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Exploring Dimensionality of Effortful Control Using Hot and Cool Tasks in a Sample of Preschool Children

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Abstract

Effortful control (EC) is an important developmental construct associated with academic performance, socioemotional growth, and psychopathology. EC, defined as the ability to inhibit or delay a prepotent response typically in favor of a subdominant response, undergoes rapid development during children's preschool years. Research involving EC in preschool children can be aided by ensuring that the measured model of EC matches the latent structure of EC. Extant research indicates that EC may be multidimensional, consisting of hot (affectively salient) and cool (affectively neutral) dimensions. However, there are several untested assumptions regarding the defining features of hot EC. Confirmatory factor analysis was used in a sample of 281 preschool children (M_{age} = 55.92 - months, *SD* = 4.16; 46.6% male and 53.4% female) to compare a multidimensional model composed of hot and cool EC factors with a unidimensional model. Hot tasks were created by adding affective salience to cool tasks so that hot and cool tasks varied only by this aspect of the tasks. Tasks measuring EC were best described by a single factor and not distinct hot and cool factors, indicating that affective salience alone does not differentiate between hot and cool EC. EC shared gender-invariant associations with academic skills and externalizing behavior problems.

Keywords

Effortful control; Preschool children; Academics; Externalizing; Confirmatory factor analysis; Structural equation modeling

Effortful control (EC) is an important individual difference in temperament that affects numerous aspects of young children's typical and atypical development (Allan & Lonigan, 2011; Blair & Razza, 2007; Nigg, 2006; Posner & Rothbart, 2000). For example, in preschool- and kindergarten-age samples, EC is associated with and predictive of academic performance and school readiness (Blair & Razza, 2007), social functioning and relationships with parents and peers (Eisenberg et al., 2000; Kochanska, Murray, & Harlan, 2000), and internalizing and externalizing behavior problems (Allan & Lonigan, 2011; Espy, Sheffield, Wiebe, Clark, & Moehr, 2011; Kochanska, Barry, Jimenez, Hollatz, & Woodard, 2009). Although it is clear that EC is associated with other developmentally important constructs, research into the mechanisms underlying these associations is hindered by an apparent conflict between how aspects of EC are conceptualized and how they are

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operationalized. Emerging evidence suggests that EC may be best conceptualized as made up of a hot (affectively salient) factor and a cool (affectively neutral) factor, but it is unclear whether affective salience alone distinguishes between hot and cool EC.

EC is considered the regulatory dimension of temperament, and as such it has dynamic relations with the reactive temperament dimensions (i.e., extraversion/surgency and negative affectivity; Gartstein, Putnam, & Rothbart, 2012). Whereas extraversion/surgency and negative affectivity appear early in infancy (e.g., Kagan & Fox, 2007), EC tends to develop later. In general, EC can be measured by around 2½ years of age (Rothbart, Posner, & Kieras, 2006), and it tends to undergo a period of rapid development during the preschool years (e.g., Zelazo & Carlson, 2012). Behaviorally, EC is defined as the ability to delay or inhibit a prepotent response, typically in favor of a subdominant response. EC is considered important for the flexible handling of situations that arise in the environment as well as in executing goal-directed behavior (Rothbart et al., 2006).

Research on EC has been hindered by confusion regarding whether effortful control is distinct from other similarly defined self-regulation terms. The confusion often lies in determining whether EC and executive functioning (EF) are two related but distinct constructs or the same construct with different labels (Allan & Lonigan, 2011; Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011). Some researchers argue that EF and EC are indistinguishable from each other (Zhou, Chen, & Main, 2012). However, there are important distinctions between EF and EC; although EF does contain a construct that is similar to EC labeled inhibitory control (IC), it also contains additional distinct cognitive constructs (i.e., working memory, shifting/updating; Miyake et al., 2000) that are dissociable from IC in adults and children (McAuley & White, 2011; Miyake et al., 2000). Therefore, given that the same behavioral tasks are used to measure IC and EC and research from one tradition is commonly cited in the other tradition (e.g., Allan & Lonigan, 2011; Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Kim, Nordling, Yoon, Boldt, & Kochanska, 2013; Willoughby et al., 2011), the overlap between EC and EF is specific to IC. For the purpose of clarity, constructs in prior studies that fit the definition of EC in this study are referred to as such.

Recently, researchers across multiple psychology disciplines (e.g., developmental, neuropsychological, cognitive) have suggested that EC may consist of hot and cool dimensions in young children (i.e., preschool and kindergarten age; e.g., Kerr & Zelazo, 2004; Metcalfe & Mischel, 1999; Willoughby et al., 2011; Zelazo & Müller, 2002). Both hot and cool EC are purported to be activated in situations or tasks for which the suppression or delay of a prepotent response is required. The difference is that for hot EC there is a proximal affective or emotional stimulus, whereas for cool EC there is not an affective or emotional stimulus. In studies that have examined whether hot and cool factors emerge in young children, hot tasks have been defined as those for which a proximal extrinsic reward or punishment for performance is included (i.e., response–gain or response–cost tasks) and cool tasks have been defined as those for which no extrinsic motivator for performance is included, although it is recognized that the difference between hot and cool EC is likely to be dimensional to some degree (e.g., Brock et al., 2009; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Kim et al., 2013; Willoughby et al., 2011).

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Neurobiological research regarding EC has provided some evidence that there are distinctions in the neural substrates associated with hot versus cool EC. Whereas early research on EC and neural systems focused almost exclusively on the prefrontal cortex (PFC), there is emerging evidence that different neural systems may be more or less involved depending on whether hot or cool EC is necessary. It is hypothesized that the dorsolateral prefrontal cortex (DL–PFC) and the anterior cingulate cortex (ACC) are primarily involved in processes requiring cool EC. In contrast, it is hypothesized that the orbitofrontal cortex (OFC) and associated limbic systems as well as the posterior ACC are implicated in processes requiring hot EC (e.g., Happaney, Zelazo, & Stuss, 2004; Kerr & Zelazo, 2004; Willoughby et al., 2011). However, it is important to note that this portrayal is overly simplistic given that both the DL–PFC and the OFC are likely involved in situations requiring hot and cool EC, systems other than the OFC (e.g., the amygdala) have been implicated in reward-dependent performance, and there is increasing evidence that the OFC is composed of dissociable components (Happaney et al., 2004).

Confirmatory factor analysis (CFA) has been used in several studies to determine whether tasks intended to measure different aspects of young children's EC are best represented by distinct hot and cool EC factors. For example, Willoughby and colleagues (2011) conducted a CFA of several EC tasks that they classified as either hot or cool in a sample of 759 preschool children. They reported that a two-factor model, consisting of hot and cool EC factors, fit better than a one-factor model. Other researchers also have reported that a two-factor model consisting of hot and cool EC factors, or a hierarchical model with hot and cool factors subsumed under a global EC factor, fit better than a one-factor model (e.g., Bassett, Denham, Wyatt, & Warren-Khot, 2012; Brock et al., 2009; Denham, Warren-Khot, Bassett, Wyatt, & Perna, 2012; Kim et al., 2013). In contrast to these studies, however, Allan and Lonigan (2011) did not provide support for distinct hot and cool EC factors in a sample of 234 preschool children. An imprecise correspondence between the theoretical assumptions of hot EC and the tasks typically used to assess this construct may explain the discordant finding of Allan and Lonigan.

From a theoretical perspective, many researchers argue that hot EC differs from cool EC by virtue of the affective salience a situation elicits (e.g., Brock et al., 2009; Kim et al., 2013; Willoughby et al., 2011; Zelazo & Carlson, 2012). As such, the presumption is that the inclusion of response–gains (i.e., rewards) or response–costs (i.e., removal of rewards) requiring regulation of affect coupled with behavioral regulation typical in cool EC tasks (i.e., response–conflict tasks) is sufficient to create hot EC tasks. However, this is an untested assumption in young children given that the preponderance of research on hot and cool EC has used hot EC tasks that include affective salience in the form of a reward and a behavioral regulation demand (response– delay) that is different from that found in cool tasks (e.g., Brock et al., 2009; Kim et al., 2013; Willoughby et al., 2011). For example, performance on the Gift Delay task is recorded as a child's ability to refrain from peeking (response–delay) while a present is wrapped (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996). One exception to this is Allan and Lonigan (2011), who included reward tasks other than response–delay to measure hot EC and did not find separate hot and cool EC factors. Therefore, research is needed to determine whether the theoretical supposition

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that it is affective regulation—disregarding whether response–gain or response–cost tasks assess affective regulation—that distinguishes between hot and cool EC is viable.

Theoretically, affective salience can be of positive or negative valence (Zelazo & Carlson, 2012). Therefore, the assumption is that hot EC will be activated in both response–cost (negative valence) and response–gain (positive valence) tasks (e.g., Kim et al., 2013; Zelazo & Carlson, 2012). Tasks that include a response cost for incorrect performance should measure hot EC as effectively as tasks that include a response gain for correct performance. However, studies examining whether hot and cool EC factors emerge have included only response–gain tasks (e.g., Allan & Lonigan, 2011; Willoughby et al., 2011). Thus, studies that include response–cost tasks to assess affective regulation should mirror those that use response–gain tasks to assess affective regulation.

A better understanding of the structure of EC may be important because recent findings have led some researchers to propose that hot and cool EC contribute differentially to the development of other important behaviors and skills in young children (e.g., Brock et al., 2009; Hongwanishkul et al., 2005; Willoughby et al., 2011). For example, because academic skills require self-regulation for success but do not typically require affective or emotional control, it has been proposed that academic skills are more associated with cool EC than with hot EC (e.g., Hongwanishkul et al., 2005). In the same preschool sample where they found hot and cool EC factors, Willoughby and colleagues (2011) used structural equation modeling (SEM) to examine the relation between those latent hot and cool EC variables and several academic measures (as well as several externalizing behavior measures). They reported that only cool EC was uniquely associated with the academic measures. In a sample of 173 kindergarten children, Brock and colleagues (2009) examined the relations between hot and cool EC factor scores collected during the fall and several academic outcomes collected during the spring while controlling for classroom-level variance and academic performance during the fall. They reported that cool EC, but not hot EC, uniquely predicted spring mathematics ability. In this same study, neither cool nor hot EC predicted spring literacy ability. However, examination of zero-order correlations indicated that cool EC was associated with both fall and spring literacy abilities, whereas hot EC was associated with only spring literacy ability. Allan, Hume, Allan, Farrington, and Lonigan (2014) examined the differential relations of EC tasks classified as hot versus cool with academic abilities in preschool and kindergarten children in a meta-analysis of 30 studies. Although both hot and cool tasks were associated with concurrently administered academic measures, cool tasks were significantly more related to academic measures than were hot tasks.

It has been hypothesized that hot EC, and not cool EC, would be the strongest correlate of behavior problems that are associated with the inability to regulate emotion, such as externalizing behaviors, because hot EC is more complex than cool EC, requiring both behavior and emotion regulation (Kim et al., 2013; Zelazo & Carlson, 2012). Kim and colleagues (2013) examined the relations between hot and cool EC factors collected when children were 38 and 52 months old and parent-, teacher-, and self-report ratings of behavior problems (as measured by internalizing and externalizing behaviors) collected when children were 67, 80, and 100 months old. Across all informants, only hot EC uniquely predicted behavior problems. Willoughby and colleagues (2011) used SEM to examine the

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relations between latent hot and cool EC variables and externalizing behaviors (i.e., inattentive/overactive, oppositional/defiant, and aggressive). They reported that only hot EC uniquely predicted inattentive/overactive behaviors and that neither oppositional/defiant behavior nor aggressive behavior was predicted by either hot or cool EC. Studies such as these that explore differential relations of hot and cool EC with academic skills and behavior problems provide support for the supposition that the distinction between hot and cool EC is essential when considering the role of EC in development.

The current study

The purpose of this study was to examine, in a sample of preschool children, whether EC was best conceptualized as latent hot and cool dimensions or as a unitary construct when hot and cool tasks differed only in their level of affective salience. Six tasks with similar behavioral regulation demands were selected to represent hot and cool EC. Half of the tasks were then modified to add affective salience (i.e., response–cost tasks). Models were compared using CFA. Based on prior studies' findings (e.g., Brock et al., 2009; Willoughby et al., 2011) and theoretical rationale, we hypothesized that the two-factor model of EC, consisting of hot and cool EC factors, would fit better than the one-factor model of EC. Although not a primary focus of this study, we examined age and gender invariance in the best-fitting EC model. Associations between EC and age and gender have been found in past research (e.g., Allan & Lonigan, 2011; Bull, Espy, Wiebe, Sheffield, & Nelson, 2011; Willoughby et al., 2011), such that we hypothesized that older children would perform better than younger children and that girls would outperform boys. In addition, based on previous findings of differential relations between hot and cool EC with other developmental outcomes (e.g., Brock et al., 2009; Willoughby et al., 2011), we hypothesized that if separate hot and cool EC factors emerged, children's academic skills would be more related to the cool EC factor than to the hot EC factor and that children's externalizing behaviors would be more related to the hot EC factor than to the cool EC factor. In the event that separate hot and cool EC factors did not emerge, we hypothesized that equally strong relations would be found between EC and children's academic skills and externalizing behaviors.

METHOD

Participants

As part of a larger study exploring the associations between cognitive and temperament constructs and academic readiness, children were recruited from 20 preschools in Tallahassee, Florida, in the southeastern United States. Parents of 286 preschool children signed consent forms allowing their children to participate in this study. Five children left the school before data collection began, resulting in a sample of 281 children (46.6% male and 53.4% female) who had data on one or more variables used in this study. Children ranged in age from 38 to 75 months (M = 55.92 months, SD = 4.16). Age could not be calculated for 6 of the children because their parents did not provide these children's birthdates. There were no significant differences between these 6 children and the remaining children on any of the variables used in the analyses. The sample was racially/ethnically diverse (58.0% White, 30.2% African American/Black, 2.1% Hispanic, 3.6% Asian, and 6.0% of other or mixed race). Family income was collected via parent report and was

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available for 56.9% of the sample. Parents were asked to indicate their income from 14 possible ranges from approximately $5,000 per year to more than $175,000 per year. Average median and modal family income was in the range of $51,000 to $75,000.

Measures

All children completed six tasks designed to assess EC as well as a measure of early academic skills. In addition, teacher reports were collected about children's behavior in the classroom, which included a measure of externalizing behaviors. To create a strong test of hot and cool dimensionality, all of the hot and cool tasks used were previously validated EC tasks that included similar behavioral regulation requirements (i.e., Stroop-like tasks). To create hot tasks, children were given a number of small prizes (i.e., erasers, jumping frogs, and toy tops) prior to task administration and told that they would lose a prize if they responded incorrectly to a trial (response–cost tasks). Examiners removed a prize for each incorrect response but gave no other feedback once the trials began. Anecdotal evidence by examiners provides support that the hot tasks elicited affective responses by the children because it was reported that children were more excited to "play the games with prizes" and would often ask whether the task in which they were participating had prizes.

Hot Head-to-Toes task—This task was modified from the task developed by Cameron Ponitz et al. (2008) to make it a response–cost task. Children were asked to do the opposite of the experimenter-given command (i.e., to touch their heads when the experimenter said "toes" and vice versa). For each trial, two points were awarded if children responded correctly, one point was given if children made any movement toward the incorrect body part but ultimately responded by touching the correct body part (self-correct), and zero points were given for an incorrect response. There were 10 trials, and children were given 10 prizes prior to task administration and told that they would lose a prize whenever they gave the incorrect response (i.e., a response scored as 0); no prizes were removed for self-corrects (i.e., a response scored as 1). Internal consistency reliability, measured using Cronbach's alpha, for this task was .95.

Hot Shapes task—This task was modified from the protocol of Kochanska and colleagues (1996) to make it a response–cost task. There were two parts to this task. For the first part, children were told that they would be shown images consisting of small fruits inside larger fruits and that they were to name the small fruits. There were two fruits (apples and strawberries) that were used. Over the course of 12 trials, half of the trials were congruent (small and large fruits were the same) and half were incongruent. Children were given 12 prizes prior to task administration and were told that they would lose a prize only when they gave an incorrect response. After the initial 12 trials, two additional fruits (bananas and grapes) were introduced. Children were again told to identify the small fruits within the large fruits. They were then presented with 16 more trials (half congruent and half incongruent) and were given 16 more prizes. For scoring, children were given one point for a correct response and zero points for an incorrect response. Cronbach's alpha for this task was .91.

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Hot Grass/Snow task—This task was modified from the protocol of Carlson and Moses (2001) to make it a response–cost task. Children were told to point to a white block when the experimenter said “grass” and to point to a green block when the experimenter said “snow.” There were 10 test trials. For each trial, two points were given if children pointed to the correct block, one point was given for a self-correct, and zero points were given for an incorrect response. Prior to administering the test trials, children were given 10 prizes and were told that they would lose a prize for each incorrect response (i.e., a response scored as 0). No prizes were removed for self-corrects (i.e., responses scored as 1). Cronbach’s alpha for this task was .86.

Day/Night task—This task was based on the protocol used by Kochanska and colleagues (1996). Children were told to point to a picture of a sun when the experimenter said “night” and to point to a picture of a moon when the experimenter said “day.” There were 10 test trials. For each trial, two points were given if children pointed to the correct block, one point was given if children self-corrected, and zero points were given for an incorrect response. Cronbach’s alpha for this task was .85.

Knock/Tap task—This task was based on the task originally developed by Luria (1966) to measure neuropsychological functioning of adults and is currently a part of the Neuropsychological Assessment Battery (NEPSY; Korkman, Kirk, & Kemp, 1998). In this task, children were first trained to knock on the table when the experimenter knocked on the table and to tap on the table when the experimenter tapped on the table. They were then told to do the opposite (i.e., to knock when the experimenter tapped and to tap when the experimenter knocked) over the course of 12 test trials. For scoring, two points were given if children performed the opposite action, one point was given if children self-corrected, and zero points were given if children completed the convergent action (e.g., knocked when the experimenter knocked). Cronbach’s alpha for this task was .90.

Bird/Dragon task—This task was based on the task developed by Kochanska and colleagues (1996). There were two puppets: a bird and a dragon. Children were asked to follow commands that the bird gave them because the bird was “nice” and to ignore commands that the dragon gave them because the dragon was “mean.” Children’s responses were scored on a scale of 0 to 2 over 12 test trials (6 bird and 6 dragon test trials). For the bird test trials, this ranged from 0 for failing to move to 2 for performing the requested movement. For the dragon test trials, this ranged from 0 for performing the requested movement to 2 for not moving. Cronbach’s alpha for this task was .85.

Florida Voluntary Prekindergarten Assessment—The Florida Voluntary Prekindergarten (VPK) Assessment (Florida Department of Education, 2011) comprises four subtests: Print Knowledge, Phonological Awareness, Mathematics, and Oral Language. The literacy-related measures (i.e., Print Knowledge, Phonological Awareness, and Oral Language) were used in the current study. The Print Knowledge subtest consists of 12 items measuring children’s abilities to recognize letters and words and to identify and produce letter names and letter sounds. Cronbach’s alpha in this sample was .86. The Phonological Awareness subtest consists of 14 items assessing children’s ability to manipulate or delete

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sounds to form new words. Cronbach's alpha in this sample was .84. The Oral Language subtest consists of 22 items assessing children's expressive and receptive vocabulary skills. Cronbach's alpha in this sample was .82. The subtests of the VPK Assessment have strong evidence of validity, with concurrent correlations with standardized, nationally normed measures of these same constructs ranging from .57 to .87 and predictive correlations with Florida's Kindergarten Readiness Screener ranging from .31 to .55.

Strengths and Weaknesses of ADHD Symptoms and Normal Behavior Scale— The Strengths and Weaknesses of Attention Deficit/Hyperactivity Disorder Symptoms and Normal Behavior Scale (SWAN; Swanson et al., 2001) consists of 30 items assessing children's inattentive, hyperactive/impulsive, and oppositional defiant behavior from very high levels of these behaviors to very low levels of these behaviors. In this study, teachers rated children based on comparisons with their same-age peers, with item scores ranging from 0 (far below average) to 6 (far above average). Higher scores indicate fewer behavior problems. Scores ranged from 0 to 60 for each subscale. The SWAN has been shown to have strong internal consistency (Cronbach's alphas P .95) and test–retest reliability (rs between .71 and .76) for each subscale (Lakes, Swanson, & Riggs, 2012). Cronbach's alpha estimates for teacher ratings in this sample were high (i.e., .97 for the Inattention subscale, .96 for the Hyperactivity/Impulsivity subscale, and .95 for the Oppositional Defiant Behavior subscale).

Procedure

Children were administered all measures by graduate students in clinical psychology or trained research assistants who had either completed a bachelor's degree or were in the process of completing a degree. Children were assessed over four testing sessions. The measure of early academic skills was completed over the course of one session. The EC tasks, as well as several tasks not relevant to this study, were completed over the course of three sessions. Children were first assigned to one of two conditions of randomly ordered tasks. For each condition, the tasks were divided into three batteries, and children received the batteries in random order. Each session took place in a quiet location in children's preschool and took an average of 25–40 min to complete. Children's preschool teachers completed the measures of children's behavior concurrently with assessment of the children.

Data analytic procedures

Data were examined for outliers, and values that were above or below 3 standard deviations from the mean were corrected to the upper or lower boundary of this range, respectively. Distributions of variables were then examined to determine whether there was problematic skew or kurtosis. Based on simulation studies in SEM (e.g., Curran, West, & Finch, 1996), absolute values for skew greater than 3 were considered problematic, and based on recommendations by Kline (2011), absolute values for kurtosis greater than 10 were also deemed problematic. Corrections in the form of transformations were made to the variables if skew or kurtosis was problematic. Prior to analysis, all EC task scores were converted to z scores to minimize the influence of scaling on model invariance testing.

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CFAs using Mplus version 5.1 (Muthén & Muthén, 1998–2008) were conducted on the EC tasks using *z*-transformed raw data. CFAs (and all additional analyses) were conducted using full information maximum likelihood (FIML) and the Yuan–Bentler scaled chi-square (Y-B χ^2) to adjust standard errors to correct for non-normality and data missingness (Yuan & Bentler, 2000). In addition, because children were nested within classrooms, a sandwich estimator was used to provide standard errors that were robust to this nesting (Muthén & Satorra, 1995). Two a priori models for the EC tasks were examined. In Model 1, all EC tasks were explained by a single factor. Model 2 was a two-factor model in which the hot EC factor consisted of the Hot Head-to-Toes, Hot Shapes, and Hot Grass/Snow tasks, and the cool EC factor consisted of the Day/Night, Knock/Tap, and Bird/Dragon tasks. Fit for each model was examined independently to assess overall model fit using the Y-B χ^2 as well as several other fit indexes (i.e., comparative fit index [CFI], root mean square error of approximation [RMSEA], and standardized root mean squared residual [SRMR]). A nonsignificant Y-B χ^2, a CFI value equal to or greater than .95, and an SRMR value less than .08 indicate a well-fitting model (Hu & Bentler, 1999). RMSEA values of .01, .05, and .08 are representative of excellent, good, and marginal fit, respectively (MacCallum, Browne, & Sugawara, 1996). Models were also compared using the χ^2 difference test. Because Model one was nested within Model two, a significant χ^2 value would indicate that Model two demonstrated improved model fit relative to Model one and a nonsignificant χ^2 would indicate that the more parsimonious Model one provided the best fit to the data.

Once the best-fitting model of EC was selected, an SEM was examined with pathways from EC predicting academic skills and externalizing behaviors. Age was included as a predictor of EC and the outcome variables. This model was evaluated for overall fit. Comparisons of the pathways from EC to academic skills and externalizing behaviors were tested for equality. Gender invariance was then examined over multiple steps. The CFA model was first tested for configural invariance, metric invariance (factor loadings), scalar invariance (factor intercepts), and latent factor variance and covariances, sequentially, using χ^2 difference tests for adjacent models. Age was then included as a covariate, and the pathways from age to EC were examined for gender invariance. Finally, gender invariance in the pathways from EC and age to the academic and externalizing behavior outcome variables was examined.

RESULTS

Descriptive statistics

Scores for the EC tasks, academic subtests, and teacher ratings of externalizing behavior were computed, allowing for 10% of the data missing per task or subscale, with the total score for a child entered as missing if the number of items with missing data exceeded this threshold. For the EC tasks, between 6 and 10 children were missing data on a particular task. For the academic subtests, three children were missing data on all subtests. Finally, for the externalizing behaviors, between 72 and 74 children were missing data for a particular behavior rating. There were no significant differences between children with and without externalizing behavior ratings on EC task performance. Children with missing data were included in the models because missing data were handled using FIML. Mean scores for the

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EC tasks, averaged across trials, and aggregated scores for the academic subtests and teacher ratings of inattention, hyperactivity/impulsivity, and oppositional behavior are shown in Table 1 with ranges, numbers of outliers, and skew and kurtosis values after outliers were corrected. Correlations among EC tasks, academic subtests, and teacher ratings are provided in Appendix Table A1.

Confirmatory factor analysis of EC tasks

All EC tasks were significantly related to each other, indicating that CFA was an appropriate modeling approach (see Appendix Table A1). The one-factor model of EC provided good fit to the data, and all tasks loaded significantly on this factor (see Table 2). The two-factor model consisting of hot and cool EC factors also provided good fit to the data, and all tasks loaded significantly on their respective factors (see Table 2). The between-factor correlation for the two-factor model was .91. The χ^2 difference test revealed no difference between the one- and two-factor models ($\Delta\chi^2 = 2.26$, $df = 1$, $p > .05$), and by parsimony the one-factor model was selected as the best-fitting model.

Structural equation models predicting children’s academic skills and externalizing behavior

SEM was conducted with the EC factor and age as predictors of children’s academic skills and externalizing behaviors. Age was also included as a predictor of EC. Although the two-factor model did not improve model fit over the one-factor model, SEMs also were conducted with the hot and cool EC factors independently as an exploratory evaluation of the relations between hot and cool factors and academic skills and externalizing behaviors. A model with hot and cool factors together was examined first, but issues of multicollinearity between the hot and cool factors resulted in unreliable pathway estimates. The one-factor EC model as well as the separate hot and cool models predicting academic skills and externalizing behaviors all provided marginal to adequate fit to the data, although the significant χ^2 value across models indicated some degree of model misfit (see Table 3). Standardized model parameters for the one-factor model are presented in Fig. 1. Parameter estimates across the one-factor EC model and the separate hot and cool models were similar; therefore, only the results of the one-factor EC model are discussed. Controlling for age, EC significantly predicted academic skills and externalizing behaviors. For every standard deviation of improvement in a child’s EC skills as compared with his or her peers, the child’s literacy skills increased .86 standard deviations. Because the externalizing scale was coded so that children with higher scores demonstrated fewer behavior problems, the results were as expected. Children whose level of EC was a standard deviation below their peers were rated by their teachers as possessing .44 standard deviations greater externalizing problems than their peers. A model in which the path between EC and academic skills and the path between EC and externalizing behaviors were constrained to equality did not result in a reduction of model fit (Y-B $\chi^2 = .06$, $p > .05$).

Gender invariance

Results of invariance tests for the one-factor EC model are shown in the top panel of Table 4. Tests of invariance revealed no gender differences regarding configural invariance, factor

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loadings, intercepts, or variance of the EC factor. Invariance testing for the pathway from age to EC also revealed no differences between boys and girls (see bottom panel of Table 4). Results of tests of gender invariance in the pathways from EC and age to academic skills and externalizing behaviors (see Table 5) revealed that the factor loadings, intercepts, and factor variances of academic skills and externalizing problems were invariant. Furthermore, the pathways from age and EC to academic skills and externalizing problems were invariant across gender as well.

DISCUSSION

The results of this study indicate that EC tasks that varied only on their level of affective salience were best represented as a single dimension in a sample of preschool-age children. This unidimensional EC construct was associated both with all academic skills and with externalizing behavior problems. Both the structural and measurement findings were robust to age and gender. Differences between the results of this study and the results of some prior studies that investigated hot and cool EC in preschool-age populations are likely explained by factors related to construct definitions and associated task selection. The structure of EC and its association with external correlates suggest that preventive and intervention efforts targeting EC may be particularly useful; however, refining the EC construct by use of well-articulated and explicit definitions of hypothesized components and measures that match these definitions is crucial for conducting research aimed at disentangling the mechanisms through which EC affects other developmentally significant constructs in young children.

Dimensionality of EC

The results of this study indicate that EC, as measured by tasks with similar behavioral regulation demands but different affective regulation demands, is best conceptualized as a unitary construct in preschool children. This finding is in contrast to the theoretical supposition that it is affective regulation only that distinguishes between hot and cool EC (Brock et al., 2009; Carlson, Davis, & Leach, 2005; Kerr & Zelazo, 2004). Instead, the delineation between hot and cool EC may be more complex, involving multiple features, one of which may be affective salience. The results of the current study are consistent with at least one prior study that conducted a CFA of EC in preschool children. Allan and Lonigan (2011) reported that EC was best represented by a single factor. An evaluation of the task demands used in studies that found hot and cool EC factors and studies that did not find hot and cool EC factors may reveal additional features necessary to properly measure hot EC.

There were differences in the task demands of this study and the study conducted by Allan and Lonigan (2011) versus the task demands in several of the studies that found separate hot and cool EC factors. The hot tasks used in this study included previously validated Stroop-like tasks that had been modified by including a response–cost component (i.e., punishment) for poor performance. Because both hot and cool tasks used in this study were Stroop-like tasks, the behavioral regulation demand was the same across hot and cool tasks. Although Allan and Lonigan did include a delay of gratification task, the remaining tasks they selected to measure hot EC were Stroop-like tasks that included a response–gain component.

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The approach in this study and in Allan and Lonigan (2011) contrasts with the approach used in studies that reported separate hot and cool dimensions (e.g., Brock et al., 2009; Kim et al., 2013; Willoughby et al., 2011). In these studies, cool EC was measured by Stroop-like tasks, whereas hot EC was measured by delay of gratification tasks. Delay of gratification tasks typically require children to choose between an immediate smaller reward and a delayed larger reward or to inhibit a behavior while awaiting a reward. In their discussion of hot and cool dimensions of EF, Zelazo and Carlson (2012) argued that it is not just the affective salience but also the cognitive processes required that separates hot and cool tasks. The findings of distinct hot and cool dimensions in studies that use tasks that include a different behavioral regulation component (delay) as well as an aspect of affective regulation suggest that the simple delineation of hot and cool EC on the basis of affective regulation does not adequately capture the differences between hot and cool EC. Instead, hot and cool dimensions of EC might be more accurately defined as varying on both affective regulation and behavioral regulation demands.

This refined definition is easily reconciled with theories of the neurobiology underlying hot and cool EC. Whereas the PFC has primarily been implicated in cool EC and the OFC has primarily been implicated in hot EC, Happaney and colleagues (2004) argues that these brain regions operate in tandem in situations requiring regulation regardless of whether it is hot or cool. There is also evidence of a more fine-grained functioning in the OFC, where medial OFC is implicated in initial evaluation of affective salience, such as would be required by the tasks in this study, and lateral OFC is implicated in reappraisal of affective salience, such as would be required in delay of gratification-type tasks (e.g., Evans, Lewis, & Iobst, 2004; Happaney et al., 2004). Therefore, the distinction in neural substrates between hot and cool EC may be related to the activation of the lateral OFC more specifically, and not just the OFC generally, in situations requiring hot EC.

Relations between EC and academic skills and externalizing behavior

EC was significantly associated with academic skills, and this relation was robust across child age and gender. This finding is similar to prior studies with samples of preschool children that reported that the relations between EC and early academic skills were robust to general intellectual ability, vocabulary, and socioeconomic status (SES) (e.g., Allan & Lonigan, 2011; Bull et al., 2011; Denham et al., 2012). The association between EC and academic skills in young children is hypothesized to be causal (e.g., Garon, Bryson, & Smith, 2008; Posner & Rothbart, 2007) in that the executive attention system, which is purported to underlie EC, allows children to more efficiently orient toward classroom learning activities. Support for this claim can be found in that EC is associated with academic skills directly (e.g., Allan & Lonigan) but is also associated with learning-related behaviors (e.g., Denham et al., 2012). If the relation between EC and academic skills is in the ability to orient to classroom content, then learning-related behaviors should mediate this relation. Future studies should address this.

EC also was significantly associated with externalizing behaviors in this study, and this finding was robust to age and gender effects. Other researchers have reported similar effects that were robust to intelligence, language skills, SES, and informant (i.e., parent report vs.

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teacher report; e.g., Allan & Lonigan, 2011; Denham et al., 2012; Espy et al., 2011). Because this and other studies have examined the association between EC and externalizing behaviors using non-overlapping measures (i.e., behavioral tasks for EC and other-report measures for behavior problems), method variance can be ruled out as a contributing factor. Furthermore, because only a single factor of EC emerged and was strongly correlated with externalizing behaviors, it is unlikely that emotion regulation is the contributing factor for the relation between EC and externalizing behaviors as has been hypothesized to be the reason why hot EC would share a stronger relation with externalizing behaviors than would cool EC (e.g., Kim et al., 2013; Zelazo & Carlson, 2012).

Implications

Given that this and other studies have found that EC is associated with direct measures of academic skills, others' reports of academic skills and motivation, externalizing behavior problems, the development of social skills, and other important developmental outcomes (e.g., Allan & Lonigan, 2011; Denham et al., 2012; Espy et al., 2011; Nigg, 2006), it appears that EC plays a fundamental role in modulating behavior across a variety of contexts regardless of the thought, emotion, and behavioral demands or setting (i.e., home or preschool classroom; e.g., Blair & Razza, 2007). The domain-general relations of EC provide a valuable framework for viewing potential preventive and intervention efforts. Whereas researchers have already begun implementing successful EC interventions for specific deficits (e.g., Halperin, Bédard, & Curchack-Lichtin, 2012; Tamm, Nakonezny, & Hughes, 2012), it seems likely that effective EC interventions could be useful in rectifying problems across a variety of developmental areas.

Limitations

There were limitations in this study that should be considered when interpreting the findings. All measures in this study were collected concurrently; therefore, the possibility that children's academic skills or externalizing behaviors affected EC, and not the other way around, cannot be ruled out. However, studies that have examined longitudinal relations (e.g., Blair & Razza, 2007; Ponitz, McClelland, Matthews, & Morrison, 2009) provided support for the assumption that EC influences academic skills and externalizing behaviors. In this study, EC was assessed using direct measures only. Response–gain and delay of gratification tasks were not included in the current study. An expanded study examining the associations between the different potential modalities of hot and cool EC might further clarify distinctions between hot and cool EC. As of yet, there have not been informant measures designed to explore hot and cool dimensionality. Finally, the amount of missing data present for the measure of SES included in this study limited the potential use of this variable as a covariate, and this may limit generalizability of the findings. However, the effect of children nested within the classroom was accounted for because classrooms typically varied as a function of family SES of children, providing at least some evidence that the findings are generalizable across level of SES.

Summary and conclusion

The results of this study indicate that the delineation between hot and cool tasks is not merely due to the affective salience incorporated in hot EC tasks. It is more likely that hot

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EC tasks differ from cool EC tasks by differential behavioral regulation demands coupled with affective salience. Similar to the findings in past studies (e.g., Sulik et al., 2010), the structure of EC appears invariant across gender and EC was associated with both academic skills and externalizing behaviors. These findings suggest avenues for future research regarding relations with other developmentally important constructs, especially regarding the utility of EC interventions to improve behavior and academic performance.

Acknowledgments

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Appendix A

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Appendix A

Appendix Table A1. Correlations among EC tasks, age, academic measures, and externalizing behaviors.

	1	2	3	4	5	6	7	8	9	10	11	12
1. Head-to-Toes	–											
2. Shapes	.41***	–										
3. Grass/ snow	.38***	.24***	–									
4. Day/ night	.42***	.21***	.34***	–								
5. Knock/ tap	.35***	.28***	.20***	.33***	–							
6. Bird/ dragon	.48***	.36***	.36***	.38***	.43***	–						
7. PK	.28***	.30**	.18**	.23***	.28***	.20***	–					
8. PA	.51***	.28***	.23***	.32***	.28***	.33***	.39***	–				
9. OL	.59***	.45***	.31***	.47***	.39***	.47***	.40***	.58***	–			
10. Inattention	.37***	.40***	.28***	.31***	.33***	.35***	.34***	.31***	.41***	–		
11. Hyperactivity	.26***	.28***	.14*	.16*	.22**	.21**	.10	.20**	.25***	.77***	–	
12. Oppositional	.24***	.30***	.19**	.24***	.25***	.21**	.06	.17*	.29***	.73***	.83***	–
13. Age	.37***	.19**	.23***	.17**	.06	.18**	.09	.34***	.31***	.18*	.17*	.12

Note. PK, Print Knowledge; PA, Phonological Awareness; OL, Oral Language; Hyperactivity, hyperactivity/impulsivity; Oppositional, oppositional defiant behavior.

* $p \le .05$.

** $p \le .01$.

*** $p \le .001$

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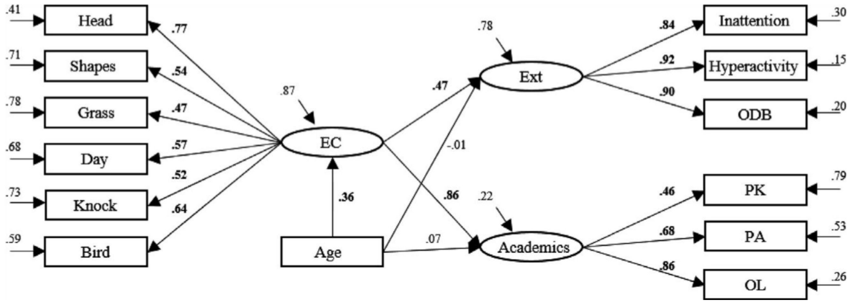

Fig. 1.

Structural equation model predicting children’s externalizing behaviors and academic skills from EC and age. EC, effortful control; Ext, externalizing behaviors; ODB, oppositional defiant behavior; PK, Print Knowledge; PA, Phonological Awareness; Oral, Oral Language. Residual variances are provided for the indicators and latent variables. Significant path estimates are in bold.

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Table 1

Descriptive statistics for EC tasks, emergent literacy measures, and externalizing behavior ratings.

Variable	Mean	*SD*	Range		Outliers		Skew	Kurtosis
			Minimum	Maximum	LB	UB		
EC tasks								
Head-to-Toes	1.31	0.75	0.00	2.00	0	0	−0.88	−0.90
Shapes	0.92	0.15	0.29	1.00	10	0	−2.27	4.36
Grass/ Snow	1.49	0.54	0.00	2.00	1	0	−1.44	1.36
Day/ Night	1.55	0.52	0.00	2.00	2	0	−1.31	0.94
Knock/ Tap	1.68	0.39	0.33	2.00	4	0	−1.62	1.73
Bird/ Dragon	1.81	0.42	0.17	2.00	13	0	−2.39	4.35
VPK								
Print Knowledge	8.36	3.37	1.00	12.00	0	0	−0.56	−1.04
Phonological Awareness	7.41	3.61	0.00	14.00	0	0	0.14	−1.03
Oral Language	16.55	3.75	4.00	22.00	1	0	−0.92	0.20
SWAN	104.58	32.41	18.00	180.00				
Inattention	31.91	11.06	2.00	54.00	0	0	0.12	−0.11
Hyperactivity	30.91	10.31	1.00	54.00	0	0	0.47	0.38
Oppositional	41.82	13.78	13.00	72.00	0	0	0.50	−0.14

Note. LB, lower bound; UB, upper bound; VPK, Voluntary Prekindergarten Screener; SWAN, Strengths and Weaknesses of ADHD Symptoms and Normal Behavior Rating Scales. Ns = 271 to 281 for EC tasks and VPK subtests; Ns = 207 to 209 for SWAN Behavior Rating Scales.

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Table 2

Factor loadings from the one- and two-factor models.

One-factor model	**Head-to-Toes**	**Shapes**	**Grass/ Snow**	**Day/ Night**	**Knock/ Tap**	**Bird/ Dragon**
Standardized loadings	.72***	.50***	.50***	.56***	.54***	.69***
Standardized residuals	.48	.75	.75	.68	.71	.52
Two-factor hot and cool model						
Standardized loadings	.75***	.52***	.51***	.57***	.56***	.72***
Standardized residuals	.43	.73	.75	.68	.69	.49

*** $p < .001$.

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Table 3

Model fit indexes for confirmatory factor analysis models and structural equation models predicting academic skills and externalizing behaviors including age as a covariate.

Model	**Y-B χ^2**	***df***	***p***	**CFI**	**RMSEA**	**SRMR**
One-factor	12.37	9	.19	.99	.04	.03
Two-factor (hot and cool)	10.16	8	.25	.99	.03	.03
Model predicting academic skills and externalizing behaviors						
One-factor	147.97	60	.00	.94	.07	.06
Hot	86.79	30	.00	.94	.08	.06
Cool	90.93	30	.00	.94	.09	.05

Note. Y-B χ^2, Yuan–Bentler scaled chi-square; CFI, comparative fit index; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual.

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Table 4

Measurement and structural invariance model fit indexes of latent EC with age as a predictor.

Model	Y-B χ^2	*df*	*p*	CFI	RMSEA	SRMR	$\Delta\ \chi^2$
Baseline	14.12	17	.66	1.00	.00	.04	–
Metric invariance	17.51	23	.78	1.00	.00	.05	3.02
Scalar invariance	26.81	29	.58	1.00	.00	.07	11.99
Factor invariance	27.77	30	.58	1.00	.00	.07	0.96
Age included as a predictor							
Baseline age model	49.02	40	.15	.97	.04	.08	–
Age invariance	50.46	41	.15	.97	.04	.08	1.66

Note. Y-B χ^2, Yuan–Bentler scaled chi-square; CFI, comparative fit index; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; Baseline, configural invariance model; Baseline age model, latent EC model including age as a predictor of EC. Adjacent models were compared. There were no significant differences in χ^2.

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Table 5

Measurement and structural invariance model fit parameters for academic skills and externalizing behaviors.

Model	Y-B χ^2	*df*	*p*	CFI	RMSEA	SRMR	$\Delta\chi^2$
Baseline	217.73	131	.00	.93	.07	.08	–
Academics metric invariance	219.35	134	.00	.93	.07	.09	1.30
Academics scalar invariance	224.55	137	.00	.93	.07	.09	5.22
Academics factor invariance	227.78	138	.00	.93	.07	.08	3.23
Age pathway invariance	227.89	139	.00	.93	.07	.08	0.30
EC pathway invariance	228.88	140	.00	.93	.07	.08	0.99
Externalizing metric invariance	230.57	142	.00	.93	.07	.08	1.97
Externalizing scalar invariance	235.46	145	.00	.93	.07	.09	4.89
Externalizing factor invariance	236.70	146	.00	.93	.07	.09	1.08
Age pathway invariance	237.45	147	.00	.93	.07	.09	0.60
EC pathway invariance	245.27	148	.00	.92	.07	.10	3.65

Note. Y-B χ^2, Yuan–Bentler scaled chi-square; CFI, comparative fit index; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; Baseline, configural invariance model including age and EC as predictors of all academic skills and externalizing behaviors. Adjacent models were tested stepwise.

Note: no differences in chi-square values.