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Effortful Control in “Hot” and “Cool” Tasks Differentially Predicts Children’s Behavior Problems and Academic Performance

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Abstract

Effortful control (EC), the capacity to deliberately suppress a dominant response and perform a subdominant response, rapidly developing in toddler and preschool age, has been shown to be a robust predictor of children’s adjustment. Not settled, however, is whether a view of EC as a heterogeneous rather than unidimensional construct may offer advantages in the context of predicting diverse developmental outcomes. This study focused on the potential distinction between “hot” EC function (delay-of-gratification tasks that called for suppressing an emotionally charged response) and more abstract “cool” EC functions (motor inhibition tasks, suppressing-initiating response or Go-No Go tasks, and effortful attention or Stroop-like tasks). Children (*N*=100) were observed performing EC tasks at 38 and 52 months. Mothers, fathers, and teachers rated children’s behavior problems and academic performance at 67, 80, and 100 months, and children participated in a clinical interview at 100 months. Structural Equation Modeling (SEM) analyses with latent variables produced consistent findings across all informants: Children’s scores in “hot” EC tasks, presumably engaging emotion regulation skills, predicted behavior problems but not academic performance, whereas their scores in “cool” EC tasks, specifically those engaging effortful attention, predicted academic performance but not behavior problems. The models of EC as a heterogeneous construct offered some advantages over the unidimensional models. Methodological and clinical implications of the findings are discussed.

Keywords

Effortful control; Behavior problems; Academic performance

The developmental and clinical importance of children’s emerging ability for deliberate self-regulation of behavior and emotion has been long recognized (Kopp 1982). Research on children’s self-regulation has encompassed studies on inter-related constructs, such as impulsivity, impulse control, self-control, inhibitory control, executive function, and physiological regulation (Calkins and Fox 2002; Eisenberg et al. 2003, 2004b; Kochanska and Knaack 2003; Rothbart and Bates 2006; Rothbart et al. 2004). Recently, the term “effortful control” (EC) has become increasingly common. EC, the capacity to deliberately and voluntarily suppress a dominant or prepotent response and perform a subdominant response, is a key aspect of children’s temperament (Derryberry and Rothbart 1997; Rothbart and Bates 2006) and personality (Caspi and Shiner 2006). EC emerges in the

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second year of life and develops rapidly at toddler and preschool age. The growing body of studies and reviews (e.g., Rueda in press) documents the essential role of EC for broadly ranging aspects of children's functioning, including behavior problems and psychopathology, school readiness and academic performance, conscience and morality, social relationships with parents and peers, resilience, and adjustment (Blair and Razza 2007; Eisenberg et al. 2003, 2004b; Kochanska et al. 2009; Kochanska and Knaack 2003; Kochanska et al. 2000; 1997; Nigg 2006; Posner and Rothbart 2000).

Although all EC tasks call, in general, for suppressing a predominant, prepotent response and performing a subdominant response, recently researchers have sought a more refined understanding of processes subsumed under the broad umbrella of EC (Duckworth and Kern 2011). Some studies indicate that different forms of EC may differentially predict varying developmental outcomes (Brock et al. 2009). The evidence, however, is mixed and hard to integrate, in part because both behavioral and parent-reported measures of EC have been used (e.g., Blair and Razza 2007). In addition, even studies that use only behavioral measures provide mixed data, perhaps because some studies implement extended effortful control batteries (Kochanska et al. 2009), whereas others use only selected tasks (Gusdorf et al. 2011).

An important focus of the controversy in recent literature concerns the issue of uni-versus multi-dimensionality structure of EC, particularly in the context of the implications for future developmental outcomes. We address this issue in the current work.

In the past, we proposed (Kochanska et al. 2000) that EC encompasses four key functions: delaying, motor inhibition, suppressing-initiating response to signal (Go-No Go), and effortful attention (Stroop-like tasks). Those four functions map onto the recently discussed distinction between "hot" and "cool" EC, with delaying representing the former and the remaining three functions representing the latter.

The "hot" versus "cool" distinction has a long history (Metcalfe and Mischel 1999). Generally, "hot" tasks include a salient emotional component (typically, an affectively positive or negative consequence). "Cool" tasks do not include such a component, and they demand a more abstract form of self-regulation (Brock et al. 2009; Hongwanishkul et al. 2005; Zelazo and Müller 2002). Delay of gratification is the most typical "hot" task, particularly when it involves hedonically attractive, highly salient rewards that can be easily consumed (Shoda et al. 1990). "Cool" tasks may involve various demands, as long as the affective component is absent: inhibition of gross and fine movements, lowering voice, and conflict-eliciting tasks, Go-No Go and effortful attention (Stroop tasks). Although there is a consensus that "hot" and "cool" tasks engage different brain regions (Bechara et al. 1994; Bush et al. 2000; Hongwanishkul et al. 2005) and may have different antecedents (Huijbregts et al. 2008), whether they differentially predict developmental outcomes remains controversial and not settled, and the findings are mixed.

Recent research on "hot" and "cool" tasks has suggested that multidimensional "hot" and "cool" models can be useful and can fit data well (e.g., Brock et al. 2009). However, Allan and Lonigan (2011) found that the "hot" and "cool" model did not show a *better* fit than a unidimensional model of EC. Thus, Allan and Lonigan (2011) suggested that a one-factor model of EC may be the most parsimonious. Given the well-known implications of EC for developmental outcomes (Eisenberg et al. 2003, 2004b; Rothbart and Bates 2006; Rueda in press), including a broad range of behavior problems (Espy et al. 2011) clearly, more research on this topic is needed.

We propose that delay-of-gratification tasks, where rewards are salient and easily accessible, are infused with emotion; therefore, those "hot" EC tasks engage children's emotion regulation to a much greater degree than “cool” EC tasks that involve much less emotion. Consequently, we expected that children’s performance in “hot” EC tasks would be particularly predictive of those developmental outcomes that also heavily regress on emotional regulation—mostly behavioral problems. The inability to regulate emotion has been strongly implied in the emergence of both internalizing and externalizing psychopathology and mental health (Cole and Deater-Deckard 2009; Cole et al. 2008; Eisenberg et al. 2004a; Frick and Morris 2004; Nigg 2006; Thompson et al. 1995). Krueger et al. (1996) found that the inability to delay gratification was associated with externalizing disorders in preadolescents. Shoda and colleagues (Shoda et al. 1990) reported that preschoolers’ ability to delay gratification with exposed salient rewards predicted coping strategies in adolescence.

By contrast, we expected that the tasks that assess the “cool” EC functions (motor inhibition, Go-No Go, effortful attention) that involve less affect but engage more abstract capacities would be most predictive of academic success (Brock et al. 2009; Lan et al. 2011). It should be noted, however, that robust relations between “cool” EC functions and behavior problems have also been reported, both for a broad range of problems (Espy et al. 2011) and particularly, those specific to ADHD (e.g., Barkley 1997; Sonuga-Barke et al. 2002).

We examined the structure of EC in the context of the prediction of two important developmental outcomes: academic performance and behavior problems. We employed a rich behavioral battery of EC tasks, administered twice in preschool age, and collected outcome data from multiple informants (mothers and fathers at 67, 80, 100 months, teachers at 80 months, and children at 100 months).

Using Structural Equation Modeling (SEM) analyses, we examined EC as encompassing the latent “hot” (delaying gratification) and “cool” (motor inhibition, Go-No Go, effortful attention) functions as predictors of children’s behavior problems and academic achievement. The outcomes were modeled as latent variables whenever feasible, with the informants’ ratings at each age treated as separate indicators, and as observed variables when assessed only once. Furthermore, we also examined the predictions from EC seen as a homogeneous construct, and modeled as representing one global underlying latent factor.

Method

Participants

Two-parent families of infants from a college town, a small city, and rural areas in Iowa volunteered for the longitudinal study. The demographic range was broad (20 % of parents had a postgraduate education and 30 % a high school education; 25 % had annual income of $40,000 or less, and 34 % had income of $70,000 or more). Ninety percent of mothers and 84 % of fathers were White, 3 % and 8 % were Hispanic, 2 % and 3 % were African American, 1 % and 3 % were Asian, 1 % and 0 % were Pacific Islanders, and 3 % and 2 % were “other” non-White. Twenty percent of families had at least one non-White parent.

We report data collected at 38 months (N=100, 50 girls), 52 months (N=99, 49 girls), 67 months (N=92, 45 girls), 80 months (N=90, 43 girls), and 100 months (N=87, 41 girls). At 38 and 52 months, we collected behavioral data on EC during observational sessions. Data on children’s behavior problems were collected from both parents at 67, 80, and 100 months and from teachers at 80 months. Children’s self-reports of behavioral problems were gathered through a clinical interview at 100 months during an observational session. All sessions were videotaped for future coding. Parents signed informed consents, and children (at 100 months) signed assents.

Our behavioral EC tasks are broadly used; thus, they are described briefly (details are available from the first author). Their selection was based on our view of children's capacities, tested in our several longitudinal studies. At 52 months, the 38-month tasks were repeated, and several new tasks were added. All EC tasks were coded by multiple coding teams. At least 20 % of cases were used for reliability; coders also frequently "realigned" to prevent drift.

Assessments of EC "Hot" Function: Delay-of-Gratification Tasks, 38 and 52 Months

In these tasks, children were asked to wait before consuming (candy) or getting access to rewards (gifts). The candy/reward remained in clear view and within reach throughout the delay period. At 38 months, the tasks involved Snack Delay (child waited to retrieve an M&M from under a see-through cup, 4 trials), Gift-Wrap and Gift-Bow (child waited, without peeking, while the experimenter (E) wrapped a gift, and then waited for a bow). At 52 months, both tasks were repeated, and a new task was added: Gift in Bag (child waited to retrieve a gift from a bag).

In Snack Delay, child behavior was coded from 1 to 4, with higher scores denoting better delaying capacity, averaged across the trials, at 38 months, M=3.64, SD=0.64, at 52 months, M=3.85, SD=0.54. Separate scores were created for the Gift-Wrap, at 38 months, M=0.00, SD=0.91, at 52 months, M=0.00, SD=0.93; and Gift-Bow, at 38 months, M=0.00, SD=0.69, at 52 months, M=0.00, SD=0.68; and for Gift in Bag, at 52 months, M=0.00, SD=0.69 (each was a composite of several standardized codes, such as peeking, touching, latencies to look or open gift, etc.).

There were thus *four indicators* of the latent "hot" function of delay: a Snack Delay score, Gift-Wrap, Gift-Bow (those were averaged across 38 and 52 months; r=0.30, r=0.28, and r=0.48 respectively), and Gift in Bag.

Assessments of EC "Cool" Functions: Motor Inhibition, Go-No Go, Effortful Attention Tasks, 38 and 52 Months

Motor Inhibition Tasks—In these tasks, children were asked to slow down fine or gross motor activity. At 38 and 52 months, the tasks included Walk-a-Line-Slowly (child walked along a line as slowly as possible, average of 2 trials, at 38 months, M=7.74, SD=4.30, at 52 months, M=9.85, SD=6.17) and Turtle and Rabbit (child led two toys as fast and as slowly as possible along a curvy path into a barn, 2 trials for each). A difference was computed between the slow and fast trials, at 38 months, M=33.43, SD=46.28, at 52 months, M=74.47, SD=68.37). At 52 months, a Drawing Task was also added (child drew a line as slowly as possible, M=2.46, SD=2.42).

There were thus *three indicators* of the latent "cool" function of motor inhibition: Walk-a-Line-Slowly, Turtle and Rabbit (both averaged across 38 and 52 months; r=0.18 and r= 0.30 respectively), and the Drawing task.

Go-No Go Tasks—At 38 months, there was one task, Tower, with the child taking turns with E building a tower from blocks (2 trials, up to 16 blocks each; the number of correctly taken turns, M=5.08, SD=2.41). At 52 months, we used Green Signs-Red Signs task (10 trials for Green series and 10 trials for Red series). In this task, the child performed the requested movement to one stimulus, but inhibited the movement to another (e.g., raise the same hand as the model if the model raised the green sign, but the opposite hand when the model raised the red sign). The scores captured the difference between percent of correct and percent of wrong answers. We created separate scores for Green Signs, M=0.58, *SD*=0.46, and Red Signs, *M*=0.19, *SD*=0.65. There were thus three *indicators* of the latent “cool” function of Go-No Go: Tower, Green Signs, and Red Signs.

Effortful Attention Tasks (Stroop-like Tasks)—At both 38 and 52 months, there were two tasks: Snow-Grass and Day-Night, 10 trials for each (Carlson and Moses 2001). We created a difference between percent of correct answers and percent of wrong answers. For Snow-Grass, at 38 months, *M*=0.25, *SD*=0.51, at 52, *M*=0.61, *SD*=0.50; for Day-Night, at 38 months, *M* =0.37, *SD* =0.53, at 52 months, *M*=0.67, *SD*=0.47. Those two tasks (each averaged across the assessments; *r*=0.21 and *r*=0.11 respectively) were the *two indicators* of the latent “cool” function of effortful attention.

Reliability of Coding—All codes were strongly behaviorally grounded and required little inference. Reliability at 38 months, kappas for categorical judgments were 0.71–1.00, alphas for continuous scores (e.g., latency) were 0.89–1.00, and at 52 months, kappas were 0.81–1.00 and alphas were 0.94–1.00.

Assessments of Parents’ and Teachers’ Reports of Children’s Behavior Problems and Academic Performance, 67, 80, and 100 Months

Behavior Problems—At all three times, mothers and fathers completed Child Symptom Inventory-4 (CSI-4, Gadow and Sprafkin 2002; Gadow et al. 2001; Sprafkin et al. 2002), a well-established measure that yields scores compatible with DSM-IV (APA 2000). Teachers completed the Teacher Version of CSI that yields comparable scores to those produced by parents (at 80 months only). We created the *total behavior problems scores* for each informant. To that effect, we relied Symptom Severity scoring, where each item is rated from 0 (never) to 3 (very often). The total scores were the sums of externalizing problems (oppositional defiant disorder and conduct disorder), internalizing problems (depression, generalized anxiety disorder, specific phobia, obsessive compulsive disorder, posttraumatic stress disorder, tic disorders, social phobia, and separation anxiety disorder) and the additional scales (or single items): attention deficit/hyperactivity, schizophrenia, pervasive developmental disorders, and elimination disorders.

Academic Performance—Eight items that capture child academic performance (math and reading) were drawn from the MacArthur Health Behavior Questionnaire (HBQ, Boyce et al. 2002; Essex et al. 2002), completed by mothers (alphas at 67, 80, and 100 months, 0.92, 0.85, 0.91) and fathers (0.90, 0.92, 0.90). For each parent’s report, the mean score was the measure of child academic performance at each time.

Teachers completed the Teacher Version of the HBQ at 80 months. The item targeting the child’s overall academic performance was used.

Assessments of Self-Reported Children’s Behavior Problems, 100 Months

Having established good rapport with the child, E administered the interactive, computerized version of Dominic-R, a visual-auditory clinical interview instrument that employs vignettes portraying specific symptoms, appropriate for 8-year-olds, with excellent psychometric qualities established in studies with large samples (Arseneault et al. 2005; Breton et al. 1999; Valla et al. 2000). Based on the sums of the instances when the child endorses a given symptom, Dominic-R produces continuous, DSM-IV-compatible scores (APA 2000) for several disorders (oppositional defiant disorder, conduct disorder, attention deficit/hyperactivity, separation anxiety, generalized anxiety disorder, specific phobias, and depression; Valla 2000). The *total behavior problems score* for each child informant was created by summing the symptom endorsements. All descriptive data for children’s outcomes are in Table 1.

Results

Overview

Initially, we conducted a series of confirmatory factor analysis (CFA) to compare competing measurement models for our EC functions. Then, on basis of the CFA results, we performed two sets of SEM analyses to estimate the effects of EC on children's behavior problems and academic performance. At first, we tested a heterogeneous approach to EC that posed the “hot” and “cool” functions. Next, we examined an approach where EC was modeled as a second-order unidimensional construct (Bollen 1989; Denham et al. 2012; Marsh and Hocevar 1988). In all analyses, missing values were treated with listwise deletion method.

Confirmatory Factor Analysis Comparing Measurement Models

Table 2 is the summary of goodness-of-fit indices for four CFA models. In Model 1 (1-Hot, 3-Cool Factor Model), each function (one “hot”, Delay) and three “cool” (Motor Inhibition, Go-No Go, and Effortful Attention) was treated as a separate latent variable with its own observed indicators. In Model 2 (1-Hot, 1-Cool Factor Model), the “hot” latent variable was again Delay, but all the indicators of the three “cool” functions were modeled to measure a single “cool” latent variable. In Model 3 (Single-EC Factor Model), all the indicators (for all functions) were modeled to measure a unidimensional EC latent variable. In Model 4 (Second-Order Single-EC Factor Model), the four latent variables and their own indicators in Model 1 were retained as they were, but the four latent variables were additionally modeled to measure a second-order unidimensional EC latent variable.

Overall, the goodness-of-fit indices indicated that Model 1 with the four latent variables fits our data well. Model 2 and 3, however, did not provide acceptable fit-indices and performed significantly worse than Model 1 (for Model 1 and 2, $\Delta\chi^2$=30.97, df=5, $p<0.001$; for Model 1 and 3, $\Delta\chi^2$=42.74, df=6, $p<0.001$). Model 4 performed as well as Model 1 in representing the data. Given these CFA results, we used Models 1 and 4 to predict the effects of EC functions on children's behavior problems and academic performance.

Structural Equation Models Estimating the Effects of Children's “Hot” and “Cool” EC Functions (Model 1) on their Behavior Problems and Academic Performance

In the first series of SEM analyses, Model 1 (from CFA) was adopted. Each of the four EC functions was treated as a separate exogenous latent variable with multiple observed indicators. Each of mother- and father-reported children's behavioral problems and academic performance was modeled as an endogenous latent variable with three observed indicators (the scores at 67, 80, and 100 months). Teacher-reported children's behavioral problems and academic performance at 80 months, and self-reported children's behavior problems at 100 months were all modeled as observed endogenous variables, given that those constructs were measured at one time only.

Figures 1, 2, 3, 4, 5, 6 and 7 represent the results of SEM analyses for the seven outcome variables (mother-reported behavior problems and academic performance, father-reported behavior problems and academic performance, teacher-reported behavior problems and academic performance, and child-reported behavior problems), predicted by “hot” and “cool” EC functions. Table 3 is the summary of goodness-of-fit indices for Figs. 1, 2, 3, 4, 5, 6 and 7. The overall model fit indices generally indicated that these models fit the data well. In all seven models, the chi-square test was not rejected at 0.05 alpha level. The examination of the goodness-of-fit indices revealed that CFI and TLI (Bentler 1990; Hu and Bentler 1999), were greater than the conventional standard of 0.95. RMSEA was lower than the conventional standard of 0.05 in all the seven models (Steiger and Lind 1980), whereas

SRMR ranged from 0.06 to 0.07 (Hu and Bentler 1999). Factor loadings for all observed indicators of the latent variables were significant at 0.05 alpha level.

There was an impressive pattern of results across Figs. 1, 3, 5, and 7 (predicting children's behavior problems), consistent with our view of the implications of "hot" EC. In all those models, significant structural coefficients were found only for the effect of the "hot" latent EC function, regardless of the informant (mothers, fathers, teachers, and children). Children who had been better able to delay the action to consume the clearly exposed rewards (eating candy, seeing and opening gifts) had fewer behavior problems. By contrast, and also consistent with our view, none of the "cool" EC functions, as indexed by motor inhibition, Go-No Go, or Stroop-like tasks significantly predicted future behavior problems.

The pattern of findings was quite different for children's academic performance, and again, it was impressively consistent across all three informants (mothers, fathers, and teachers). In Figs. 2, 4, and 6, respectively, the significant structural coefficients were found only for the effects of the "cool" Stroop-like tasks (but not for other "cool" EC functions, motor inhibition and Go-No Go). Note also that children's "hot" ability to delay was unrelated to future academic performance.

Second-Order Structural Equation Models Estimating the Effect of Children's Unidimensional EC (Model 4) on their Behavior Problems and Academic Performance

In the second series of SEM analyses, Model 4 (from CFA) was adopted. We tested *unidimensional* EC model in predicting children's behavior problems and academic performance by using second-order structural equation models. In these alternative models, the first-order factors (Delay, Motor Inhibition, Go-No Go, and Effortful Attention, each indexed by the specific behavioral tasks) are assumed to represent linear combinations of a single latent second-order factor that represents general or overall EC. We tested seven second-order SEM models for all outcome variables (mother-reported behavior problems and academic performance, father-reported behavior problems and academic performance, teacher-reported behavior problems and academic performance, and child-reported behavior problems).

When predicting mother-reported child behavior problems, this model indicated good overall model fit: χ^2=81.03 (df= 85, p>0.05); CFI=1.00; TLI=1.01; RMSEA=0.00; SRMR= 0.07. The second-order overall EC latent variable significantly predicted mother-reported children's behavior problems (b=−0.99, SE=0.25, p<0.001), as expected: Children with greater overall EC capacities had fewer problems.

When predicting mother-reported children's academic performance, this model also produced good overall model fit: χ^2=77.33 (df=84, p>0.05); CFI=1.00; TLI=1.03; RMSEA=0.00; SRMR=0.07. The effect of the overall EC latent variable on the outcome was significantly positive (b=1.21, SE=0.33, p<0.001). Consequently, we conclude that the unidimensional EC model was also acceptable when predicting mother-reported child academic performance.

However, the second-order unidimensional EC model for father-reported behavior problems was not supported. In this model, the latent variable covariance matrix was not positively defined. This problem can be solved only by adding a restriction such that the "hot" delay function be set to predict the outcome. This additional restriction led to a good overall model fit and a significant structural coefficient from the Delay function, not the second-order EC latent variable. This result indicates that the second-order unidimensional EC model is not appropriate when predicting father-reported behavior problems.

When predicting father-reported children's academic performance, this model provided acceptable overall model fit: $\chi^2=98.12$ (df=84, $p>0.05$); CFI=0.95; TLI=0.94; RMSEA= 0.04; SRMR=0.07. The effect of the EC latent variable on the outcome remained significantly positive ($b=1.04$, $SE=0.33$, $p<0.01$).

The second-order unidimensional EC model for teacher-reported behavior problems revealed the same problem as the model for father-reported behavior problems. Without the additional restriction from the "hot" Delay function on the outcome, the model was not constructed.

When predicting teacher-reported children's academic performance, this model revealed a good overall model fit: $\chi^2 =60.69$ (df =61, $p > 0.05$); CFI =1.00; TLI =1.00; RMSEA=0.00; SRMR=0.07. The effect of the EC latent variable on the outcome remained significantly positive ($b=0.61$, $SE=0.31$, $p<0.05$).

When predicting children's self-reported behavior problems, this model still had good overall model fit: $\chi^2=64.30$ (df=61, $p<0.05$); CFI=0.98; TLI=0.98; RMSEA=0.03; SRMR=0.07. The effect of the EC latent variable on the outcome was significantly negative ($b=-0.62$, $SE=0.28$, $p<0.05$).

Summary

For mother-reported child behavior problems and academic performance, both types of EC models—one assuming the "hot" and "cool" functions and one assuming a second-order unidimensional structure—performed equally well. Those models were also comparable when predicting father- and teacher- reported academic performance, as well as child self-reported behavior problems. However, the former model, assuming the distinct "hot" and "cool" EC functions, was superior when predicting father- and teacher-reported behavior problems.

Discussion

This study addresses the as yet unsettled issue whether, when it comes to predicting children's developmental outcomes, EC is better viewed as comprising the "hot" and "cool" functions, or as a global unidimensional construct. The strengths of the study include behavioral assessments of EC that employed a broad repertoire of behavioral tasks, most administered twice at preschool age, multiple informants (mothers, fathers, teachers, and children themselves), and the assessment of two types of outcomes, behavior problems and academic performance.

The SEM analyses produced consistent and straightforward findings. The model of EC that assumed the "hot" and "cool" functions supported our predictions. It was clear that the "hot" delay tasks, presumably regressing heavily on emotion regulation capacities, were particularly predictive of children's behavior problems. Preschoolers' performance in multiple delay-of-gratification tasks that involved emotionally compelling, easily accessible rewards significantly predicted their behavior problems from age 5 to 8. Children who had difficulty regulating their behavior in the "hot" tasks were clearly at risk for a broad range of future behavior problems. This pattern of findings emerged across all informants, indirectly supporting our view that "hot" EC tasks require effective emotion regulation capacities, and that deficits in those capacities are strongly implicated in the emergence of psychopathology (Cole and Deater-Deckard 2009; Eisenberg et al. 2004a; Frick and Morris 2004; Keenan 2000; Krueger et al. 1996; Nigg 2006; Thompson et al. 1995), whereas high EC abilities may serve a protective role (Muris and Ollendick 2005).

Our “hot” tasks engaged primarily the regulation of positive emotion and the approach system. Children were asked to delay acts that were positively motivating: peeking at or reaching for gifts, or eating candy. But “hot” EC tasks could also be designed to capture the regulation of negative emotion, where children are asked to delay or suppress an expression such as anger or frustration, or to tolerate an aversive state. The classic disappointment paradigm (Cole et al. 1994) is one relevant example, although in this task, the demand for emotion regulation is typically implied rather than explicitly articulated. The Cold Pressor Task (CPT), where children are asked to tolerate the unpleasant sensation when holding a hand in cold water (Keenan et al. 2009) is another example. Individual differences in such tasks have been meaningfully related to behavior problems.

If indeed the findings indicating that “hot” EC is particularly significant in the etiology of childhood behavior problems and psychopathology can be replicated, then such research would have useful treatment implications. For example, intervention programs that target specifically young children’s capacities for delay (e.g., using behavioral therapy, play, or games) may produce significant payoffs in terms of reducing their risks for future behavior problems. As well, a child’s early visible impairments in delay capacities, as compared to his or her peers, may be important early warning signs.

Only one of the “cool” EC functions, effortful attention, captured in the Stroop-like tasks, predicted academic performance. This pattern of results was also consistent across informants. Robust relations between “cool” EC or “cool” executive functioning and academic achievement have been often reported (e.g., Lan et al. 2011). Although the other two “cool” EC functions, motor inhibition and Go-No Go, were not significant in predicting academic performance, we retained all three “cool” functions in our models, because pertinent data in extant research are inconsistent. For example, Allan and Lonigan (2011) found that motor conflict tasks and cognitive conflict tasks both had similar association with phonological awareness, print knowledge, and definitional vocabulary. Likewise, Brock et al. (2009) found that motor inhibition and motor go-no go tasks both predicted math achievement and learning-related behaviors. Consequently, given that this issue appears not settled, we opted to retain all three “cool” EC functions in the model.

The absence of the relations between “cool” EC and behavior problems was also inconsistent with a large body of research on the importance of “cool” EC in ADHD (e.g., Barkley 1997; Nigg 2006; Sonuga-Barke et al. 2002). Perhaps our study failed to discern such relations because of the comprehensive approach to children’s behavior problems that relied on total scores across the broad range of symptoms. Imaginably, the testing of our EC models applied specifically to the prediction of ADHD would reveal relations with the “cool” functions.

Together, our findings suggest that the issue of heterogeneity within EC is far from settled. The approach to EC as encompassing “hot” and “cool” components performed better in some respects than the unidimensional model, and it offered unique and useful insights that may stimulate further research. However, the unidimensional model, with EC modeled as a global second-order latent factor, was also acceptable for predicting some outcomes. Consequently, our current findings do not invalidate a comprehensive approach to EC, where the distinction between “hot” and “cool” tasks is not made, and where a global measure of EC is created and related to other constructs. A comprehensive score has been and will remain a valuable construct that both predicts a broad range of developmental outcomes and is itself an outcome of development. For example, Sulik et al. (2010) administered a battery of EC tasks, including several adapted from the current battery, to a large and diverse group of low-income preschoolers; their findings supported the use of diverse behavioral measures as indicators of a single latent EC construct. As well, Wiebe and colleagues (Wiebe et al. 2011), studying 3-year-olds, found that a battery of executive function tasks that included those adapted from our research (Snack Delay, Stroop task), and working memory and Go-No Go tasks yielded data that supported a single latent construct. They, however, proposed that the multidimensional structure, or more generally, EC seen as a heterogeneous construct, might better predict variation in important outcomes such as externalizing symptomatology or academic skills. Our current data, with heterogeneity within both the exogenous and endogenous variables, certainly support such a premise. Consequently, whereas we believe that the comprehensive EC measures should continue to be used, we demonstrate that using more specific EC scores—such as “hot” and “cool”—may improve our predictions of diverse developmental outcomes. Clearly, more research is needed to explore the issue of homogeneity versus heterogeneity of EC.

The limitation of this study is a fairly small, ethnically homogeneous (though 20 % of families had at least one non-White parent), low-risk sample. Although Sulik et al. (2010), using several of our tasks, found similar EC structures across ethnic groups, all children in his study came from low-income families, and thus, that sample was also limited in socio-economic diversity. Future research with larger, low-and high-risk, diverse groups of children will further inform our understanding of the role of EC in developmental trajectories of children’s adjustment.

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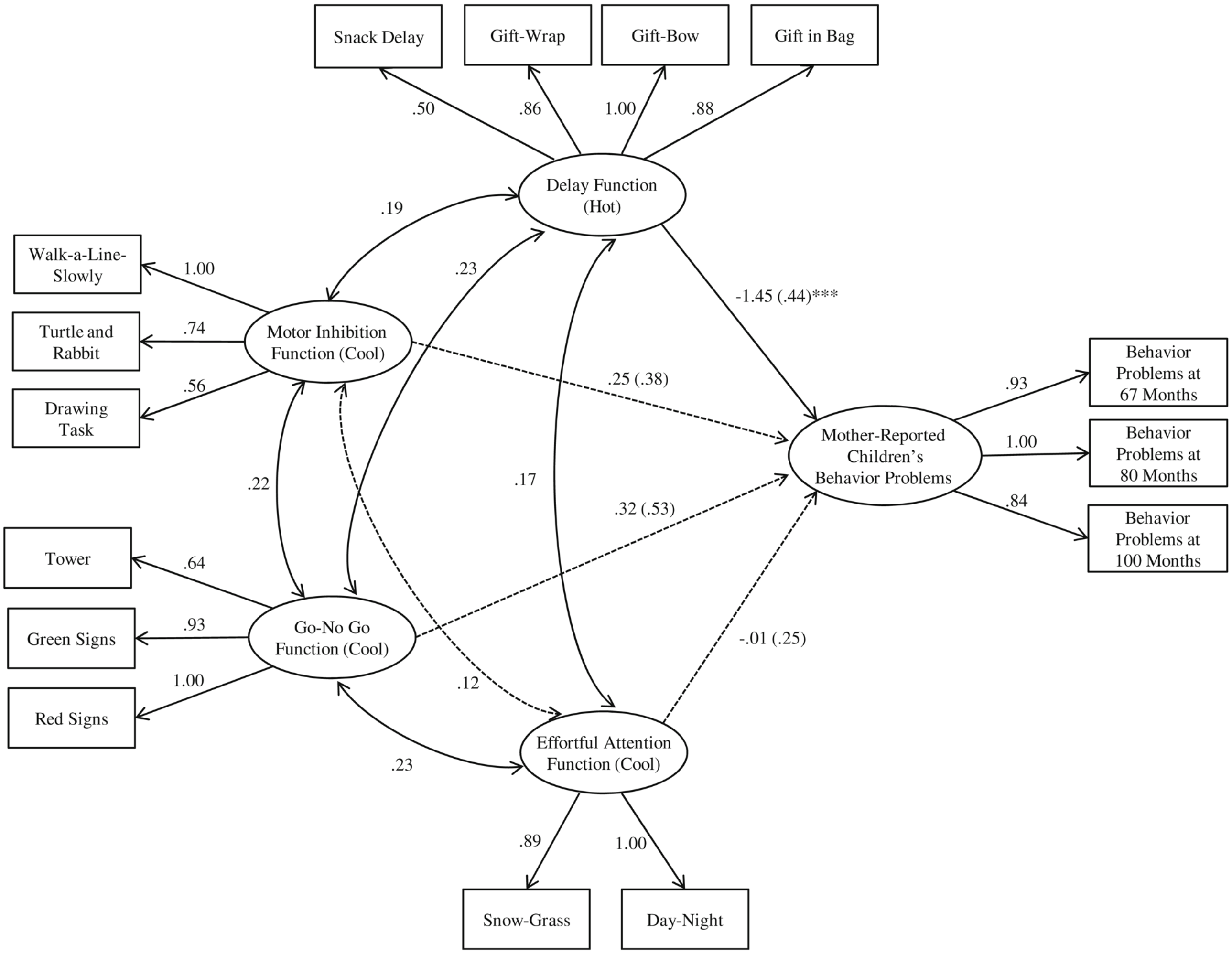

Fig. 1.

A structural equation model estimating the effects of “hot” and “cool” EC functions (38–52 months) on mother-reported (67–100 months) children’s behavior problems (CSI-4). Coefficients are unstandardized maximum likelihood estimates (SE in parentheses). *Solid lines* represent significant effects (*** $p<0.01$), and *dashed lines* represent non-significant effects

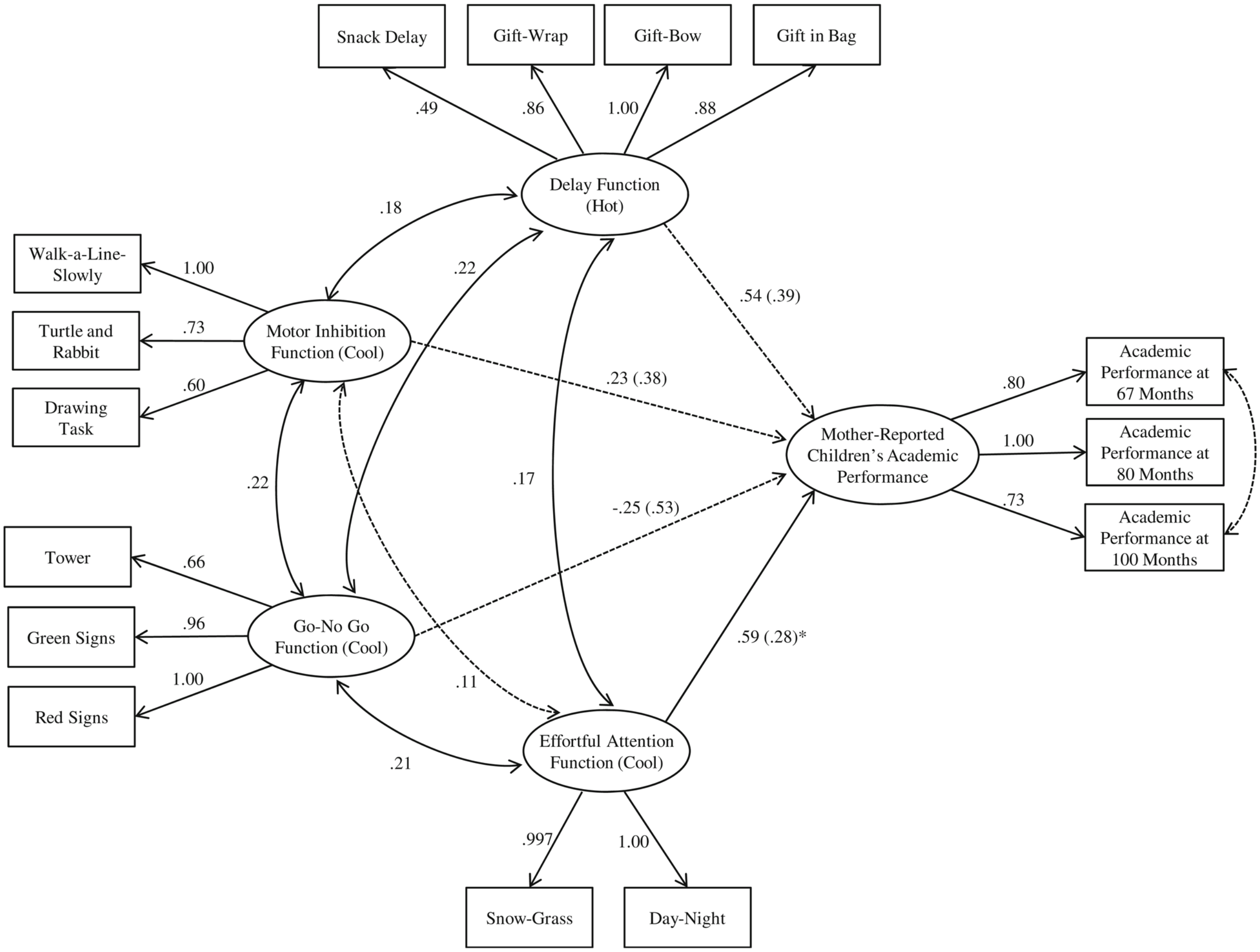

Fig. 2.

A structural equation model estimating the effects of "hot" and "cool" EC functions (38–52 months) on mother-reported (67–100 months) children's academic performance (HBQ). Coefficients are unstandardized maximum likelihood estimates (SE in parentheses). *Solid lines* represent significant effects (* $p<0.05$), and *dashed lines* represent non-significant effects

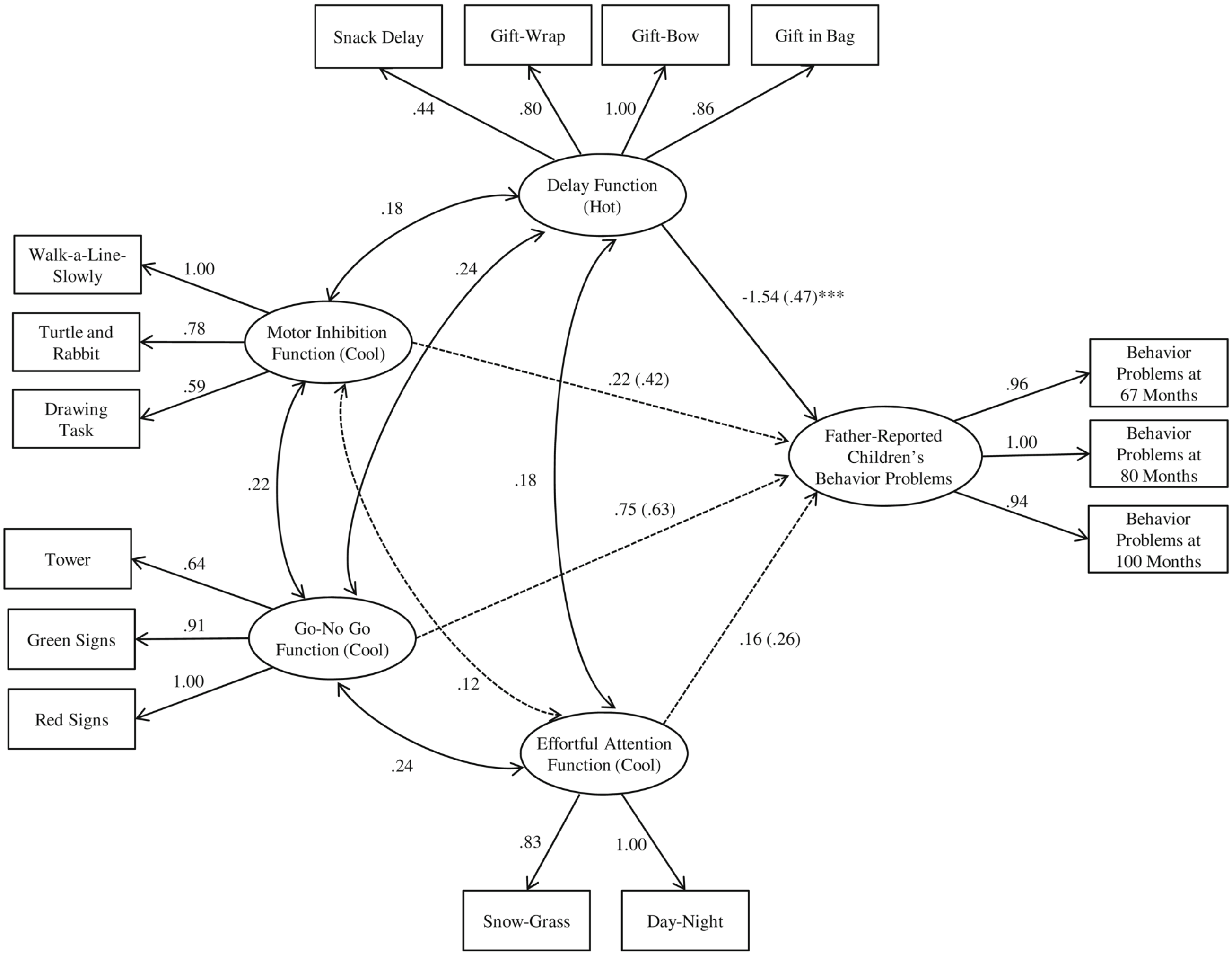

Fig. 3.

A structural equation model estimating the effects of "hot" and "cool" EC functions (38–52 months) on father-reported (67–100 months) children's behavioral problems (CSI-4). Coefficients are unstandardized maximum likelihood estimates (SE in parentheses). *Solid lines* represent significant effects (*** $p<0.01$), and *dashed lines* represent non-significant effects

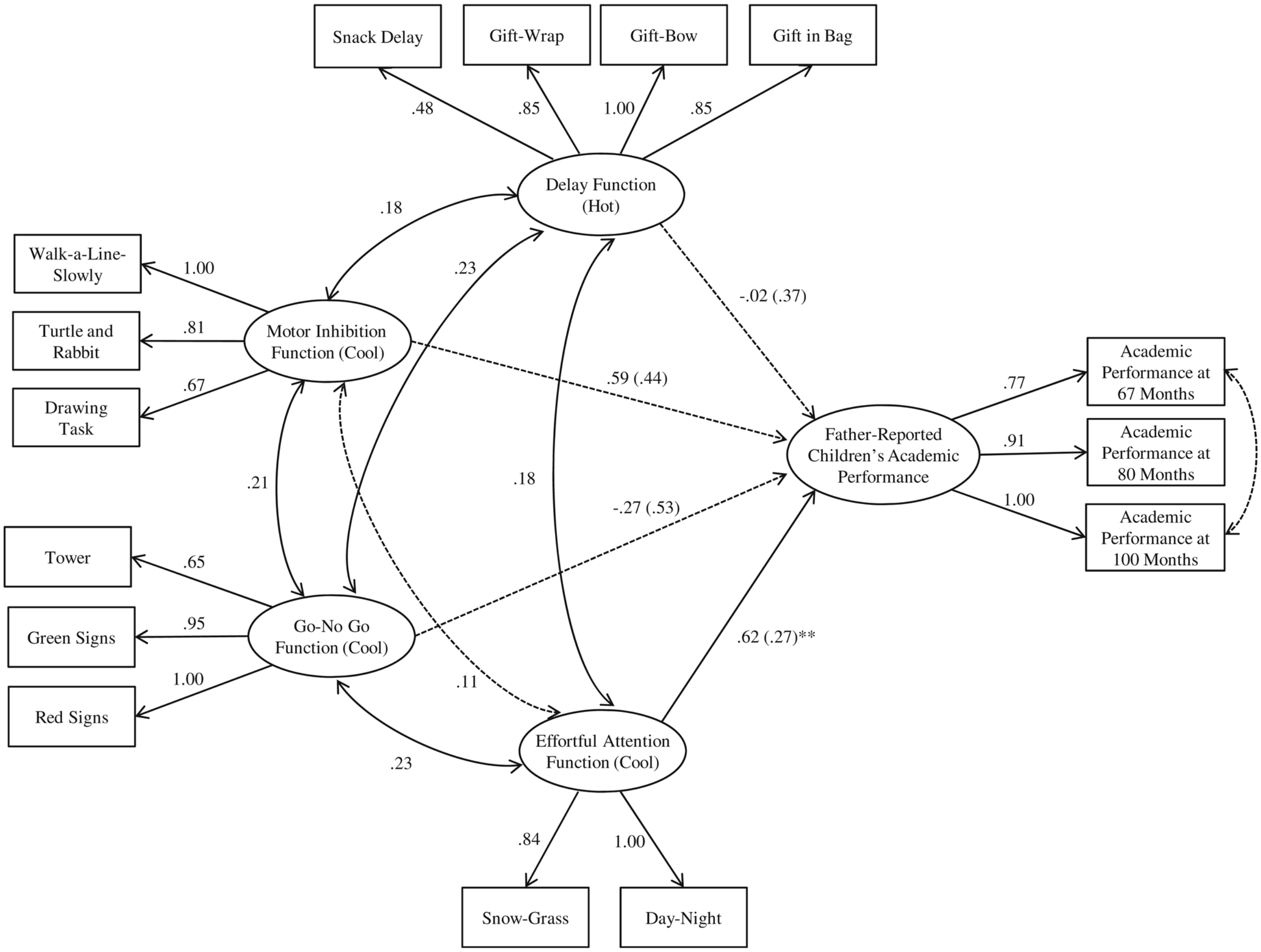

Fig. 4.

A structural equation model estimating the effects of “hot” and “cool” EC functions (38–52 months) on father-reported (67–100 months) children’s academic performance (HBQ). Coefficients are unstandardized maximum likelihood estimates (SE in parentheses). *Solid lines* represent significant effects (*** p*<0.025), and *dashed lines* represent non-significant effects

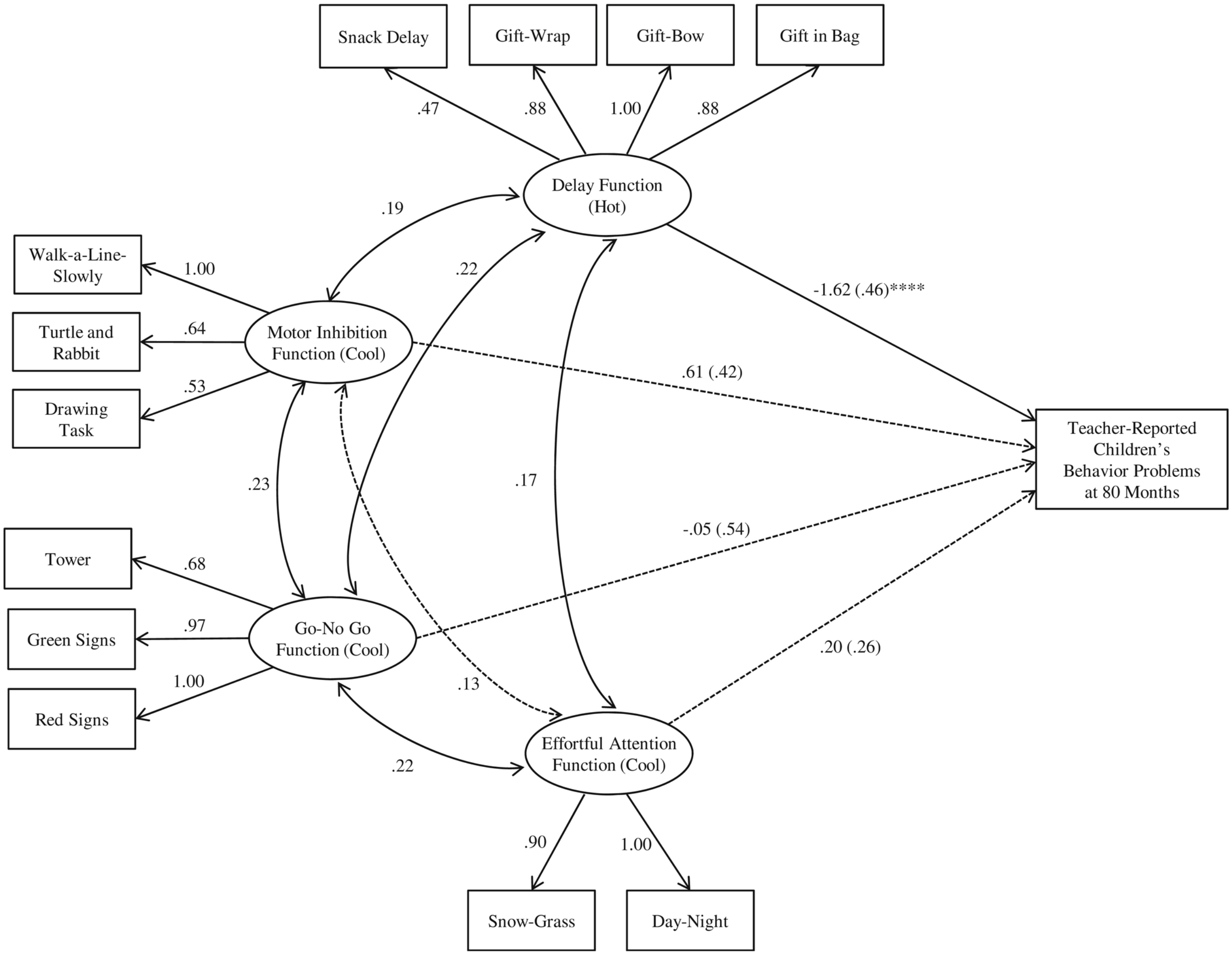

Fig. 5.

A structural equation model estimating the effects of "hot" and "cool" EC functions (38–52 months) on teacher-reported (80 months) children's behavioral problems (CSI-4). Coefficients are unstandardized maximum likelihood estimates (SE in parentheses). *Solid lines* represent significant effects (**** p<0.001), and *dashed lines* represent non-significant effects

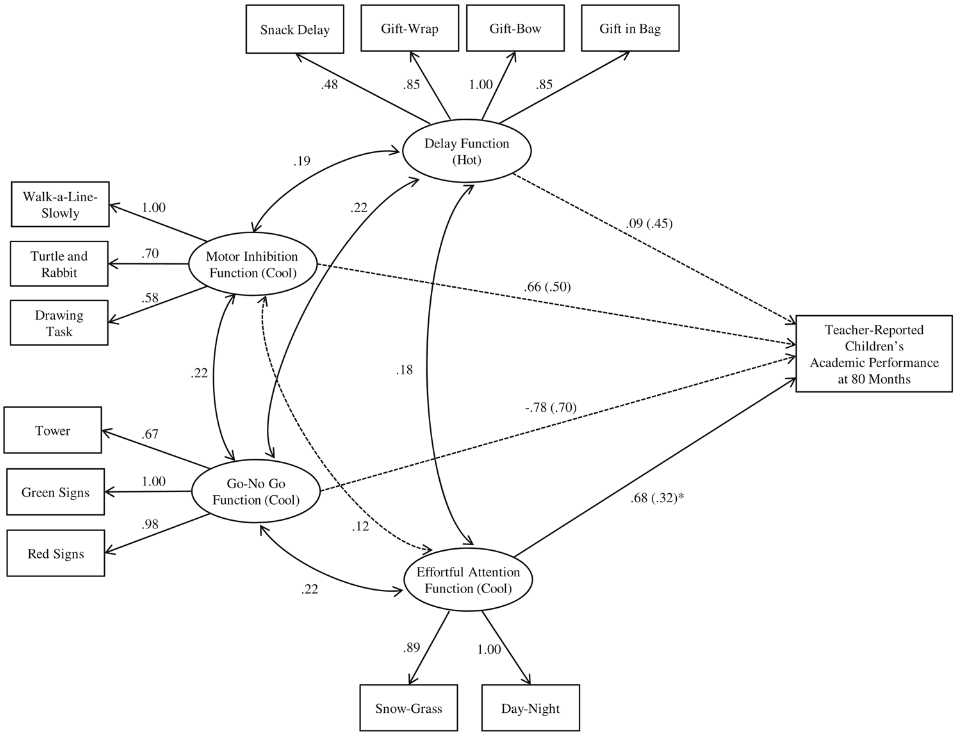

Fig. 6.

A structural equation model estimating the effects of "hot" and "cool" EC functions (38–52 months) on teacher-reported (80 months) children's academic performance (HBQ). Coefficients are unstandardized maximum likelihood estimates (SE in parentheses). *Solid lines* represent significant effects (* $p<0.05$), and *dashed lines* represent non-significant effects

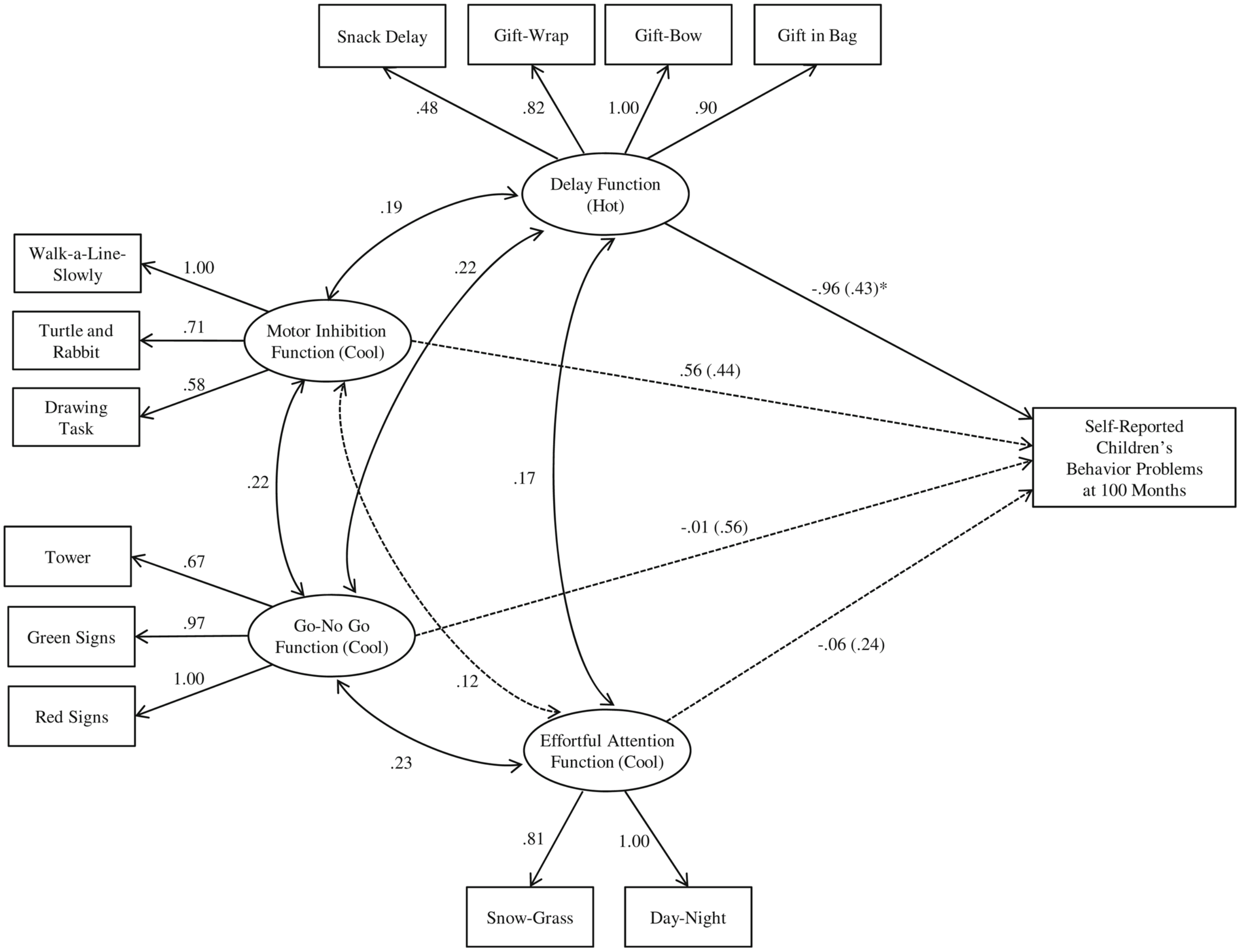

Fig. 7.

A structural equation model estimating the effects of "hot" and "cool" EC functions (38–52 months) on self-reported (100 months) children's behavioral problems (Dominic-R). Coefficients are unstandardized maximum likelihood estimates (SE in parentheses). *Solid lines* represent significant effects (* $p<0.05$), and *dashed lines* represent non-significant effects

Table 1

Descriptive Data for All Outcome Measures

C Age in Months:	**67**		**80**		**100**	
	M	**SD**	**M**	**SD**	**M**	**SD**
M Reported						
C Total Behavior Problems[a]	39.20	18.84	36.39	16.08	33.53	18.50
C Academic Performance[b]	4.82	1.27	5.38	1.06	5.58	1.09
F Reported						
C Total Behavior Problems[a]	40.40	15.06	38.81	15.05	35.46	15.82
C Academic Performance[b]	4.50	1.25	5.30	1.11	5.62	0.99
T Reported						
C Total Behavior Problems[a]			15.87	15.39		
C Academic Performance[b]			4.16	0.83		
C Self-Reported						
C Total Behavior Problems[c]					24.55	17.68

M Mother, *F* Father, *T* Teacher, *C* Child

[a] Child Symptom Inventory, CSI-4

[b] Health Behavior Questionnaire, HBQ

[c] Dominic-R interview

Table 2

Goodness-of-Fit Indices for Confirmatory Factor Analysis Models

	χ^2	**CFI**	**TLI**	**RMSEA**	**SRMR**
Model 1: 1-Hot, 3-Cool Factor Model	40.70 (df=48, p=0.76)	1.00	1.06	0.00	0.06
Model 2: 1-Hot, 1-Cool Factor Model	71.67 (df=53, p=0.04)	0.90	0.87	0.06	0.08
Model 3: Single-EC Factor Model	83.44 (df=54, p=0.01)	0.84	0.80	0.08	0.09
Model 4: Second-Order Single-EC Factor Model	41.79 (df=50, p=0.79)	1.00	1.06	0.00	0.06

Table 3

Goodness of Fit Indices for Structural Equation Models from Figs. 1 to 7

	χ^2	**CFI**	**TLI**	**RMSEA**	**SRMR**
Figure 1, predicting M-reported C's Behavior problems	73.40 (df=80, *p*=0.69)	1.00	1.02	0.00	0.06
Figure 2, predicting M-reported C's Academic performance	71.91 (df=79, *p*=0.70)	1.00	1.03	0.00	0.06
Figure 3, predicting F-reported C's Behavior problems	81.13 (df=80, *p*=0.44)	1.00	1.00	0.01	0.07
Figure 4, predicting F-reported C's Academic performance	90.44 (df=79, *p*=0.18)	0.96	0.95	0.04	0.07
Figure 5, predicting T-reported C's Behavior problems	50.52 (df=56, *p*=0.68)	1.00	1.04	0.00	0.06
Figure 6, predicting T-reported C's Academic performance	52.69 (df=56, *p*=0.60)	1.00	1.02	0.00	0.06
Figure 7, predicting self-reported C's behavior problems	57.55 (df=56, *p*=0.42)	0.99	0.99	0.02	0.07

M Mother, *F* Father, *T* Teacher, *C* Child