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Factor Structure of Self-Regulation in Preschoolers: Testing Models of a Field-Based Assessment for Predicting Early School Readiness

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Abstract

The importance of early self-regulatory skill has seen increased focus in the applied research literature, given the implications of these skills for early school success. A three-factor latent structure of self-regulation consisting of compliance, cool executive control, and hot executive control, was tested against alternative models, and retained as best fitting. Tests of model equivalence indicated the model held invariant across Head Start and private child care samples. Partial invariance was supported for age and gender. In the validity model, because of substantial amount of shared variance among latent factors, we included a second-order factor explaining the two types of executive control. Higher-Order Executive Control positively predicted teacher report of learning behaviors and social competence in the classroom. These findings are discussed in light of their practical and theoretical significance.

Keywords

self-regulation; school readiness; preschool; latent construct; confirmatory factor analysis; SEM

Self-regulatory skills have important implications for early school success (Blair, 2002; Blair & Diamond, 2008; Blair & Razza, 2007; Morrison, Ponitz, & McClelland, 2010; Raver, Garner, & Smith-Donald, 2007). For example, at school entry, young children are expected to self-regulate in many ways—to internalize and follow rules, listen to directions and respond accordingly, share toys, and wait their turn, all while facing a myriad of new and competing stimuli in the context of the preschool classroom (Cole, Martin, & Dennis, 2004; Eisenberg, Hofer, & Vaughan, 2007; Kochanska, Coy & Murray, 2001; Raver, 2002; Smith-Donald, Raver, Hayes, & Richardson, 2007). Enthusiastic inquiry into the ontogeny and sequelae of self-regulation has uncovered the need for high quality, cost-effective instruments to detect change in its various indicators (Denham, 2006; Raver, Carter, Smith-Donald, & Goyette, 2009).

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Despite clear recognition and empirical evidence (see, e.g., Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011) that self-regulation plays a key role in young children's early school success, developmentalists have struggled with its nomenclature and true nature (Carlson, 2005; Raver et al., 2009). Exemplifying these contrasting approaches, some theorists consider that a most important distinction is between (a) cortically controlled executive function – maintaining and internally guiding behavior via specific information processing strategies, without immediate reinforcement, while inhibiting automatized or prepotent responses to stimuli; and (b) subcortically controlled, temperamentally-based effortful control – quickly inhibiting a dominant response to perform a subdominant one, in the face of reward or punishment (Blair, Calkins, & Kopp, 2010; Raver, Jones, Li-Grining, Zhai, Bub, & Pressler, 2011). Others may, for example, give more weight to individual differences in temperamental effortful control and motivation (giving less consideration to executive function; e.g., Kochanska & Aksan, 2006), or on other definitions of executive function or executive attention. However, despite these differences, virtually all self-regulation theorists and researchers emphasize, to various degrees, modulating systems of attention, emotion, and behavior in response to a given situation or stimulus (e.g., Jahromi & Stifter, 2006; Smith-Donald et al., 2007). As noted by Willoughby and colleagues, there is much overlap in these constructs (although processes inherent in inhibitory control, working memory, and attentional flexibility are almost always involved), and much confusion in terminology (e.g., If effortful control is fast-acting, why is it termed “effortful”? How are executive function and effortful control to be distinguished if both involve inhibiting a prepotent or dominant response?).

For our purposes in capturing the key aspects of self-regulation, the current state of inquiry suggests that it may be fruitful to consider the preponderance of neurobiological and behavioral evidence, and to specify as clearly as possible the distinctions that 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.

Modeling Self-Regulatory Skills: Cool Executive Control, Hot Executive Control, and Compliance

We base our constructs on the 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 that strive for equilibrium. The more plausible distinctions among constructs of self-regulation tasks that confront preschoolers daily may best be based on the predominance of cognitive, affective/motivational, or behavioral processes.

Such cognitive and affective/motivational processes, supported as they are by cortical involvement, are implicated in what we will term *executive control*.¹ Recent advances in both developmental psychobiological theorizing and research, and neuroimaging, suggest that two types of executive control are distinguishable, both neurally and behaviorally, and that such distinctions are important both theoretically and practically (Willoughby et al., 2011). Therefore, the first two aspects of self-regulation within our model are cool executive control (CEC; more affectively neutral, slow acting and developing) and hot executive

¹We agree with Willoughby et al. (2011), that the many constructs studied within extant self-regulation research are highly overlapping, but nonetheless studied by researchers hailing from different theoretical perspectives and disciplines, with large nomenclature and measurement differences. For this reason we choose to refer to one of our constructs as “executive control,” with subdivisions of “hot” and “cool” executive control.

control (HEC; more reflexive, fast acting, early developing, and under stimulus control; Willoughby et al.).

Both CEC 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 the activation of information in working memory, the flexible use of attention (i.e., focusing or shifting), and inhibiting a prepotent response while activating an alternative, subdominant response (Bernier, Carlson, & Whipple, 2010; Blair, Zelazo, & Greenberg, 2005; Garon, Bryson, & Smith, 2008). In particular, the dorsolateral prefrontal cortex (DL-PFC) plays an important role in CEC (Best & Miller, 2010; Garon et al., 2008; Happaney, Zelazo, & Struss, 2004). Thus, the PFC is central to these aspects of self-regulation, but it is not the only neural structure that plays a role in these skills.

CEC 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, 2002; Diamond, 2006). Children entering school need CEC abilities to purposefully shift or focus their attention, to more flexibly respond to conflicting stimuli in the new and stressful situations that they face in school (Blair, Granger, & Razza, 2005; Ruff & Rothbart, 1996). Not surprisingly, CEC skills have been shown to predict early literacy skills (McClelland, Cameron, Connor, Farns, Jewkes, & Morrison, 2007; Willoughby et al., 2011), and to mediate intervention effects of research-based curricula implemented in Head Start programs (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008).

Regulating cognitive, emotional, and behavioral outcomes during learning activities, as indicated by competent CEC, is important, but young children also need to demonstrate self-regulation requiring more affective and motivational processes (e.g., not touching a toy that belongs to someone else). This kind of self-regulation is indicated by the second component of self-regulation, HEC. In contrast to CEC, HEC involves emotional and appetitive/motivational processes. Neurally, such processes involve orbitofrontal cortical (OFC) and limbic, in addition to PFC, control (Calkins & Marcovitch, 2010; Lewis & Todd, 2007; Willoughby, et al., 2011). The complexity of self-regulatory tasks requiring HEC necessitates a more intricate set of neural processes.

Whereas earlier theorizing considered CEC “top down” and HEC “bottom up” in terms of brain function, current thinking paints a more reasonable picture of what happens when children self-regulate. That is, given that both cortical and limbic structures already mentioned can be active when children are confronted with stimuli, tasks, and social mandates requiring regulation, some sort of bridging mechanism would seem necessary. Recent research in neurodevelopmental and biobehavioral perspectives has brought attention to the role of the anterior cingulate cortex (ACC) on deliberate, higher-order self-regulation (Lewis & Todd, 2007). The ACC includes a cognitive (anterior) subdivision, which has connection to the prefrontal cortex, and an emotional (posterior) subdivision connected to the limbic system (Bush, Luu, & Posner, 2000; Calkins & Marcovitch, 2010; Lewis & Todd, 2007). As such, the ACC can be a bridge managing information incoming between higher cortical and limbic systems.

Thus HEC, guided by both emotional information from the limbic system and cortical “braking” (and assisted by the ACC), enables children to regulate their anger and approach systems and purposefully deploy attention during emotional arousal (Rothbart, 1989; Rothbart & Bates, 1998). A decades-long program of research provides exceptionally strong empirical evidence that the demonstration during preschool of one aspect of HEC, the ability to delay gratification, predicts a myriad of outcomes through adulthood (i.e., Eigsti et al.,

2006; Mischel, Shoda, & Rodriguez, 1989; Shoda, Mischel, & Peake, 1990). Regarding our focus on school readiness, preschoolers better able to control their impulses and balance their own self-defined needs with societal norms are considered more “well-regulated,” and ready to be motivated and engaged in schooling (Blair & Razza, 2007; Raver, 2002; Raver & Knitzer, 2002; Rothbart & Jones, 1998). However, as yet little research shows that HEC contributes to school readiness over and above CEC (Brock et al., 2009; Howes, Calkins, Anastopoulos, Keane, & Shelton, 2003; Willoughby et al., 2011).

CEC and HEC represent cognitive and affective/motivational aspects of self-regulation.² But another, *behavioral*, aspect of self-regulation may be deemed central during the preschool period. The processes underlying this aspect of self-regulation are thus neither cognitive nor affective/motivational, but behavioral. That is, complying with adults is an overt behavioral index of children’s ability to generate appropriate behavior that may run counter to their wishes (similar to McClelland, Cameron, Wanless, & Murray’s 2007 “behavioral regulation”; see also Ramani, Brownell, & Campbell, 2010). Specifically, *compliance* is considered the ability to use internalized rules and standards to help regulate behavior adaptively and flexibly, and is included as the third component of self-regulation (Blair, 2002; Eisenberg & Spinrad, 2004; Kochanska, 2002).

Being able to initiate, maintain, and cease one’s own behavior according to adult requests, without adult support, is an emerging, developmentally appropriate aspect of self-regulation (Kopp, 1982). Parents and teachers socialize young children to act in a prosocial and cooperative manner, and it is with these skills that children can promote a harmonious learning environment for themselves and others (Crockenberg & Litman, 1990; Rimm-Kaufman et al., 2000). Children must learn to negotiate the needs of their independence with that of societal expectations in order to be considered “good citizens” in their early learning environment.

Given this framework, our first goal for the present study is to identify and test a model of early self-regulatory constructs. Our model measures hypothesized latent constructs that comprise specific aspects of self-regulation, which we propose as facilitative of children’s early academic behavior and social functioning at school entry. Because they can be clearly, discriminably defined, and given their particular importance at school entry, we consider the following three constructs as central in the measurement of preschoolers’ self-regulation: *cool executive control*, *hot executive control*, and *compliance*.

We met this aim empirically by obtaining directly observed indicators of self-regulation obtained from a portable, easily administered and reliable measurement instrument administered to children attending either Head Start or private child care programs. Collecting multiple indicators of three aspects of self-regulation enabled us to test the underlying structure of the construct. Specifically, we used all the tasks in Smith-Donald and colleagues’ (2007) Preschool Self-Regulation Assessment (PSRA), a battery tapping early self-regulatory behaviors and designed for use in field-based research. The PSRA includes tasks gathered from the self-regulation literature (Blair, 2002; Diamond & Taylor, 1996; Murray & Kochanska, 2002), and we test our tripartite model’s ability to describe adequately variability in children’s performance on these tasks. This methodology presents a unique opportunity to validate our models of self-regulation using a brief, age-appropriate battery that is a promising contribution to applied research in educational settings.

²Although situations calling for CEC and HEC, and the tasks by which these aspects of self-regulation are measured, all involve the production and observation of *behavior*, our distinction amongst CEC, HEC, and compliance is on the *processes* underlying each – as already noted, these are cognitive, affective/motivational, and behavioral.

Measuring Self-Regulatory Predictors of School Readiness in Diverse Samples

Because self-regulation is so important for promoting children's long-term success, assessments tapping predictors of children's school readiness are sorely needed (Denham, 2006; National Research Council of the National Academies, 2009). Thus, we examine both factorial and predictive validity of our model using the PSRA. First, in terms of factorial validity, we test the structure of the model – do the tasks fit a model of CEC, HEC, and compliance? Part of assessing factorial validity also includes determining the equivalence of the measure's latent structure across varying groups. Specifically, normative models of development may fit differently for children of different sociocultural contexts, and careful consideration of the appropriateness of the assessment tool for evaluating school readiness is needed (Denham, 2006; Garcia Coll et al., 1996; Raver, Gershoff & Aber, 2007). Although ample research evidence substantiates the crucial foundational nature of the transition into formal schooling for setting all children on a cycle of success or failure, racial minorities already demonstrate a significant achievement gap as early as kindergarten (Brooks-Gunn & Duncan, 1997; Campbell & von Stauffenberg, 2008; Lee & Burkham, 2002; McClelland, Acock, & Morrison, 2006; Ryan, Fauth, & Brooks-Gunn, 2006; Stipek & Ryan, 1997). Given these facts, can we use the same self-regulation measure with young children from different backgrounds, and feel comfortable making inferences from the data generated? The onus on researchers is to ensure that we do not introduce large amounts of error into models of early developing skills when examining groups of boys and girls, and at different ages and levels of socioeconomic risk.

Thus, in the current study, our second aim was to evaluate the psychometric measurement equivalence of our model in multiple groups (age, gender, risk status) (see also Bingenheimer, Raudenbush, Leventhal, & Brooks-Gunn, 2005; Raver et al., 2007; Raver et al., 2009; Wiebe, Espy & Charak, 2008). Our large, diverse sample allowed us to answer important questions regarding the “universality” of this field-based measure by systematically testing its measurement equivalence across various groups. Armed with an empirically supported measurement model, our third aim was to test its predictive utility for understanding young children's early school readiness. Specifically, given the hypothesized structure of the PSRA, we examined whether CEC, HEC, and compliance predicted learning behaviors and social-emotional competence.

In accord with these aims, we predicted that the hypothesized model would fit well, and be invariant across gender and socioeconomic risk, and at least partially equivalent across age (Raver et al., 2009; Wiebe et al., 2008). Regarding the predictive utility of the hypothesized structure of the PSRA, we predicted that HEC and compliance would be related to social competence, whereas CEC would be related to learning behaviors.

Method

Participants

The present study was a part of a larger study focused on developing a portable assessment tool for measuring the social and emotional aspects of school readiness. Head Start and private child care centers in the greater Northern Virginia area were selected due to variability in race, ethnicity, and income as well as access to large number of children. Within these sites, participants were recruited at parent and teacher meetings, and via flyers posted in classrooms. Rate of participation for private child care centers was 38% of the total chain in the northern and central Virginia region (range = 17% to 67% by site) and 86% of the Head Start centers in Fredericksburg, Virginia region (range = 59% to 100% by site).

Parental consent was received for a total of 392 children in the greater Northern Virginia area; a total of 364 children were administered at least one part of the battery as part of the

larger study. Among these children, 323 children (178 private, 145 Head Start) were administered the PSRA and were therefore included in the current analyses.

Age at the time of first assessment was used to distinguish the age groups ($M = 35.09$ months, $SD = 5.20$ and $M = 45.75$ months, $SD = 4.66$). At the start of the study, 66.1% were in four year old classrooms, whereas 33.9% were in three year old classrooms. Participants were 50.2% female, with a majority of children identified by their parent as either Caucasian or African American (43% Caucasian, 35% African-American, 6.8% multi-racial, 2.5% Asian, 12% not reported, and less than 1% other). As for ethnicity, nearly half of the sample (42.9%) was non-Hispanic/Latino (15.2% Hispanic/Latino, 41.8% other/not reported). Due to unequal sample size and missing data, model equivalence for ethnicity was not included in the present study.

Nearly 80% of Caucasians were in private childcare, and over 70% of African Americans were enrolled in Head Start, $\chi^2 (6, N = 323) = 81.56, p < .001$. Median education for mothers of children in private childcare was attainment of an associate's degree, whereas for mothers of children in Head Start, it was high school graduation, $\chi^2 (5, N = 323) = 51.46, p < .001$. Because of these associations among two indices of risk (i.e., race and maternal education) with program type, program type was used to capture risk status, as a variable to examine for model equivalence.

General procedures

Children's performance on the Preschool Self-Regulation Assessment (Smith-Donald et al., 2007) was collected in the late fall to early spring (November to March). Assessments were conducted with child participants in quiet areas of their programs during the school day. Teacher measures were collected at the end of the academic year (May). For each participating child in their classroom, teachers were paid \$20 in compensation for their time in the completion of the questionnaires.

Measures

The Preschool Self-Regulation Assessment (PSRA)—This measure (Smith-Donald et al., 2007) was utilized to capture children's strengths and weaknesses in behavioral self-regulation. The PSRA consists of 10 structured tasks, which include four delay tasks (Toy Wrap, Toy Wait, Snack Delay, and Tongue Task) to tap HEC and three tasks requiring children to filter competing stimuli (Pencil Tap, Balance Beam, and Tower Task Turn Taking) from laboratory-based work to tap CEC (e.g., Blair, 2002; Diamond & Taylor, 1996; Murray & Kochanska, 2002). In addition, the PSRA includes latency to complete three "do" tasks to assess children's compliance (Tower Clean-Up, Toy Sort, and Toy Return; see Brumfield & Roberts, 1998). Table 1 provides a description of the procedure for each task, the corresponding measurement method, and the corresponding latent construct for our models.

The PSRA battery was administered by 12 trained and certified research assistants who live-coded latencies or performance levels for each task. A majority of the assessors were female with at least four years of college (91.6% female; 25% bachelor's degree, 67% master's degree, 9% > master's degree). Assessors met all training criteria (i.e., 80% or greater error-free rate) established by the fourth author, following the Chicago School Readiness Project procedures manual (Towsend, 2007). All assessments with consent to be videotaped were double coded (approximately 7% of the sample). Interrater reliability, using intra-class correlation for continuous variables and Cohen's kappa for categorical variables, was moderate to high (.57 to .97 across all tasks). In pilot studies, Smith-Donald and colleagues (2007) examined the construct and concurrent validity of the measure in a Head Start

sample; the PSRA demonstrated expected associations with children's behavior problems and competencies as assessed by the Social Competence and Behavior Evaluation (SCBE-30, see below; LaFreniere & Dumas, 1996) and the Behavior Problems Index (BPI; Zill & Peterson, 1986), and early academic skills (math and verbal) as assessed by the National Rating System (NRS; Administration for Children and Families, 2003).

Social Competence and Behavior Evaluation (SCBE-30)—The 30-item version of the Social Competence and Behavior Evaluation (SCBE-30 Teacher Report; LaFreniere & Dumas, 1996) is designed to measure the socio-emotional competence of 3- to 6-year-olds. Teachers provide ratings on child behaviors such as “easily frustrated” (Angry/Aggressive factor), “avoids new situations” (Anxious/Withdrawn factor), and “comforts or assists children in difficulty” (Sensitive/Cooperative factor). In the current sample, SCBE-30 subscales demonstrated adequate to very high internal consistency ($\alpha = .77$ to $.94$). LaFreniere and Dumas (1996) report similar reliabilities in four samples of 4–6 year olds (across the U.S. and Canada). LaFreniere and Dumas also demonstrated the construct and convergent validity of the measure in a nationally representative sample, via moderate 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, in a multi-national study, the SCBE-30 demonstrated structural equivalence across diverse demographic groups including children in U.S. urban areas (LaFreniere et al., 2002).

Preschool Learning Behaviors Scale (PLBS)—The PLBS (McDermott, Leigh, & Perry, 2002) is a 29-item teacher behavior rating instrument assessing preschool children's approaches to learning. Using a 3-point Likert scale, teachers report on specific, observable behaviors that occur during classroom learning activities over the previous two months. In general, content 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 behavior dimensions: Competence Motivation (“Is reluctant to tackle a new activity.”), Attention/Persistence (“Tries hard, but concentration soon fades and performance deteriorates.”), and Attitudes Toward Learning (“Doesn't achieve anything constructive when in a sulky mood.”). High internal consistency estimates from a national standardization sample were found for the three learning behavior dimensions. In the current study, the PLBS demonstrated adequate to high internal consistency ($\alpha = .79$ to $.89$). Multimethod, multisource validity analyses further substantiated the PLBS dimensions for preschool and Head Start children (28 out of 30 possible correlations with teacher- and parent-rated behaviors were significant at the .01 level or greater), and reliability estimates were similar for both White and non-White portions of the sample based on high coefficients of congruence for generality (.79–.99) (Fantuzzo, Perry, & McDermott, 2004; McDermott et al., 2002).

Results

Data preparation

Following Smith-Donald et al. (2007), a score for each task was created (see Table 2 for descriptive results). Many tasks showed moderate significant inter-correlations (see Table 3). Toy Wait (*skew* = 14.21) and Toy Return (*skew* = 18.16) demonstrated absolute skew indices greater than 3, suggesting extreme skew (Kline, 2005). With kurtosis indices of 28.69 and 34.45, respectively, Toy Return and Tower Clean Up (Latency to Start) also demonstrated serious kurtosis, based on Kline's (2005) conservative estimates. These three indicators were therefore excluded from subsequent analysis due to non-normal distributions.³ Missing data on each task ranged from 0% to 1.9%. Given such minute levels of missing data, missing values were addressed by mean imputation. Due to severe

multivariate kurtosis, the Bollen-Stine bootstrapping method, a modified bootstrap method for the χ^2 goodness of fit statistic, was utilized (Bollen & Stine, 1993).⁴

Confirmatory Factor Analysis

All models were estimated using AMOS 18.0. Model fit was assessed through the use of several fit indices: χ^2 statistic, Comparative Fit Index (CFI; Bentler, 1990), and Root Mean Square Error of Approximation (RMSEA; Browne & Cudeck, 1993). A non-significant χ^2 value represents good model fit. However, because χ^2 is typically sensitive to even the smallest deviations from a perfect model, especially as the sample size increases, it is important to consult other indicators of fit. Two indices of practical fit were utilized here: CFI and RMSEA. According to Hu and Bentler (1999), values below .06 for the RMSEA and values above .95 for the CFI indicate good model fit.

Examining Model Fit—A three-factor model of self-regulation that specified three latent factors representing Compliance (latency to clean up blocks, latency to start sorting toys, latency to complete sorting toys), HEC (snack delay, toy wrap, tongue task) and CEC (pencil tap, balance beam, tower task) was tested first (Figure 1). The three-factor model provided an excellent fit to the data, χ^2 (24, $N = 323$) = 22.78, *n.s.*; CFI = 1.00, RMSEA = .00; however, the latency to clean up blocks—one of the indicators for Compliance—showed a small factor loading (.25), which was below the cutoff point generally recommended (Bowers et al., 2010). Thus, we removed the latency to clean up blocks from the model. This revised model showed excellent fit to the data, χ^2 (17, $N = 323$) = 15.06, *n.s.*; CFI = 1.00, RMSEA = .00, and all factor loadings were above the cutoff point (range from .41 for balance beam to .79 for latency to complete sorting toys).

With the revised model, four nested models were obtained (three 2-factor and one 1-factor) by setting the covariances between difference sets of PSRA latent variables equal to one. All four alternative models showed a significant increase of χ^2 compared to the hypothesized 3-factor model. The fitness indices (χ^2 , CFI and RMSEA) also indicated that three out of four alternative models had poor fit to the data (Hu & Bentler, 1999) (see Table 4). Although the χ^2 difference was significant, the overall χ^2 for one alternative 2-factor model (the covariance between CEC and HEC was set equal to one) was non-significant χ^2 , with good CFI and RMSEA fit indices. Thus, the results suggested that both our hypothesized 3-factor and the alternative 2-factor models fitted equally well to the data.

In the 3-factor model, covariances between each of the latent factors were moderate to high (Compliance and HEC $r = .50$, $p < .001$, Compliance and CEC, $r = .48$, $p < .001$, HEC and CEC $r = .82$, $p < .001$). The high covariance between CEC and HEC and the equivalent level of fitness to the data between the two competing models (i.e., the hypothesized 3-factor and alternative 2-factor models) suggested that the alternative 2-factor model was the best fitting model, if parsimony were the major criterion on which to base the decision. Based on theoretical models of self-regulation (Happaney et al., 2004; Zelazo & Müeller, 2002) and empirical findings showing different associations of CEC and HEC to social and academic competence (Brock et al., 2009; Willoughby et al., 2011), however, we concluded that keeping the distinction between CEC and HEC was important.

³Despite skew based on Kline's (2005) recommendations, Toy wrap (peek) was retained for these analyses due to the following: (1) it demonstrated adequate variability in comparison to other non-normally distributed variables (2) the theoretical importance of delay of gratification tasks as indices of self-regulatory behavior and (3) a decades-long program of research providing exceptionally strong empirical evidence that the ability to delay of gratification in preschool predicts behavior through adulthood (i.e., Eigsti et al., 2006; Mischel et al., 1989; Shoda, Mischel, & Peake, 1990).

⁴The bootstrapping sampling distribution allows for comparison of parametric values over repeated samples that have been drawn (with replacement) from the original sample, yet rendered free from restrictions of normality (Byrne, 2001).

Testing Model Equivalence—The hypothesized 3-factor-model was used to test for measurement equivalence across gender, age, and program type (Head Start or private childcare). In groups where negative error variances were detected, Dillon, Kumar and Mulani's (1987) recommendations for resolving Heywood cases (evaluated favorably in both empirical and simulation settings) were followed.⁵

Prior to testing model equivalence, we examined model fit of the 3-factor model for each subgroup (i.e., boys, girls, younger, older, Head Start, and private childcare). All groups showed a good fit to the data (i.e., nonsignificant χ^2 , CFI ranged from .98 to 1.00, and RMSEA ranged from .00 to .03). Then, following Brown (2006), we tested a series of hierarchically nested models for each subgroup. First, a full model that allowed all parameters to be freely estimated separately across groups was estimated (Model 1). Next, three reduced models were estimated: (a) constrained factor loadings to be equivalent across groups (Model 2); (b) constrained indicator intercepts to be equivalent across groups (Model 3); and (c) constrained factor covariances to be equivalent across groups (Model 4). Because the nested models were created by adding the restrictions of a single set of parameters at a time, model invariance was evaluated hierarchically with the chi-square difference test to detect the sources of non-invariance. However, the result of the chi-square difference test is influenced by distribution and sample size of the data, the CFI difference was also used for model evaluation (Chen, Sousa, & West, 2005; Cheung & Rensvold, 2002).⁶

As seen in Table 5, for program type, invariance of the factor loadings, indicator intercepts, and covariances was achieved based on the chi-square and/or CFI differences. Therefore, the highest level of equivalence was suggested for program type.

For age and gender, based on the chi-square and CFI differences, invariance of the factor loadings was not achieved (i.e., Model 1 (unconstrained) vs. Model 2 (factor loading invariant)). The comparison between Model 2 and Model 3 (indicator intercept invariant) indicated that the indicator intercepts were also non-invariant for these groups. These results indicated that, in addition to the different relations among the indicator variables and the latent factors, significant score differences were also observed between these groups. Inspection of intercepts indicated that girls scored higher than boys in all tasks, except for two tasks in CEC (i.e., the Pencil Tap and Balance Beam), and the older group scored higher than younger group in all tasks.

Analyses were then conducted to determine which of the factor loadings could be constrained across age and gender groups and which needed to be estimated separately. To test for the degree of model equivalence, we systematically unconstrained factor loadings of the indicator variables until the χ^2 tests were reduced to non-significance and/or the change on CFI became negligible (partially constrained models). For age, the chi-square differences between the unconstrained model and partially constrained models ranged from 8.03 ($\Delta df = 7$, ns) to 20.96 ($\Delta df = 7$, $p < .001$). A non-significant chi-square change was observed in the model in which the factor loading of Snack Delay was released to be free across age groups. For gender, the chi-square differences ranged from 14.78 ($\Delta df = 7$, $p < .05$) to 23.14 ($\Delta df = 7$, $p < .01$). The smallest chi-square change was observed in the model in which the factor loading of Tongue Task was released to be free across gender groups. Although the chi-square test was significant, a negligible change of CFI was found only for this model (1.00

⁵All cases met all three of Dillon et al.'s conditions for an offending estimate resulting from sampling fluctuations, and were therefore set to a negligible amount (.01).

⁶According to Cheung and Rensvold (2002), a difference of larger than .01 in the CFI would indicate a meaningful change in model fit for testing measurement invariance.

vs. .99). The PSRA therefore demonstrated partial equivalence of the factor loadings across age and gender.

Testing Predictive Validity—Two teacher-reported measures of early school readiness (learning behaviors and social behavior) collected at the end of the academic year were utilized as indicators of predictive validity. A single scale was created for each measure (a total problem solving scale for the PLBS and a social competence scale for the SCBE). Internal consistencies for these two scales were good to excellent; alphas equaled .92 for the PLBS and .93 for the SCBE.

Predictive validity of the PSRA was assessed through inspection of structural path coefficients from each of the three PSRA self-regulation factors to the two school readiness scales. The results showed that only HEC significantly predicted both PLBS and SCBE ($\beta = .47, p < .05$, $\beta = .73, p < .05$, respectively). CEC also had a marginally significant path to SCBE ($\beta = -.54, p < .10$); however, the direction was negative, which was opposite from what we expected. This finding may be due to a “net suppression” between HEC and CEC; because all three scores are positivity correlated, the function of CEC in this model, statistically, becomes that of suppressing error in the HEC/SCBE relation.

Results examining the model together, however, may not tell the full story because of the intercorrelations amongst the latent factors. To more fully understand the potential contribution of each of the latent factors to our validity measures, we examined predictive validity of each latent factor to two school readiness scales separately. All three latent factors significantly predicted both scales in expected manner (β s ranged from .20, $p < .01$ to .33, $p < .001$; note the smaller β s that those reported above, suggesting that our notion about suppression was correct). Thus, these findings allowed a deeper examination of the three factors’ validity, and confirmed the effects of their substantial shared variance in predicting our school readiness scales.

Next, based on the findings for the original validity model (i.e., both 3- and 2-factor structures plausible, and high covariance between CEC and HCE in the 3-factor model), we revised our validity model to include a higher-order factor explaining two first-order factors (i.e., CEC and HEC) (Figure 2). The revised validity model showed a good fit to the data, $\chi^2(29) = 40.81, p < .10$; $CFI = .98$, $RMSEA = .04$. The Higher-Order Executive Control factor was a significant predictor of the PLBS scale ($\beta = .26, p < .01$) and the SCBE scale ($\beta = .23, p < .05$). The latent factor of compliance predicted neither aspect of early school readiness.

However, the Higher-Order Executive Control and the Compliance factor were moderately correlated, $r = .54, p < .001$, again indicating substantial shared variance. Thus, as before, we examined contributions of the Higher-Order Executive Control and the Compliance factor to the two school-readiness scales separately. In the model with only the Higher-Order Executive Control factor predicting the two school-readiness scales, again, the Higher-Order Executive Control factor significantly predicted the PLBS scale ($\beta = .33, p < .001$) and the SCBE scale ($\beta = .25, p < .001$). In the model with only the Compliance factor predicting the two school-readiness scales, the Compliance factor significantly predicted the PLBS scale ($\beta = .29, p < .001$) and the SCBE scale ($\beta = .20, p < .01$). These results indicated that, although the Compliance factor did not significantly predict in the model with both self-regulation factors simultaneously predicting the school-readiness scales, due to the shared variance between them, the Compliance factor again is a significant predictor of the school-readiness scales when considered alone.

In sum, our findings indicated that preschoolers who showed higher self-regulation during the direct assessment were later seen as more ready for school by their teachers, compared to children who obtained lower scores on the self-regulation assessment.

Discussion

One of the greatest challenges for contemporary investigations of self-regulation involves the definition and measurement of these skills, particularly in young populations. The first aim of this study was to amass empirical support for a coherent factor structure of self-regulation in early childhood. Specifically, we examined a model positing three *a priori* hypothesized dimensions of self-regulation (CEC, HEC, and Compliance), in comparison to alternative, more parsimonious models of the construct. We next examined the model for measurement invariance across groups differing in age, gender, and preschool program type. Finally, we utilized this measurement model to predict children's success in the classroom (i.e., learning behaviors and social competence) from their self-regulatory skill.

Latent Factor Structure of Self-Regulation

In constructing our hypothesized model, we chose the three constructs based on recent findings from neurodevelopmental and biobehavioral perspectives. Two types of deliberate regulation (i.e., CEC and HEC) were used, differentiated by involvement of varying brain regions; both involve PFC processes, but HEC is also marked by OFC and posterior ACC, as well as limbic system trajectories, and CEC is influenced by the anterior ACC. Along with these neurological differences, CEC and HEC differ theoretically in terms of the predominant mechanism involved, cognitive or cognitive *and* affective/motivational. Last, *compliance* was intended to tap the internalization of rules (Blair, 2002).

Although the hypothesized three-latent-factor model and one of the alternative reduced models (i.e., two-factor model in which CEC and HEC was treated as a one factor) showed an equally good fit to the data, we retained the three-factor model as our model of preschoolers' self-regulation based on already-noted theoretical and empirical reasons. These findings provided empirical evidence to suggest a distinction between CEC and HEC in the measurement of self-regulation in early childhood. Results of our study further suggest that these factors, along with compliance, should be measured, ideally in a multi-method assessment, to obtain a complete portrait of self-regulation in early childhood (Warren, Bassett, Wyatt, Perna, & Denham, 2008).

In contrast, previous exploratory analyses of PSRA data revealed two different self-regulation factors: impulse control and compliance/executive function (Smith-Donald et al., 2007). Although some of the differences between our findings and those of Smith-Donald and colleagues (2007) may be attributable to difference in exploratory and confirmatory analyses, several other issues come to mind. First, it is important to note that there are overall similarities in structure between our study and others using the PSRA for CEC and HEC (e.g., Brock et al., 2009; Raver et al., 2009; Willoughby et al., 2001), even though Brock and Willoughby and colleagues' studies selected only four tasks each, and even though Raver and colleagues had to drop one task due to ceiling effects. Next, children participating in both Raver and colleagues' (2009) and the current study were about one year younger, on average. It may well be that compliance becomes more automatized, even more internalized, with time, and as such more akin to a cool executive control task (e.g., remembering the instructions of the tester to sort the toys, inhibiting the desired response, such as playing with the toys, and keeping attention on the types of toys rather than their other interesting properties) than to a behavioral compliance task where the very fact that an adult gave an instruction is its salient quality.

Testing Model Equivalence of the Three-Factor Model

To examine the invariance of our three-factor model, equivalence of factor loadings, indicator intercepts, and factor covariances across groups (program type, age, and gender) was tested. We found evidence to suggest the three-factor model of self-regulation is suitable for use in both Head Start and private preschool settings at two different ages for both boys and girls. Overall, as indicated by the goodness of fit statistics, the structure of self-regulation is well-described by the three-factor model (i.e., CEC, HEC, and compliance). Differences, however, were noted at the task level for younger and older children, and for boys and girls.

These findings improve the confidence with which inferences can be made when utilizing this measurement tool in more diverse samples, particularly with respect to Head Start settings. Such findings support the operational equivalence of the constructs across these groups, and facilitate valid cross-group comparisons. Knowing they operate similarly, researchers are better armed to answer questions about early exposure to poverty, economic resources, and the role of self-regulation in understanding the income-achievement gap for samples such as this one (cf. Evans & Rosenbaum, 2008; Noble, Norman, & Farah, 2005). These findings help to foster policy-relevant evidence regarding how best to promote early school success.

In tests of competing nested models, we found partial model equivalence for gender and age, indicating subtle differences at the task level. Subtle differences in the relations between individual tasks and the latent factor structure (Byrne, 2001) imply that different tasks are better indices of this facet of self-regulation, depending on group status (Wiebe et al., 2008). To adequately measure the construct, selected tasks should be equally valid and discriminative across groups.

Gender differences on the tasks' scores, as indicated by non-equivalent indicator intercepts, fit well with those documented in the development of the neural substrates of self-regulation (PFC), and higher risk for ADHD and disruptive behavior disorders in boys (Keenan & Shaw, 1997; Scahill & Schwab-Stone, 2000). However, patterns of factor loadings between tasks for boys and for girls on self-regulation have been, for the most part, equivocal, occurring only in some types of tasks (Overman, Bachevalier, Schuhmann & McDonough-Ryan, 1996; Seidman et al., 2005; Thorell & Wahlstedt, 2006; Wiebe et al., 2008). In our study, only the tongue task of the PSRA demonstrated differences in the pattern of factor loadings for boys versus girls. Future research is needed to see if our findings are replicable, and to better understand how these constructs, and their associated tasks, may operate differently by gender.

Intercept differences found for age groups are not surprising, considering the rapid increase in self-regulatory ability is expected for the age range included in our study. As with gender, however, the patterns of factor loadings were equivalent for age groups, except for Snack Delay. The snack delay task's particular salience as part of the HEC latent variable for younger children may suggest that motivational qualities inherent in waiting for a treat are more difficult for younger children. Certainly decades of work on delay of gratification (e.g., Eigsti et al., 2006) suggest that these abilities at a young age predict much important variation in later functioning.

Predictive Validity of the Three-Factor Structure

We revised our self-regulation model to include a higher-order executive control latent factor; it demonstrated predictive relations to children's early learning and social behaviors in the preschool classroom at the end of the year. According to Carlson (2005), CEC and HEC are less differentiated during early development than later; thus, it is possible that the

distinction between CEC and HEC in predicting the types of outcomes we included in the present study may become more important for older children. Further, consonant with Carlson's suggestion that this distinction "...might be most meaningful at the level of individual differences regardless of age" (2005, p. 612), it might be more pertinent for more specifically academic outcomes, like achievement (e.g., Brock et al., 2009; Willoughby et al. 2011). Our data support the utility of direct PSRA assessments in the fall for the prediction of children's early learning and social behaviors in the spring (as reported by their classroom teacher).

Specifically, findings indicated that more effective self-regulatory management of cognition and affect/motivation (i.e., the higher order factor including CEC and HEC) is predictive of better learning behavior and social competence in the classroom. Thus, the current findings further demonstrate that self-regulatory abilities help young children to meet the myriad challenges faced upon entry into a peer-laden classroom – to stave off frustration, quell impulses, and remain composed, while exercising working memory, inhibitory control, and attentional flexibility (Ladd, Birch, & Buhs, 1999; Rimm-Kaufman, Pianta, & Cox, 2000).

Surprisingly, because of the moderate correlation between the compliance latent factor and the higher order executive control latent factor, this aspect of regulation was not a significant predictor of preschooler's learning behaviors and social competence in the model where both were used to predict child outcomes in the present study. Thus, in addition to our full model, we tried models in which only one of the latent factors predicted child outcomes. In these reduced models, we found that compliance was a significant predictor of preschoolers' learning behaviors and social competence. These results indicated that, despite the non-significant findings in the full model, compliance was an important factor for young children's school readiness.

Taken together, these findings support the notion that the components of self-regulation posited here can be considered separable, but to function, at least for our sample of three- and four-year-olds, in a somewhat unitary fashion. Perhaps it should not be surprising that this is the case, given the likelihood of shared neural pathways across all PSRA tasks of hot and cool executive control and compliance, with the PFC as a "brakeman" for nuanced responding to varying cognitive, emotional, and behavioral demands.

Limitations and Future Directions

It is important to highlight future work still needed in organizing the literature on the measurement of self-regulatory skill development. First, we are not able to make unequivocal conclusions about model equivalence across sociodemographic groups on the basis of preschool program type. Two-thirds of the private child care centers where we gathered data had at least 15% of the population qualify for subsidized care through the Child Care and Development Fund (CCDF). This fact suggests that both preschool center types may represent some level of sociodemographic risk; the dichotomy we created with program types was a conservative estimate of the children in reduced circumstances in our sample. Further, given restrictions of our sample size, we were unable to test model equivalence for ethnic groups (e.g., Hispanic vs. non Hispanic). Future work needs to expand these findings to ethnic groups, and to more precisely measure socioeconomic status, to fully understand how this measurement model operates for ethnically diverse samples.

Next, our outcome data reflect teacher-reported outcomes on two well-validated questionnaires of classroom early learning behaviors and social competence. Asking teachers about children's competencies and preschool experiences has practical and theoretical value; further, this methodology is convenient from the teacher's perspective, and unobtrusive from the child's (McDermott et al., 2002). Teachers' judgments represent the

nature of early school success as one of the earliest indicators of school readiness. Children's interpersonal characteristics and classroom behavioral orientations are important antecedents of classroom participation and achievement in kindergarten. In sum, they characterize the expectations that will soon be placed upon the child during the transition to kindergarten (Rimm-Kaufman et al., 2000; Zill, 1999). In addition to the teacher-reported outcomes we examined here, however, it is also important for future research to: (a) obtain directly observed school readiness behaviors, as well as young children's pre-academic skills, as proximal measures of child performance; and (b) to consider the overlap between constructs assessed in direct assessments like the PSRA, and ratings teachers can make from observing children across multiple contexts varying in self-regulatory requirements (Cost & Simpson, 2004).

Finally, our findings underscore the potential usefulness of multi-faceted self-regulation-related programming for preschoolers (Blair et al., 2010), such as *Tools of the Mind* (Barnett et al., 2008; Bodrova & Leong, 2007; Diamond, Barnett, Thomas, & Munro, 2007), potentially not only for proximal outcomes in self-regulation, but also for broader school readiness outcomes in school adjustment and social competence domains. At the same time, in agreement with Willoughby and colleagues' assertion (2011), our findings also point to a greater role for programming relevant to HEC, such as Preschool PATHS (Domitrovich, Cortes, & Greenberg, 2007). When considering the single-factor impact of compliance on school readiness, one could even envision adaptations of the Good Behavior Game for the preschool classroom (McGoey, Schneider, Rezzetano, Prodan, & Tankersley, 2010). Increased, integrated attention to these aspects of self-regulation could yield enhanced outcomes in children's readiness to success in school.

Conclusions

In sum, our analyses suggest the juxtaposition of separate, yet unitary facets in the definition of self-regulation. Our theoretically derived model of self-regulation comprised of three related but distinct factors provided the best fit for the data. Then, we demonstrated measurement equivalence on the three-factor model across various groups of young children differing on gender, age, and program type. We were able to use this model to predict children's learning behaviors and social competence in the classroom as reported by their teachers. These findings echo and extend current theoretical work describing the complexity of the development of self-regulation in early childhood, and have important methodological implications.

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References

- Administration for Children and Families. National reporting system child assessment. Washington, D. C: Westat Inc., Xtria LLC; 2003.
- Barnett WS, Jung K, Yarosz DJ, Thomas J, Hornbeck A, Stechuk R, Burns S. Educational effects of the Tools of the Mind curriculum: A randomized trial. *Early Childhood Research Quarterly*. 2008; 23:299–313.10.1016/j.ecresq.2008.03.001
- Bentler PM. Comparative fit indexes in structural models. *Psychological Bulletin*. 1990; 107:238–246.10.1037/0033-2909.107.2.238 [PubMed: 2320703]

- Bernier A, Carlson SM, Whipple N. From external regulation to self-regulation: Early parenting precursors of young children's executive functioning. *Child Development*. 2010; 81:326–339.10.1111/j.1467-8624.2009.01397.x [PubMed: 20331670]
- Best JR, Miller PH. A developmental perspective on executive function. *Child Development*. 2010; 81:1641–1660.10.1111/j.1467-8624.2010.01499.x [PubMed: 21077853]
- Bierman K, Nix R, Greenberg MT, Blair C, Domitrovich C. Executive function and school readiness intervention: Impact, moderation, and mediation in the Head Start REDI program. *Development and Psychopathology*. 2008; 20:821–843.10.1017/S0954579408000394 [PubMed: 18606033]
- Bingenheimer JB, Raudenbush SW, Leventhal T, Brooks-Gunn J. Measurement equivalence and differential item functioning in family psychology. *Journal of Family Psychology*. 2005; 19:441–455.10.1037/0893-3200.19.3.441 [PubMed: 16221024]
- Blair C. School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist*. 2002; 57:111–127.10.1037/0003-066X.57.2.111 [PubMed: 11899554]
- Blair, C.; Calkins, S.; Kopp, L. Self-regulation as the interface of emotional and cognitive development: Implications for education and academic achievement. In: Hoyle, RH., editor. *Handbook of personality and self-regulation*. Wiley-Blackwell; 2010. p. 64-90.
- Blair C, Diamond A. Biological processes in prevention and intervention: The promotion of self-regulation as a means of preventing school failure. *Development and Psychopathology*. 2008; 20:899–911.10.1017/S0954579408000436 [PubMed: 18606037]
- Blair C, Granger D, Razza RP. Cortisol reactivity is positively related to executive function in preschool children attending Head Start. *Child Development*. 2005; 76:554–567.10.1111/j.1467-8624.2005.00863.x [PubMed: 15892778]
- Blair C, Razza RP. Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development*. 2007; 78:647–663.10.1111/j.1467-8624.2007.01019.x [PubMed: 17381795]
- Blair C, Zelazo PD, Greenberg MT. The measurement of executive function in early childhood. *Developmental Neuropsychology*. 2005; 28:561–571.10.1207/s15326942dn2802_1 [PubMed: 16144427]
- Bodrova, E.; Leong, DJ. *Tools of the mind: The Vygotskian approach to early childhood education*. 2. Upper Saddle River, NJ: Prentice-Hall; 2007.
- Bollen, KA.; Stine, RA. Bootstrapping goodness-of-fit measures in structural equation modeling. In: Bollen, KA.; Long, JS., editors. *Testing structural equation models*. Newbury Park, CA: Sage; 1993. p. 111-135.
- Bowers EP, Li Y, Kiely MK, Brittian A, Lerner JV, Lerner RM. The five Cs model of positive youth development: A longitudinal analysis of confirmatory factor structure and measurement invariance. *Journal of Youth and Adolescence*. 2010; 39:720–735.10.1007/s10964-010-9530-9 [PubMed: 20397040]
- Brock LL, Rimm-Kaufman SE, Nathanson L, Grimm KJ. The contributions of 'hot' and 'cool' executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten. *Early Childhood Research Quarterly*. 2009; 24:337–349.10.1016/j.ecresq.2009.06.001
- Brooks-Gunn J, Duncan GJ. The effects of poverty on children. *The Future of Children*. 1997; 7:55–71.10.2307/1602387 [PubMed: 9299837]
- Brown, TA. *Confirmatory factor analysis for applied research*. New York, NY: Guilford; 2006.
- Browne, MW.; Cudeck, R. Alternative ways of assessing model fit. In: Bollen, KA.; Long, JS., editors. *Testing structural equation models*. Newbury Park, CA: Sage Publications; 1993. p. 445-455.
- Brumfield BD, Roberts MW. A comparison of two measurements of child compliance with normal preschool children. *Journal of Clinical Child Psychology*. 1998; 27:109–116.10.1207/s15374424jccp2701_12 [PubMed: 9561943]
- Bush G, Luu P, Posner MI. Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*. 2000; 4:215–222.10.1016/S1364-6613(00)01483-2 [PubMed: 10827444]
- Byrne, BM. *Structural equation modeling with AMOS*. Mahwah NJ: Lawrence Erlbaum Associates; 2001.

- Calkins, SD.; Marcovitch, S. Emotion regulation and executive functioning in early development: Integrated mechanisms of control supporting adaptive functioning. In: Calkins, SD.; Bell, MA., editors. *Child development at the intersection of emotion and cognition*. Washington, DC: American Psychological Association; 2010. p. 37-57.
- Campbell, SB.; von Stauffenberg, C. Child characteristics and family processes that predict behavioral readiness for school. In: Crouter, A.; Booth, A., editors. *Early disparities in school readiness: How families contribute to transitions into school*. Mahwah, NJ: Erlbaum; 2008. p. 225-258.
- Carlson SM. Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology*. 2005; 28:595–616.10.1207/s15326942dn2802_3 [PubMed: 16144429]
- Chen FF, Sousa KH, West SG. Teacher's corner: Testing measurement invariance of second-order factor models. *Structural Equation Modeling: A Multidisciplinary Journal*. 2005; 12:471–492.10.1207/s15328007sem1203_7
- Cole PM, Martin SE, Dennis T. Emotion regulation as a scientific construct: Methodological challenges and directions for child development research. *Child Development*. 2004; 75:317–333.10.1111/j.1467-8624.2004.00673.x [PubMed: 15056186]
- Crockenberg S, Litman C. Autonomy as competence in 2-year-olds: Maternal correlates of child defiance, compliance, and self-assertion. *Developmental Psychology*. 1990; 26:961–971.10.1037/0012-1649.26.6.961
- Denham S. Social-emotional competence as a support for school readiness: What is it and how do we assess it? *Early Education and Development*. 2006; 17:57–89.10.1207/s15566935eed1701_4
- Denham SA, Blair KA, DeMulder E, Levitas J, Sawyer K, Auerbach-Major S, Queenan P. Preschool emotional competence: Pathway to social competence. *Child Development*. 2003; 74:238–256.10.1111/1467-8624.00533 [PubMed: 12625448]
- Diamond, A. The early development of executive functions. In: Bailystok, E.; Craik, F., editors. *Lifespan cognition: Mechanisms of change*. New York, NY: Oxford University Press; 2006. p. 70-95.
- Diamond A, Barnett WS, Thomas J, Munro S. Preschool program improves cognitive control. *Science*. 2007; 318:1387–1388. [PubMed: 18048670]
- Diamond A, Taylor C. Development of an aspect of executive control: Development of the abilities to remember what I said and to “Do as I say, not as I do. *Developmental Psychobiology*. 1996; 29:315–334.10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T [PubMed: 8732806]
- Dillon WR, Kumar A, Mulani N. Offending estimates in covariance structure analysis: Comments on the causes of and solutions to Heywood Cases. *Psychological Bulletin*. 1987; 101:126–135.10.1037/0033-2909.101.1.126
- Domitrovich CE, Cortes RC, Greenberg MT. Improving young children's social and emotional competence: A randomized trial of the Preschool “PATHS” Curriculum. *The Journal of Primary Prevention*. 2007; 28:67–91.10.1007/s10935-007-0081-0 [PubMed: 17265130]
- Eigsti I, Zayas V, Mischel W, Shoda Y, Ayduk O, Dadlani MB, Casey BJ. Predicting cognitive control from preschool to late adolescence and young adulthood. *Psychological Science*. 2006; 17:478–484.10.1111/j.1467-9280.2006.01732.x [PubMed: 16771797]
- Eisenberg, N.; Hofer, C.; Vaughan, J. Effortful control and its socioemotional consequences. In: Gross, JJ., editor. *Handbook of emotion regulation*. New York, NY, US: Guilford Press; 2007. p. 287-306.
- Eisenberg N, Spinrad T. Emotion-related regulation: Sharpening the definition. *Child Development*. 2004; 75:334–339.10.1111/j.1467-8624.2004.00674.x [PubMed: 15056187]
- Evans GW, Rosenbaum J. Self-regulation and the income-achievement gap. *Early Childhood Research Quarterly*. 2008; 23:504–514.10.1016/j.ecresq.2008.07.002
- Fantuzzo J, Perry MA, McDermott P. Preschool approaches to learning and their relationship to other relevant classroom competencies for low-income children. *School Psychology Quarterly*. 2004; 19:212–230.10.1521/scpq.19.3.212.40276

- Garcia Coll C, Lamberty G, Jenkins R, McAdoo HP, Crnic K, Wasik BH, Garcia H. An integrative model for the study of developmental competencies in minority children. *Child Development*. 1996; 67:1891–1914.10.2307/1131600 [PubMed: 9022222]
- Garon N, Bryson SE, Smith IM. Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*. 2008; 134:31–60.10.1037/0033-2909.134.1.31 [PubMed: 18193994]
- Happaney K, Zelazo PD, Stuss DT. Development of orbitofrontal function: Current themes and future directions. *Brain & Cognition*. 2004; 55:1–10. [PubMed: 15134839]
- Howse R, Calkins S, Anastopoulos A, Keane S, Shelton T. Regulatory contributors to children's kindergarten achievement. *Early Education and Development*. 2003; 14:101–119.10.1207/s15566935eed1401_7
- Hu LT, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*. 1999; 6:1–55.10.1080/10705519909540118
- Jahromi LB, Stifter CA. Individual differences in preschoolers' self-regulation and theory of mind. *Merrill-Palmer Quarterly*. 2008; 54:125–150.10.1353/mpq.2008.0007
- Kalpidou MD, Power TG, Cherry KE, Gottfried NW. Regulation of emotion and behavior among 3- and 5-year-olds. *Journal of General Psychology*, Vol. 2004; 131:159–178.10.3200/GENP.131.2.159–180
- Keenan K, Shaw D. Developmental and social influences on young girls' early problem behavior. *Psychological Bulletin*. 1997; 121:95–113.10.1037/0033-2909.121.1.95 [PubMed: 9000893]
- Kline, RT. *Principles and practice of Structural Equation Modeling*. 2. New York, NY: Guilford Press; 2005.
- Kochanska G. Committed compliance, moral self, and internalization: A mediational model. *Developmental Psychology*. 2002; 38:339–351.10.1037/0012-1649.38.3.339 [PubMed: 12005378]
- Kochanska G, Aksan N. Children's conscience and self-regulation. *Journal of Personality*. 2006; 74:1587–1617.10.1111/j.1467-6494.2006.00421.x [PubMed: 17083659]
- Kochanska G, Coy KC, Murray KT. The development of self-regulation in the first four years of life. *Child Development*. 2001; 72:1091–1111.10.1111/1467-8624.00336 [PubMed: 11480936]
- Kopp C. Antecedents of self-regulation: A developmental perspective. *Developmental Psychology*. 1982; 18:199–214.
- Ladd GW, Birch SH, Buhs ES. Children's social and scholastic lives in kindergarten: Related spheres of influence? *Child Development*. 1999; 70:1373–1400.10.1111/1467-8624.00101 [PubMed: 10621962]
- LaFreniere PJ, Dumas JE. Social competence and behavioral evaluation in children ages 3 to 6 years: The short form (SCBE-30). *Psychological Assessment*. 1996; 8:369–377.10.1037/1040-3590.8.4.369
- LaFreniere P, Masataka N, Butovskaya M, Chen Q, Dessen MA, Atwanger K, Frigerio A. Cross-cultural analysis of social competence and behavioral problems in preschoolers. *Early Education and Development*. 2002; 13:201–219.10.1207/s15566935eed1302_6
- Lee, VE.; Burkham, DT. *Inequality at the starting gate: Social background differences in achievement as children begin school*. Washington, DC: Economic Policy Institute; 2002.
- Lewis MD, Todd RM. The self-regulating brain: Cortical-subcortical feedback and the development of intelligent action. *Cognitive Development*. 2007; 22:406–430.10.1016/j.cogdev.2007.08.004
- McClelland MM, Acock AC, Morrison F. The impact of kindergarten learning-related skills on academic trajectories at the end of elementary school. *Early Childhood Research Quarterly*. 2006; 21:471–490.10.1016/j.ecresq.2006.09.003
- McClelland MM, Cameron CE, Connor CM, Farris CL, Jewkes AM, Morrison FJ. Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology*. 2007; 43:947–959.10.1037/0012-1649.43.4.947 [PubMed: 17605527]
- McClelland, MM.; Cameron, CE.; Wanless, SB.; Murray, A. Executive function, behavioral self-regulation, and social-emotional competence: Links to school readiness. In: Saracho, ON.; Spodek, B., editors. *Contemporary perspectives on social learning in early childhood education*. Charlotte, NC, US: Information Age Publishing; 2007. p. 83-107.

- McDermott PA, Leigh NM, Perry MA. Development and validation of the Preschool Learning Behaviors Scale. *Psychology in the Schools*. 2002; 39:353–365.10.1002/pits.10036
- McGoey KE, Schneider DL, Rezzetano KM, Prodan T, Tankersley M. Classwide intervention to manage disruptive behavior in the kindergarten classroom. *Journal of Applied School Psychology*. 2010; 26:247–261.10.1080/15377903.2010.495916
- Mischel W, Shoda Y, Rodriguez M. Delay of gratification in children. *Science*. 1989; 244:933–938.10.1126/science.2658056 [PubMed: 2658056]
- Morrison, FJ.; Ponitz, CC.; McClelland, MM. Self-regulation and academic achievement in the transition to school. In: Calkins, S.; Bell, MA., editors. *Child development at the intersection of emotion and cognition, Human brain development*. Washington, DC: American Psychological Association; 2010. p. 203-224.
- Murray K, Kochanska G. Effortful control: Factor structure and relation to externalizing and internalizing behavior. *Journal of Abnormal Child Psychology*. 2002; 30:503–514.10.1023/A:1019821031523 [PubMed: 12403153]
- National Research Council of the National Academies. *Early Childhood Assessment: Why, What, and How?*. Washington, D.C: National Research Council; 2009.
- Noble KG, Norman MF, Farah MJ. Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science*. 2005; 8:74–87.10.1111/j.1467-7687.2005.00394.x [PubMed: 15647068]
- Overman WH, Bachevalier J, Schuhmann E, McDonough-Ryan P. Cognitive gender differences in very young children parallel biologically based cognitive gender differences in monkeys. *Behavioral Neuroscience*. 1996; 110:673–684.10.1037/0735-7044.110.4.673 [PubMed: 8864260]
- Ramani GB, Brownell CA, Campbell SB. Positive and negative peer interaction in 3- and 4-year-olds in relation to regulation and dysregulation. *Journal of Genetic Psychology*. 2010; 171:218–250.10.1080/00221320903300353 [PubMed: 20836431]
- Raver CC. Emotions matter: Making the case for the role of young children's emotional development for early school readiness. *SRCD Social Policy Report*. 2002; 16:3–18.
- Raver, CC.; Knitzer, J. Ready to enter: What research tells policymakers about strategies to promote social and emotional school readiness among three- and four-year-old children. New York: National Center for Children in Poverty, Mailman School of Public Health, Columbia University; 2002.
- Raver, CC.; Carter, JS.; Smith-Donald, R.; Goyette, P. Testing competing models of behavioral self-regulation among Head Start enrolled children. 2009. Manuscript submitted for publication
- Raver, CC.; Garner, P.; Smith-Donald, R. The roles of emotion regulation and emotion knowledge for children's academic readiness: Are the links causal?. In: Pianta, B.; Snow, K.; Cox, M., editors. *Kindergarten transition and early school success*. Baltimore: Brookes Publishing; 2007. p. 121-148.
- Raver CC, Gershoff E, Aber L. Testing equivalence of mediating models of income, parenting, and school readiness for white, black and Hispanic children in a national sample. *Child Development*. 2007; 78:96–115.10.1111/j.1467-8624.2007.00987.x [PubMed: 17328695]
- Raver CC, Jones SM, Li-Grining C, Zhai F, Bub K, Pressler E. CRSP's impact on low-income preschoolers' preacademic skills: Self-regulation as a mediating mechanism. *Child Development*. 2011; 82:362–378.10.1111/j.1467-8624.2010.01561.x [PubMed: 21291447]
- Rimm-Kaufman S, Pianta RC, Cox M. Teachers' judgments of problems in the transition to school. *Early Childhood Research Quarterly*. 2000; 15:147–166.10.1016/S0885-2006(00)00049-1
- Rothbart, MK. Temperament and development. In: Kohnstamm, G.; Bates, JE.; Rothbart, MK., editors. *Temperament in childhood*. New York: Wiley; 1989. p. 187-247.
- Rothbart, MK.; Bates, JE. Temperament. In: Damon, W.; Eisenberg, N., editors. *Handbook of child psychology: Vol. 3 Social, emotional and personality development*. New York: Wiley; 1998. p. 105-176.
- Rothbart MK, Jones LB. Temperament, self-regulation, and education. *School Psychology Review*. 1998; 27:479–491.
- Ruff, HA.; Rothbart, MK. *Attention in early development: Themes and variations*. New York, NY: Oxford University Press; 1996.

- Ryan, RM.; Fauth, RC.; Brooks-Gunn, J. Childhood poverty: Implications for school readiness and early childhood education. In: Spodek, B.; Saracho, ON., editors. Handbook of research on the education of young children. 2. Mahwah, NJ: Lawrence Erlbaum Associates; 2006. p. 323-346.
- Scahill L, Schwab-Stone M. Epidemiology of ADHD in school-age children. Child and Adolescent Psychiatric Clinics of North America. 2000; 9:541–555. [PubMed: 10944656]
- Shoda Y, Mischel W, Peake P. Predicting adolescent cognitive and social competence from preschool delay of gratification: Identifying diagnostic conditions. Developmental Psychology. 1990; 26:978–986.10.1037/0012-1649.26.6.978
- Seidman LJ, Biederman J, Monuteaux MC, Valera E, Doyle AE, Faraone SV. Impact of gender and age on executive functioning: Do girls with and without attention deficit hyperactivity disorder differ neuropsychologically in preteen and teenage years? Developmental Neuropsychology. 2005; 27:79–105.10.1207/s15326942dn2701_4 [PubMed: 15737943]
- Smith-Donald R, Raver CC, Hayes T, Richardson B. Preliminary construct and concurrent validity of the Preschool Self-regulation Assessment (PSRA) for field-based research. Early Childhood Research Quarterly. 2007; 22:173–187.10.1016/j.ecresq.2007.01.002
- Stipek DJ, Ryan RH. Economically disadvantaged preschoolers: Ready to learn but further to go. Developmental Psychology. 1997; 33:711–723.10.1037/0012-1649.33.4.711 [PubMed: 9232386]
- Thorell LB, Wahlstedt C. Executive functioning deficits in relation to symptoms of ADHD and/or ODD in preschool children. Infant and Child Development. 2006; 15:503–518.10.1002/icd.475
- Towsend, C. Chicago school readiness project order of operations manual. Chicago Illinois: University of Chicago; 2007.
- Warren, HK.; Bassett, H.; Wyatt, TM.; Perna, AM.; Denham, SA. Structure of the Preschool Self-Regulation Assessment: A replication investigation. In J. Griffin (Chair), The inter-agency school readiness measurement consortium. Symposium conducted at the 9th National Head Start Research Conference; Washington, D.C. 2008 June.
- Wiebe SA, Espy KA, Charak D. Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. Developmental Psychology. 2008; 44:575–587.10.1037/0012-1649.44.2.575 [PubMed: 18331145]
- Willoughby M, Kupersmidt J, Voegler-Lee M, Bryant D. Contributions of hot and cool self-regulation to preschool disruptive behavior and academic achievement. Developmental Neuropsychology. 2011; 36:161–180.10.1080/87565641.2010.549980
- Zelazo, PD.; Müller, U. Executive function in typical and atypical development. In: Goswami, U., editor. Handbook of childhood cognitive development. Oxford: Blackwell; 2002. p. 445-469.
- Zill, N. Promoting educational equity and excellence in kindergarten. In: Pianta, RC.; Cox, MJ., editors. The transition to kindergarten: Research, policy, training, and practice. Baltimore, MD: Paul Brooks Publishers; 1999. p. 65-105.
- Zill, N.; Peterson, JL. Behavior problems index. Washington, D.C: Child Trends; 1986.

- Tested a three-factor latent structure of self-regulation.
- Best-fitting model included cool executive control, hot executive control, and compliance.
- Model equivalence for held across risk, gender, and age.
- Model was revised to include a second-order factor (i.e., Higher-Order Regulation).
- Second-order model predicted learning and social competence in the classroom.

Figure 1.
Hypothesized model of the Preschool Self-Regulation Assessment (PSRA) factor structure.

Figure 2.
Revised validity model, including second-order-factor of Executive Control.

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 2 nd trial and slower for 3 rd trial.	Subtract first trial from mean of second and third trials (amount of reduction of speed)
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
Tower Task (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 Return	Compliance	Ask child to return toy back to assessor after playing with it for 1 minute (after opening).	Latency to return toy (dropped due to kurtosis)
Tower Cleanup	Compliance	Ask child to put blocks back into container from tower task, give child 2 minutes to complete.	Latency to start clean up (dropped due to kurtosis); latency to complete clean up
Toy Sort	Compliance	Ask child to sort a set of intricate small objects (cars, beads, dinosaurs, and bugs) into different containers.	Latency to start sort; latency to complete sort
Toy Wrap	HEC	Ask child not to peek while assessor wraps a toy in tissue\and bag for 1 minute.	Latency to first peek
Toy Wait	HEC	Ask child to wait 1 minute before opening wrapped toy.	Latency to first touch of toy (dropped due to kurtosis)
Snack Delay (4 trials)	HEC	Ask child to wait before getting a candy from under a cup for 3 rounds (10 sec, 20 sec., 30 sec., 60 sec.)	Average of four trials on the level of waiting (ranging from does not touch cup or timer to eats candy)
Tongue Task (1 trial)	HEC	Ask child to hold a candy on their tongue for 40 sec. before eating it.	Latency to eat candy

Adapted from Smith-Donald et al. (2007).

Table 2

Descriptive Statistics of the PSRA

	N	Mean	SD	Min	Max
Pencil Tap	322	46.88	33.19	0	100
Balance Beam	319	1.61	3.23	-12.5	15
Tower Turn Taking	323	1.38	0.79	0	2
Snack Delay	317	4.13	0.9	1	5
Toy Wrap	322	40.42	23.55	1	60.5 ^a
Tongue Task	319	34.38	11.04	0	40
Tower Clean-Up – End time	322	40.07	21.36	9	121 ^b
Toy Sort – Start time	322	20.66	36.19	0	121 ^c
Toy Sort – End time	322	96.07	27.05	11	121 ^b

^aChildren who did not peek were assigned a value of 60.5 seconds for the 1 minute task.

^bChildren who did not complete this task were assigned a value of 121 seconds for the 2 minute task.

^cChildren who did not start this task were assigned a value of 121 seconds for the 2 minute task.

Table 3

Correlations Between Tasks of the PSRA and Outcome measures

	Balance Beam	Pencil Tap	Tower Task	Snack Delay	Tongue Task	Toy Wrap	Tower Clean up (End)	Toy Sort (Start)	Toy Sort (End)	PLBS
Balance Beam	—									
Pencil Tap	.26**									
Tower Task	.29**	.35**								
Snack Delay	.16**	.29**	.35**							
Tongue Task	.09	.25**	.23**	.28**						
Toy Wrap	.17**	.32**	.34**	.39**	.25**					
Tower Clean Up (End)	-.14*	-.15**	-.08	-.04	-.10	-.13*				
Toy Sort (Start)	-.10	-.16**	-.15**	-.18**	-.19**	-.17**	.09			
Toy Sort (End)	-.22**	-.25**	-.21**	-.21**	-.26**	-.22**	.21**	.45**		
PLBS	.11	.17**	.07	.23***	.17**	.17**	-.01	-.18**	-.16**	
SCBE	.03	.11*	-.00	.22***	.08	.20**	-.03	-.13*	-.11	.80***

* $p < .05$, two-tailed.** $p < .01$,*** $p < .001$, two-tailed.

Table 4

Comparing Models with Different Numbers of PSRA Factors

Variable	Fit Statistics				Comparison to 3-Factor	
	Model	df	χ^2	CFI	RMSEA	$\Delta\chi^2$ Δdf
	3 factor	17	15.06	1.00	.00	-- --
	2 factor (CEC/HEC Cov=1)	18	21.72	.99	.03	6.65** 1
	2 factor (CEC/Comp Cov=1)	18	57.31***	.89	.08	42.25*** 1
	2 factor (HEC/Comp Cov =1)	18	53.12***	.90	.08	38.06*** 1
	1 factor	20	65.64***	.87	.08	50.58*** 3

**
p<.01,***
p<.001.

CEC = Cool Executive Control; HEC = Hot Executive Control; Comp = Compliance

Table 5
Summary of Fit Statistics for Testing Measurement Invariance of 3-Factor Model of Preschoolers' Self-Regulation

Program types: Head Start vs. private childcare (n = 323; 144 vs. 179)							
Model	χ^2	df	CFI	RMSEA	Model Comparison	$\Delta\chi^2$	Δdf
Model 1: Unconstrained	43.00	36	.98	.03	—	—	—
Model 2: Factor loadings invariant	50.39	44	.98	.02	2 vs. 1	7.39	8
Model 3: Indicator intercepts invariant	58.33	52	.98	.02	3 vs. 2	7.94	8
Model 4: Factor covariance invariant	66.17	55	.97	.03	4 vs. 3	7.84*	3

Age: 3- vs. 4-year olds (n = 322; 109 vs. 213)							
Model	χ^2	df	CFI	RMSEA	Model Comparison	$\Delta\chi^2$	Δdf
Model 1: Unconstrained	37.28	34	.99	.02	—	—	—
Model 2: Factor loadings invariant	58.31*	42	.94	.04	2 vs. 1	21.03**	8
Model 3: Indicator intercepts invariant	146.15***	50	.65	.08	3 vs. 2	87.84***	8
Model 4: Factor covariance invariant	147.62***	53	.66	.08	4 vs. 3	1.47	3

Gender: boys vs. girls (n = 323; 161 vs. 162)							
Model	χ^2	df	CFI	RMSEA	Model Comparison	$\Delta\chi^2$	Δdf
Model 1: Unconstrained	31.59	35	1.00	.00	—	—	—
Model 2: Factor loadings invariant	52.45	42	.97	.03	2 vs. 1	23.14**	8
Model 3: Indicator intercepts invariant	72.51*	50	.94	.04	3 vs. 2	20.19*	8
Model 4: Factor covariance invariant	78.71	53	.93	.04	4 vs. 3	5.91	3

+ $p < .10$,

* $p < .05$,

** $p < .01$,

*** $p < .001$

Table 6
Standardized Factor Loadings for PSRA Total and Measurement Invariance Models

Factor	Total	Program type		Age		Gender	
		Head Start	Private Center	3	4	Boys	Girls
CEC							
Pencil Tap	.60***	.59***	.63***	.58***	.48***	.62***	.60***
Balance Beam	.41***	.44***	.39***	.38***	.42***	.42***	.43***
Tower Turn Taking	.62***	.60***	.65***	.61***	.67***	.60***	.63***
HEC							
Snack Delay	.61***	.62***	.60***	.81***	.46***	.60***	.61***
Toy Wrap	.61***	.61***	.62***	.53***	.60***	.59***	.65***
Tongue Task	.46***	.51***	.45***	.23***	.36***	.54***	.28**
Compliance							
Toy Sort – Start time	.57***	.43***	.48***	.56***	.66***	.52***	.59***
Toy Sort – End time	.79***	1.00*** ^a	1.00*** ^a	.82***	.65***	.80***	.82***

Note: Loadings are significant at the following levels:

** p < .01

*** p < .001. Bolded items indicate factor loadings that could not be constrained to equality across groups. Factor loadings differ across groups due to differences in standard errors.

^a Due to a negative error variance, the error variance was set to a negligible amount (i.e., .01).