knowledge (five items, e.g. 'forms explanations based on observations and explorations'); and (iii) Mathematical Thinking (seven items, e.g. 'shows an

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Table 1. Preschool Self-regulation Assessment (PSRA) tasks

Task title	Construct	Assessor directions/procedure	Measurement method
Balance Beam (3 trials)	CEC	Ask child to walk on a short length of tape for 3 trials; reduce speed for second trial and slower for third trial.	Subtract first trial from mean of second and third trials (amount of reduction of speed in seconds)
Pencil Tap (16 trials)	CEC	Ask child to tap unsharpened pencil after assessor, assessor taps 1x child should tap 2x; assessor taps 2x child should tap 1x.	Percentage of correct trials over a total of 16 trials
Tower Turn-Taking (12 blocks)	CEC	Ask child to build a very high tower with blocks taking turns with assessor.	Ordinal variable capturing amount of Turn-Taking (full, partial or none)
Toy Wrap	HEC	Ask child not to peek while assessor wraps a toy in tissue and bag for 1 min.	Latency in seconds to first peek
Toy Wait[a]	HEC	Ask child to wait 1 min before opening wrapped toy.	Latency in seconds to first touch of toy
Snack Delay (4 trials)	HEC	Ask child to wait with keeping his/her hands flat on the table before getting a candy from under a cup for 3 rounds (10, 20, 30 and 60 s).	Average of four trials on the level of waiting (ranging from does not touch cup or timer to eats candy) plus whether the child kept hands flat on the table during the trial
Tongue Task (1 trial)	HEC	Ask child to hold a candy on their tongue for 40 s before eating it.	Latency in seconds to eat candy

Adapted from Smith-Donald et al. (2007).
CEC, cool executive control; HEC, hot executive control.
[a]PSRA task scores were checked for excessive skew and truncated range denoting limited variability. Because of these problems, Toy Wait was excluded from further analysis.

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understanding of the relationship between quantities'). Teachers compared each child to their same-age peers on 5-point scales. Internal consistency reliabilities for the subscales ranged from 0.85 to 0.92; a T3 academic success aggregate was created by summing standard scores for the scales ($\alpha = 0.93$).

RESULTS

Ceiling Effects

The operationalization of ceiling effects varies somewhat depending on the measure, its potential range of scores, variability and pertinent ages for which ceiling effects are to be evaluated. However, one overarching definition is that no more than 50% of responders should obtain the maximum score (Vitale et al., 2001). Table 2 illustrates results of frequency analyses for the seven PSRA tasks (note procedure for scales with no maximum score, such as Balance Beam); Tower Turn-Taking and Tongue Task clearly exceeded the 50% criterion, and were therefore excluded from further analysis. Balance Beam, Pencil Tap and Snack Delay tasks all fell below the criteria for exclusion at both T1 and T2, and were retained. The decision was made to retain Toy Wrap task; it barely exceeded the criterion at T1, and its retention allowed for inclusion of two tasks each for HEC and CEC in the battery (despite its somewhat higher percent maximum at T2).

Structure of Self-regulation

Table 3 shows intercorrelations among retained PSRA tasks at T1 and T2; all tasks were significantly correlated at T1, but only four of six correlations were significant at T2. Especially, Balance Beam was significantly related only to Pencil Tap at T2. Four of six correlations were smaller at T2 than T1, even if significant, according to Fisher's *r*-to-*z* tests.

Next, we examined whether retained T1 and T2 PSRA task scores yielded coherent structure, similar across time. To this end, scores for the retained PSRA tasks from each period were subjected to confirmatory factor analysis (Wirth & Edwards, 2007). Models were estimated using AMOS 18. For both T1 and T2, a one-factor model showed poor fit to the data (χ^2 (2) = 8.46, $p < 0.05$, comparative fit index (CFI) = 0.94, root mean square error of approximation (RMSEA) = 0.10 for T1 and χ^2 (3) = 8.77, $p < 0.05$, CFI = 0.87, RMSEA = 0.09 for T2). In contrast, a two-factor model showed good fit to the data for both time points (χ^2 (1) = 0.16, $p = 0.69$, CFI = 1.00, RMSEA = 0.00 for T1 and χ^2 (2) = 0.38, $p = 0.83$, CFI = 1.00, RMSEA = 0.00 for T2). Furthermore, a chi-square difference between one-factor and two-factor models was significant for both T1 and T2 ($\Delta\chi^2$ (1) = 8.30, $p < 0.01$ for T1 and $\Delta\chi^2$ (1) = 8.39, $p < 0.01$ for T2), indicating that the two-factor model fits the data significantly better than one-factor model for both T1 and T2. The two discriminable factors (i.e. CEC and HEC) were moderately correlated at each time point, corroborating that, although they were related, they are nonetheless sufficiently distinct (φs = 0.68 for T1 and 0.41 for T2, ps < 0.001).

These two-factor models, with standard factor loadings, are presented in Figure 1. Retained PSRA tasks' factor loadings were significant in the expected direction for both factors in each model. Standardized factor loadings indicated that, for CEC, Pencil Tap showed a stronger contribution compared with Balance Beam at both time points. As for HEC, Toy Wrap became a stronger

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Table 2. Descriptive Data for Preschool Self-regulation Assessment tasks at T1 and T2, by Age: ceiling effect decisions

Subtest	Balance Beam[a]	Pencil Tap	Tower Turn	Toy Wrap	Snack Delay	Tongue Task
Maximum Possible Score	–	100	2.00	60.5	5.00	40.00
T1						
% at maximum	4.7	7.3	56.2	51.1	19.8	71. 6
T2						
% at maximum	1.0	16.4	68.6	62.8	22.1	79.8
Decision	No ceiling effect	No ceiling effect	Ceiling effect present	No ceiling effect	No ceiling effect	Ceiling effect present

[a]Because Balance Beam has no ‘maximum’ score, for this task’s ceiling effect metric, we calculated Minimum Detectable Change, $MDC_{95\%}$, as SEM X SD X test-retest reliability X 1 0.96 X sqrt(2) (Impellizzeri, Mannion, Leunig, Bizzini, & Naal, 2011). We then subtracted this $MDC_{95\%}$ from the observed maximum score on Balance Beam and report the percentage at or above this score for an estimate of ceiling effect.

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Table 3. Intercorrelations of Preschool Self-regulation Assessment (PSRA) Tasks at T1 and T2

PSRA tasks	Balance Beam	Pencil Tap	Toy Wrap	Snack Delay
Balance Beam				
T1	–	0.34***	0.20***	0.16**
T2	–	0.26***	0.03[a]	0.02[a]
T1/T2	0.42***			
Pencil Tap				
T1		–	0.31***	0.29***
T2		–	0.25***	0.14* [a]
T1/T2		0.66***		
Toy Wrap				
T1			–	0.40***
T2			–	0.20*** [a]
T1/T2			0.48***	
Snack Delay				
T1				–
T2				–
T1/T2				0.33***

Upper row within each entry shows intercorrelations of PSRA Tasks at T1; middle row shows intercorrelations at T2; lowest row shows T1/T2 test-retest correction.
[a]Correlations weaker at T2 than T1.
$*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

indicator than Snack Delay at T2. Given these confirmatory factor analysis results, individual factor parameter estimates were used subsequently as scores for HEC and CEC, for each child at each time point.

Test-retest Reliability

Significant relations were found between PSRA factor parameter estimates at T1 and T2, rs (259) = 0.61 and 0.69, ps < 0.001, for HEC and CEC, respectively. These relations were strong even with age, gender and risk status, partialled, rs (247) = 0.52 and 0.59, ps < 0.001. In contrast, comparable test-retest partial correlations for each task separately varied from 0.29 for Snack Delay to 0.58 for Pencil Tap, ps < 0.001 (see Table 3 for zero-order correlations).

Time, Age, Gender and Risk Status Differences in Self-regulation

We next conducted repeated multivariate analysis of covariance for HEC and CEC factor parameter estimates at T1, with child age as the continuous covariate, and gender and risk status as between-subjects independent variables, and HEC/CEC as the within-subject variable. Significant between-subjects effects were found for gender, age and risk status, Fs (1, 301) = 7.48, 107.82 and 8.56, ps < 0.01, 0.001 and 0.01, respectively (partial η^2 s = 0.024, 0.264 and 0.028). Thus, being a girl, older and low risk was all associated with higher self-regulation scores (Table 4). The dimensions of self-regulation differed, Fs (1, 301) = 25.20, with this main effect moderated by gender, Fs (1, 301) = 8.32, ps < 0.001 (partial η^2 s = 0.077 and 0.027).

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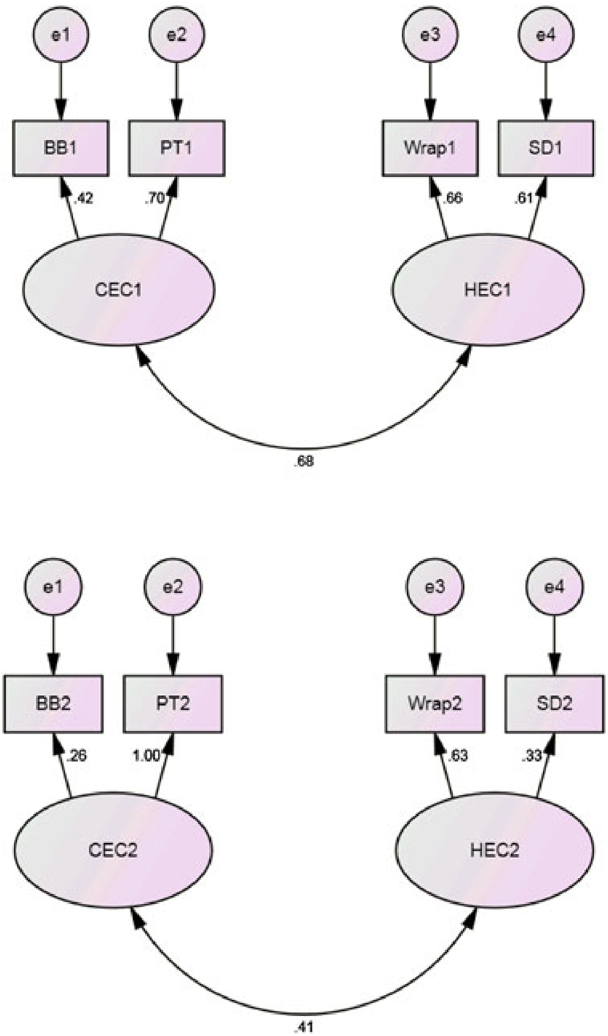

Note: Due to a negative error variance, the error variance of PT2 was set to a negligible amount (i.e., .01). BB=Balance Beam, PT = Pencil Tap, Wrap = Toy Wrap, SD=Snack Delay

Figure 1. Two-factor model of self-regulation with standardized factor loadings (upper for Time 1 and lower for Time 2).

Table 4. Adjusted means and standard errors of Preschool Self-regulation Assessment components for subgroups at T1

	Gender		Age		Centre type/risk status	
	Boys	Girls	3 years	4 years	Private	HS
CEC	1.79 (0.06)	1.92 (0.06)	1.46 (06)	2.11 (0.05)	1.97 (0.05)	1.74 (0.06)
HEC	2.59 (0.06)	2.87 (0.06)	2.39 (0.07)	2.96 (0.05)	2.84 (0.05)	2.62 (0.06)

Standard errors in parentheses.
CEC, cool executive control; HEC, hot executive control.

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Children, especially girls, performed better on HEC, as compared with CEC (Table 4); another way to look at this effect is that the main effect of gender is most true for HEC.

Relations with School Readiness

Our study expectations were that CEC would be especially related to academic success, and also to attention/persistence and motivation to learn, whereas HEC would be especially related to social competence, lack of anger and aggression, and positive attitudes in the classroom. To examine these possibilities and thus how young children's self-regulation was related to their school readiness, two sets of hierarchical multiple regression equations were calculated.

For the first set, in which T2 teacher-reports of classroom adjustment (i.e. PLBS and SCBE-30) were dependent variables, the first step controlled for child characteristics (i.e. gender, age at T1 and risk status); T1 HEC and T1 CEC factor parameter estimates were entered in the second step. For the second set, in which T3 teacher-reports (including academic success, along with classroom adjustment indices) were dependent variables, the first step again controlled for child characteristics (i.e. gender, age at T1 and risk status), as well as the corresponding T2 teacher-report; T2 HEC and T2 CEC factor parameter estimates were entered in the second step. Results are shown in Tables 5 and 6.

As seen in Table 5, after partialling of demographic indicators, T1 CEC was an independent contributor to variation in T2 Competence Motivation and Attention/Persistence (albeit at a borderline level of significance). In contrast, T1 HEC was an independent predictor of T2 Attention/Persistence, Attitudes Toward Learning, Anger/Aggression (weighted negatively) and Sensitivity/Cooperation. Both aspects of self-regulation would have been significant predictors if entered singly, suggesting that examining unique contributions was indeed necessary.

Table 6 shows results for T3 school readiness criteria. In this case, even after partialling demographic indicators and T2 teacher premeasures, T2 HEC predicted T3 increases in Attention/Persistence and Attitudes Toward Learning. T2 CEC predicted T3 increases in motivation for learning, as well as academic success. Where prediction was significant, both aspects of self-regulation would again have been significant if entered singly.

DISCUSSION

We examined properties of the PSRA, which was developed for field-based research. Findings centre on several key contributions. First, a relatively short, easily administered battery of self-regulation tasks that can be used in the field, corresponding to both HEC and CEC factors, was specified via ceiling effects analyses. Individual differences in these factors derived from the resultant short battery were reliable over a short longitudinal period, and scores differed according to age, gender and socioeconomic risk, pointing to broader reflections on the development of self-regulation during the preschool years and the vulnerability of boys and children at socioeconomic risk. Finally, aspects of EC predicted children's social competence, classroom adjustment and academic readiness. Given these implications for later school success, reliable, valid and easily used assessment tools of young children's self-regulation are needed for both research and applied usage.

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Table 5. Regression analyses predicting T2 teacher-reports of classroom adjustment

	PLBS Competence Motivation				PLBS Attention/Persistence				PLBS Attitudes/Learning			
	B	*SE B*	*β*	ΔR^2	*B*	*SE B*	*β*	ΔR^2	*B*	*SE B*	*β*	ΔR^2
Block 1				0.030*				0.079***				0.088***
Age at W2	0.003	0.004	0.048		0.002	0.004	0.033		0.001	0.003	0.011	
Gender	0.081	0.048	0.100$^+$		0.242	0.055	0.253***		0.194	0.047	0.235***	
Risk Status	0.095	0.049	0.117*		0.093	0.056	0.097 $^+$		0.131	0.048	0.159**	
Block 2				0.058*** [a]				0.112*** [a]				0.040** [a]
HEC	0.017	0.056	0.034		0.136	0.062	0.226*		0.124	0.055	0.239*	
CEC	0.130	0.057	0.248*		0.110	0.064	0.178$^+$		−0.007	0.057	−0.013	
	SCBE-Anger/Aggression				SCBE Sensitivity/Cooperation							
Block 1				0.084***				0.106***				
Age at W2	0.006	0.009	0.041		0.012	0.007	0.107$^+$					
Gender	−0.413	0.119	−0.199***		0.444	0.089	0.283***					
Risk status	−0.400	0.121	−0.192***		0.155	0.091	0.098$^+$					
Block 2				0.036** [a]				0.094*** [a]				
HEC	−0.353	0.140	−0.271*		0.355	0.101	0.360***					
CEC	0.095	0.144	0.071		−0.011	0.104	−0.011					

Total R^2 significant at least $p < 0.05$ through final step for all equations.
PLBS, Preschool Learning Behaviour Scale; CEC, cool executive control; HEC, hot executive control.
[a]Contributions of HEC and CEC would have both been significant if entered singly.
$^+p < 0.10$.
$^*p < 0.05$.
$^{**}p < 0.01$.
$^{***}p < 0.001$.

Table 6. Regression analyses predicting T3 teacher-reports of classroom adjustment and academic success

	PLBS Competence Motivation				PLBS Attention/Persistence				PLBS Attitudes/Learning			
	B	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2	*B*	*SE B*	β	ΔR^2
Block 1												
Age at W2	0.001	0.007	0.009	0.145*	0.000	0.008	−0.004	0.208***	−0.006	0.006	−0.094	0.210***
Gender	0.082	0.090	0.096		0.141	0.109	0.132		0.147	0.085	0.180⁺	
Risk status	−0.236	0.091	−0.275*		−0.200	0.108	−0.189⁺		−0.141	0.083	−0.173⁺	
T2 Premeasure	0.252	0.104	0.250*		0.379	0.102	0.379***		0.326	0.100	0.337**	
Block 2				0.074* [a]				0.072* [a]				0.041
HEC	0.077	0.076	0.123		0.183	0.091	0.235*		0.138	0.072	0.231*	
CEC	0.096	0.055	0.222⁺		0.058	0.066	0.108		−0.007	0.050	−0.016	
	SCBE-Anger/Aggression				SCBE Sensitivity/Cooperation							
Block 1				0.286***				0.225***				
Age at W2	−0.001	0.015	−0.004		−0.005	0.013	−0.043					
Gender	0.007	0.198	0.004		0.116	0.170	0.070					
Risk status	0.432	0.197	0.212*		−0.300	0.166	−0.182⁺					
T2 Premeasure	0.442	0.085	0.503***		0.444	0.107	0.427***					
Block 2				0.022				0.040				
HEC	−0.103	0.174	−0.069		0.222	0.151	0.184					
CEC	−0.127	0.120	−0.124		0.081	0.102	0.098					
	Academic success											
Block 1				0.214***								
Age at W2	0.117	0.045	0.264**									
Gender	−0.316	0.612	−0.055									
Risk status	−2.055	0.599	−0.354***									
T2 Premeasure[b]	0.101	0.043	0.245*									
Block 2				0.103**[a]								
HEC	0.210	0.487	0.050									
CEC	1.001	0.351	0.343**									

Total R^2 significant at least $p < 0.05$ through final step for all equations except SCBE-Anxious/Withdrawn.
PLBS, Preschool Learning Behaviour Scale; CEC, cool executive control; HEC, hot executive control.
[a]Contributions of HEC and CEC would have both been significant if entered singly.
[b]Premeasure is aggregate of all T2 PLBS and SCBE teacher-reports, $\alpha = 0.90$. $^{+}p < 0.10$. $^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.

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Our results showed that the shortened PSRA battery is one such measure. In the following, we discuss in more detail these key findings and their theoretical and applied import.

Measure Refinement and Developmental Considerations

Because the ability to regulate cognition, emotion and behaviour is rapidly developing during preschool years, it is important to develop assessment tools which can accurately and sensitively measure developmental changes in self-regulation throughout this age span. Of the multitude of EC tasks researchers have utilized with preschoolers in the last decade, many are appropriate for only certain parts of this age range (Best & Miller, 2010). In the current study, we found that two tasks – Tongue Task and Tower Turn-Taking – showed clear ceiling effects within the age range of our sample. The deleterious presence of ceiling effects should not be ignored in the creation of measurement batteries that can inform early childhood practice while remaining sensitive to the change across age that may predict important later outcomes (see also Carlson, 2005). Our findings suggested re-calibration of the PSRA to include specific tasks in a shortened battery, to more accurately and sensitively measure self-regulation during the 3 to 5-year-old period.

These robust tasks not prey to ceiling effects were shown to form HEC and CEC factors at both time points. Thus, we replicated earlier findings supporting a two-factor structure of young children's self-regulation as assessed by the PSRA (Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009) and also found new evidence for stability of the structure across a 3-month period. Furthermore, moderate-to large test-retest reliability indices for the shortened battery's factors and their components also indicated the usefulness of the measure as revised to yield CEC and HEC factors. Theoretically, zeroing in on two aspects of EC, Hot and Cool, can help to capture the full complexity of regulatory processes, supported by both similar and different brain structures. Further, as was seen in the differentiated prediction of aspects of school readiness by CEC and HEC, the two-factor model can facilitate more precise thinking about the functions and outcomes of self-regulation.

Finally, also consistent with earlier findings (Carlson, 2005; Carlson & Moses, 2001; Jones et al., 2003; McCabe & Brooks-Gunn, 2007), we found that 4-year-olds outperformed 3-year-olds. Reliably capturing the age-related development of young children's self-regulation is both practically and theoretically important. It appears that this shortened PSRA battery is sensitive to such differences. Regarding applications, whether child care and preschool programmes separate children into 3 and 4-year-old groups or use mixed-age groupings, knowing what to expect of children of differing ages is important.

In terms of theory development, what do these accumulated findings tell us about the nature and trajectory of EC during the preschool age range? Garon et al. (2008) have suggested that specific aspects of EC are fastest developing and thus ascendant during specific age ranges from birth to school age, and Carlson (2005) has identified ceiling effects on a number of EC tasks used in the toddler and preschool age ranges. We can use their theoretical and empirical conclusions to inform interpretation of the current findings.

Thus, during infancy through toddlerhood, the key developmental tasks of EC, irrespective of its 'hot-ness' or 'cool-ness', are developing working memory (holding events in mind and updating information) and simple response inhibition (withholding a prepotent response). From age 3–5 years, much development is focused on

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complex response inhibition (holding a rule in mind, responding according to this rule and inhibiting a prepotent response) and response-shifting. Attention-shifting becomes possible at 4 years and older.

All the HEC tasks administered in this study – Snack Delay, Toy Wrap, the Tongue Task – are simple response inhibition tasks that begin developing during toddlerhood. Nonetheless, proficiency on the Snack Delay and Toy Wrap tasks increases until children are at least 4 years and older, whereas the waiting delay in the Tongue Task shows a ceiling effect by age 3 years (Carlson, 2005). Thus, our ceiling effect findings support the assertion of Garon et al. (2008) that the trajectory of predominantly HEC simple response inhibition flows from its emergence prior to age 2 years, through age 4 years, depending on the nature of the tasks and their scoring.

The CEC tasks administered here are all complex response inhibition tasks, which can particularly benefit from developing language and abstraction skills. In concert with earlier researchers who have seen performance improved after age 3 years on tasks similar to Balance Beam, we found no ceiling effects on these tasks. In contrast, the manner in which Tower Turn-Taking was scored according to Smith-Donald et al. (2007) renders it a lower-level response inhibition skill, and we found a ceiling effect on this task.

In sum, our retained PSRA tasks can be conceptualized as squarely within emerging, age-appropriate EC response inhibition skills, both 'hot' and 'cool'. Tasks capturing aspects of working memory and simpler response inhibition (such as the Tongue Task or Turn-Taking scored as it was here) would more aptly characterize the EC of younger children, whereas the addition of response-shifting and attention-shifting tasks would be more appropriate for 5-year-olds and early primary students.

Gender and Socioeconomic Risk

Taken together, our findings shed light on vulnerability factors related to gender and socioeconomic risk. We found a gender effect on PSRA task performance; girls outperformed boys on the battery, but especially on HEC (see also Li-Grining, 2007; McCabe & Brooks-Gunn, 2007). These findings suggest stronger gender differences on the affective/motivational aspects of self-regulation compared with more cognitively oriented, relatively non-affective tasks. Girls may be socialized to delay gratification; alternatively, boys may be more susceptible to being aroused and have more difficulty regulating once aroused, so that they have greater difficulty specifically on HEC tasks (Keenan & Shaw, 1997). The practical import of this gender difference may be to suggest targeted intervention for boys, especially for HEC.

Further, low-income children are considered to be at risk for delays in self-regulation, and some researchers already focus on developing and evaluating programming to promote their self-regulation (e.g. Bierman et al., 2008). It would seem that, for children at socioeconomic risk, conditions of the home and neighbourhood environment may affect the development of self-regulation via the demands made by nonoptimal levels of arousal and hindered development of the neural networks involved (Blair & Ursache, 2011; Bierman et al., 2008). Lack of resources and unpredictable change also hamper the sensitive caregiving and appropriate stimulation that supports EC development. Our current findings provide evidence for low-income children's developmental risk regarding self-regulation and corroborate the need for intervention. Results were suggestive of

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additive influence of risk factors, with younger boys at risk warranting particular attention in the self-regulation arena.

Relations between Self-regulation and School Readiness

According to Rothbart and Jones (1998), self-regulation is important for motivation and positive engagement in school settings; our results confirm and elaborate upon this supposition. That is, even with important covariates controlled, HEC contributed to variance or growth in aspects of classroom adjustment and social competence that required emotion regulation and utilization (i.e. Attitudes Toward Learning, Anger/Aggression and Sensitivity/Cooperation).

Hot executive control also contributed to variance or growth in children's Attention/Persistence at both time points. Although we predicted that only CEC would predict Attention/Persistence (which it did at T2), upon further reflection it seems natural that HEC could be important in both more affectively toned and more cognitive dimensions of classroom experiences. Preschoolers and especially kindergartners face new task and social demands that may engender excitement, anxiety and even fear; remaining attentive and persistent in such emotion-rich environments may necessitate HEC.

As expected, CEC also predicted Competence Motivation at T2 and growth in Competence Motivation at T3, suggesting that this aspect of self-regulation may underlie children's willingness to try and zest for participating in, new activities. This finding makes sense in that competence motivation involves holding learning goals in mind and sometimes moving forward in a learning situation even when the easier route would be to give up. CEC also predicted T3 academic success, a finding in concert with Brock et al. (2009), Willoughby et al. (2011) and other amassing evidence that CEC plays a key role in the child's readiness to take on such tasks.

What does this pattern of findings regarding social competence, classroom adjustment and academic outcomes mean for theory and practice? Regarding theory, the differential results involving HEC and CEC support separate examination of these self-regulation abilities, despite their interrelation during this age range. The longitudinal nature of the findings also point to both the longer-term implications of preschoolers' self-regulation and the fruitfulness of following children across time for both research and applied reasons. For practice, it is again important to note that the shortened battery could be useful in applied settings for tracking children's individual progress over time and evaluating outcomes of programming (Berger, 2011). In sum, the shortened PSRA can yield potentially important information for early childhood educators, researchers and theoreticians alike.

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