Published in final edited form as:
Infant Child Dev. 2010 July 1; 19(4): 333–353. doi:10.1002/icd.670.

Maternal Behavior and Children's Early Emotion Regulation Skills Differentially Predict Development of Children's Reactive Control and Later Effortful Control

P. A. Graziano,
Department of Psychiatry, University of Florida, FL, USA

S. P. Keane, and
Department of Psychology, University of North Carolina at Greensboro, NC, USA

S. D. Calkins
Department of Human Development and Family Studies and Psychology, University of North Carolina at Greensboro, NC, USA

Abstract

The role of maternal behavior and children's early emotion regulation skills in the development of children's reactive control, specifically behavioral impulsivity, and later effortful control was examined in a sample of 435 children. HLM analyses indicated significant growth in reactive control across the toddlerhood to early childhood period. Emotion regulation at age-2 positively predicted initial levels of children's reactive control abilities while maternal overcontrol/intrusiveness predicted lower levels of reactive control growth. Maternal behaviors at age-2 predicted children's effortful control abilities at age-5.5. Emotion regulation did not predict effortful control abilities. Maternal behavior and children's early emotion regulation skills may differentially facilitate the development of reactive and effortful control abilities.

Keywords

temperament; maternal behavior; development; emotion regulation; effortful control; children

Cognitive theories along with neuropsychological data have stressed the role of early childhood impulsivity or lack of inhibitory processes in the development of later psychopathology (Barkley, 1997, Posner, 2004). For example, substantial research has identified impulsivity as a core feature of various childhood disorders such as Attention-Deficit/Hyperactivity Disorder (ADHD) and Conduct Disorder (Barkley, 1997; Moffit, Caspi, Rutter, & Silva, 2002). Impulsivity has also been shown to be detrimental for children's learning/academic development (Hinshaw, 1992) and social development (Cumberland-Li, Eisenberg, & Reiser, 2004; Hinshaw & Melnick, 1995). Impulsive children are also at a greater risk of engaging in risky health behaviors (e.g., alcohol abuse) in adolescence and young adulthood (Dubow, Boxer, & Huesmann, 2008). Developmental research within the self-regulation literature has also documented significant and rapid improvements in children's ability to control impulsive behaviors from toddlerhood to early childhood (Posner, 2004; Wassenberg et al., 2008). While the above evidence highlights the importance of understanding what contributes to individual differences in the development

*Correspondence: Paulo A. Graziano, Department of Psychiatry, Division of Medical Psychology, University of Florida, PO Box 100234, Gainesville, FL 32610, USA, pagrazia@ufl.edu.

of impulsivity, few studies have concurrently examined multiple facets of impulsivity (Herba, Tranah, Rubia, & Yule, 2006; Olson, Schilling, & Bates, 1999).

Impulsivity is considered a multidimensional construct that cannot be captured with a single measurement (Herba et al., 2006; Olson et al., 1999). While impulsivity includes the speed of response initiation (Rothbart, Ahadi, Hershey, & Fisher, 2001), the current study focuses on understanding the development of two control processes which are thought to be crucial in regulating such responses in the service of goal directed behaviors: *reactive control* and *effortful control* (Barkley, 1997; Eisenberg et al., 2004). These two control processes have gathered strong support within the delinquency and ADHD literature (Avila et al., 2004; Oades et al., 2008; White et al., 1994) as well as the socioemotional development literature (Eisenberg et al., 2004; 2009) as being strongly related yet distinct from response time measures of impulsivity (Olson et al., 1999).

Building on the work of Derryberry and Rothbart (1997), Eisenberg and Morris (2002) differentiated control processes that are voluntary from those that are more reactive. The voluntary branch refers to *effortful control* or an individual's ability to inhibit a dominant response and/or activate a subdominant response by voluntarily modifying one's own attention and behavior (Eisenberg & Morris, 2002; Rothbart & Bates, 2006). It is a superordinate construct that includes attentional control (i.e., ability to focus or shift attention) and inhibitory control, which refers to one's ability to appropriately/adaptively inhibit behavior (Derryberry & Rothbart, 1997; Rothbart & Bates, 2006). Effortful control is typically measured by Stroop and Stroop-like tasks or parent/teacher measures (e.g., CBQ) of effortful control (Archibald & Kerns, 1999; Livesey et al., 2006; Rothbart et al., 2001). *Reactive control*, on the other hand, refers to aspects of control that appear to be automatic and/or involuntary (Eisenberg et al., 2009). The developmental literature has also distinguished between reactive overcontrol to describe behavioral inhibition (i.e., children who approach novel and stressful situations in an inhibited fashion) as described by Kagan (1999) and reactive undercontrol to describe impulsive approach behavior typically seen in children with ADHD (Eisenberg et al., 2004). Reactive control is typically measured by a stop signal task (Sergeant, 2000) and/or parent and teacher ratings of ADHD impulsivity symptoms (Avila et al., 2004).

The importance of examining both reactive and effortful control processes as it relates to the development of self-regulation abilities has been recently documented within the neuroscience literature. For example, reactive control tasks have been shown to activate predominantly the right inferior prefrontal cortex (Aron, & Poldrack, 2005; Rubia, Smith, Brammer, Toone, & Taylor, 2005) while effortful control tasks have been shown to activate predominantly left dorsolateral prefrontal cortex, anterior cingulate gyrus, and inferior parietal lobe (Posner & Rothbart, 2007). These relative distinct neural pathways may indicate that reactive and effortful control processes have different roles in facilitating self-regulation (Eisenberg et al., 2009; Olson et al., 1999, Posner, 2004).

However, as recently pointed out by Eisenberg and colleagues (2009), most of the developmental research has failed to differentiate between effortful versus reactive control processes and instead have examined broad measures of self-regulation. In addition, the few studies that have differentiated these control processes have tended to examine how either early effortful control or reactive control relate to various developmental competencies such as moral understanding (Kochanska, 1999), social competence (Eisenberg et al., 1997), temperament and shyness (Kagan, 1999), patterns of parent-child interaction (Olson et al., 1990), and externalizing/internalizing symptoms (Eisenberg et al., 2001). Herba and colleagues (2006) also point out that relatively few studies have concurrently examined effortful control and reactive control processes. The few studies that have examined both effortful and reactive control processes have focused on either how children diagnosed with ADHD and/or behavior problems such as Conduct Disorder perform on both types of tasks (Herba et al., 2006; Moffit, 1993; White et al., 2004) or how such control processes differentially predict social competence and externalizing/internalizing problems (Cumberland-Li et al., 2004; Eisenberg et al., 2004; 2009). Even fewer studies have focused on examining what factors contribute to individual differences in children's reactive and effortful control processes. Understanding which factors contribute to individual differences in such control processes is of utmost importance to issues of risk and prevention.

A large portion of the variability in children's reactive and effortful control processes has been attributed to genetics as reported in the AD/HD literature (Barkley, 1997; Oades et al., 2008) as well as in the genetic disorders (e.g., Fragile X) literature (Loesch et al., 2003). Animal studies have also documented a strong genetic link in reactive control processes (Fairbanks et al, 2004; Groot et al., 2004). Developmental research has also documented that dispositional differences in effortful control appear to be heritable aspects of temperament that tend to exhibit some stability from infancy to childhood (Eisenberg et al., 2004; Murphy, Eisenberg, Fabes, Shepard, & Guthrie, 1999; Saudino, 2005). However, despite the strong genetic and/or temperament link, both reactive and effortful control processes have been shown to change with age (Eisenberg et al., 2009; Rothbart & Bates, 2006). Developmental changes in these control processes have been theorized as being due to not only individual factors such as sex and language (Chapple, & Johnson, 2007; Moffitt et al., 2002; Putnam, Rothbart, & Gartstein, 2008) but also socialization factors (Rothbart & Bates, 2006). For example, parenting factors such as maternal psychopathology and maternal behaviors have been associated with reactive and/or effortful control processes (Eisenberg et al., 2005; Gartstein & Fagot, 2003; Greenberg, Spelztz, & DeKlyen, 1993; Lengua, Honorado, & Bush, 2007; Olson, Bates, Sandy, & Schilling, 2002; Winsler, Diaz, McCarthy, Atencio, & Chabay, 1999). However, it remains unclear whether these socialization factors have a similar influence on the development of reactive and effortful control processes. Given the theoretical distinction between these two control processes (Eisenberg et al., 2004) as well as recent data showing potential differences in the heritability of these control processes (Oades et al., 2008), it may also be the case that socialization factors have a stronger influence on one control process over another. Hence, the current study sought to examine whether maternal behavior can differentially explain individual differences in the development of children's reactive and effortful control abilities.

Recent conceptual work and empirical research suggests that caregiver behavior may affect the development of self-regulation skills, both at the behavioral and biological level (Calkins & Hill, 2007; Gunnar, 2006). The toddlerhood period represents a particularly important period in which children test parental limits and resist control. To the extent that a caregiver can appropriately read toddlers' signals and respond in ways that minimize distress, or alternatively, motivate positive interaction, the toddler will integrate such experiences into the emerging behavioral repertoire of self-regulatory skills (Kopp, 1982; Fox & Calkins, 2003; Sroufe, 2000). In addition, deviations from supportive caregiving may contribute to patterns of self-regulation that undermine the development of appropriate skills and abilities needed for later developmental challenges (Cassidy, 1994). Maternal behaviors that are thought to facilitate children's self-regulation development include the use of appropriate language, responsiveness, sensitivity, and use of control, taking the child's developmental level into consideration (Landry, Miller-Loncar, Smith, & Swank, 2002). On the other hand, maternal overcontrol reflects excessive regulation of children's activities. This type of behavior is also characterized by intrusiveness and use of excessive demands (Gilliom & Shaw, 2004).

While the role of the caregiver in the development of children's self-regulation skills has been established, little research has examined whether the caregiver behavior has a similar influence on reactive and effortful control processes. One of the few studies that included multiple aspects of self-regulation found that toddlers who experienced low levels of maternal restrictiveness and high levels of cognitive stimulation had significantly better inhibitor control abilities, a component of effortful control, at age 8 while no effect was found for reactive control (Olson et al., 2002). An association between parenting behavior and children's effortful control has also been found in other studies, although measurements of reactive control were missing (Eisenberg et al., 2005; Lengua et al., 2003). Thus, initial evidence suggests that the caregiver behavior may have an effect on the development of children's effortful control processes but not their reactive control processes. The link between maternal behavior and effortful control but not reactive control is consistent with theoretical notions suggesting that reactive control has a stronger biological basis and therefore operates in an automatic/involuntary fashion whereas effortful control may be more amenable to socialization practices (Eisenberg & Morris, 2002). A recent genetic study has also identified reactive control processes as having a stronger genetic basis compared to effortful control (Oades et al., 2008). However, a major limitation in Olson and colleagues' study (2002) along with previous work that has examined how socialization factors predict reactive and effortful control processes was that it included only two time points, preventing the examination of a developmental trajectory. The examination of a developmental trajectory is crucial to determine whether maternal behavior affects children's initial reactive and/or effortful control processes and/or if it affects their growth rate.

A second goal of the current study was to examine whether a child's early emotion regulation skills affect the development of reactive and effortful control processes. Emotion regulation has been conceptualized as a process that involves both reactive and regulatory dimensions of emotional expressions (Fox & Calkins, 2003). The reactive dimension involves emotional reactivity which reflects the characteristic threshold, intensity, and duration of affective arousal whereas emotion regulation refers to the behaviors, skills, and strategies that modulate affective arousal in a way that facilitates adaptive functioning (Calkins, 2007; Rothbart & Bates, 2006). Considerable research has found that deficits in emotion regulation and higher levels of emotional reactivity are linked to greater levels of behavior problems, social functioning difficulties, and later psychopathology (Degnan, Calkins, Keane, & Hill-Soderlund, 2008; Eisenberg et al., 2009; Keenan, 2000; Graziano, Keane, & Calkins, 2007). While both emotional reactivity and regulation are considered aspects of temperament, emotional reactivity tends to be more stable across time compared to emotion regulation which is influenced by regulatory systems and socialization factors over time (Rothbart & Bates, 2006).

Both emotional reactivity and regulation are inherently tied to reactive and effortful control processes. For example, considerable research has documented early emotional reactivity as a predictor of reactive control processes, in particular reactive overcontrol or behavioral inhibition (Kagan, 1999) as well as reactive undercontrol or behavioral impulsivity as seen in children with ADHD (Jensen & Rosen, 2004). Research has also identified effortful control as playing an important role in facilitating emotion regulation efforts throughout development (Fox & Calkins, 2003; Posner & Rothbart, 2007). However, it remains unclear whether early success in regulating distressing emotions during toddlerhood leads to better effortful control in later childhood, especially when the use of effortful control processes occurs in more cognitively oriented tasks. This is an especially important question given that early emotion regulation skills entail several basic behavioral strategies that emerge prior to or jointly with effortful control such as self-stimulation, self-soothing, and help seeking (Fox & Calkins, 2003).

In summary, the purpose of the present study was to examine the role of maternal behavior along with children's early emotion regulation skills in the development of reactive control processes, specifically behavioral impulsivity, as well as later effortful control. Based on Derryberry and Rothbart (1997) along with Eisenberg and Morris' (2002) theoretical framework suggesting that socialization factors should have a stronger influence on effortful control versus more involuntary reactive control processes, we expected that early maternal behavior would predict children's later effortful control but not the development of their reactive control (i.e., behavioral impulsivity). Specifically, we predicted that early positive maternal behavior characterized by warmth and responsiveness at age 2 would be predictive of children's effortful control at age 5.5 while early negative maternal behavior characterized by overcontrol/intrusiveness would negatively predict children's effortful control at age 5.5. Lastly, we expected that children's early emotion regulation skills at age 2 would predict the development of reactive control, specifically behavioral impulsivity, (i.e., predict initial level of reactive control and greater improvement over time) as well as later effortful control abilities at age 5.5. This hypothesis was based on prior work documenting a strong association between emotion regulation and emotional reactivity, which is theoretically considered a reactive control process (Eisenberg & Morris, 2002; Fox & Calkins, 2003). Thus, a child who has early and successful experiences modulating their emotions to lower their emotional reactivity may also be more likely to modulate other reactive control dimensions such as behavioral impulsivity. Lastly, given the strong association between effortful control and emotion regulation (Fox & Calkins, 2003; Rothbart & Bates, 2006), we expected that early success in regulating distressing emotions via more basic behavioral strategies (e.g., self-soothing) during toddlerhood would generalize to more advanced cognitive self-regulation strategies (i.e., effortful control) in later childhood.

Method

Participants

Participants for this study included 435 children (225 girls) obtained from three different cohorts participating in a larger ongoing longitudinal study. Four hundred and forty seven participants were initially recruited at two years of age through child care centers, the County Health Department, and the local Women, Infants, and Children program. In order to obtain a broad, community-based sample of children with a wide range of disruptive behavior, potential participants were screened using the externalizing subscale of the Child Behavior Checklist (CBCL 2-3; Achenbach, 1992). Further details about the recruitment may be found in Smith, Calkins, Keane, Anastopoulos, and Shelton (2004), although it is pertinent to point out that children with externalizing problems were over-sampled. The recruitment sample was diverse with 67% percent of the children classified as European American, 27% as African American, 4% as biracial, and 2% as Hispanic. At age 2, the children were primarily from intact families (77%), and families were economically diverse, with Hollingshead (1975) scores ranging from 14 to 66 (M = 39.56). Of the original 447 participants, 399 participated at 4.5 years of age assessment. There were no significant differences between families who did and did not participate in terms of sex, race, 2-year SES, or 2-year externalizing T-scores. When children were 5.5 years of age, 365 families participated, including 4 who did not participate in the 4.5-year assessment. Again, there were no significant differences between families who did and did not participate at 5.5 years in terms of sex, race, SES, and 2-year externalizing T-scores.

Procedures

The focus of this study involved several laboratory assessments at the 2-year, 4.5-year, and 5.5-year visits. When the children were 2 years of age, mothers brought their children to the laboratory and were videotaped during several tasks designed to elicit emotion regulation and mother– child interaction. The high chair task, where the child was placed in a high chair without any toys or snacks for 5 minutes was used to code observed emotion regulation (LAB-TAB, Goldsmith & Rothbart, 1993). A teaching task where the mother was instructed to assist the child during a challenging task, a freeplay procedure in which the mother was instructed to play with her child as she would at home, and a clean up task where the mother was to try and get the child to clean up the toys from the freeplay session were all used to code observed maternal behavior. The tasks were ended early if the child was highly distressed or cried hard for more than 30 seconds. Follow up assessments took place when children were approximately 4.5 and 5.5 years of age. Similar to the 2 yr visit, mothers completed various questionnaires. Laboratory based measures assessing maternal behavior and emotion regulation were collected during the 2yr visit, a behavioral impulsivity parent questionnaire measure was collected during the 2yr, 4.5yr, and 5.5yr visit, and an effortful control laboratory task was conducted during the 5.5 yr visit.

Measures

Maternal Behavior—Maternal behavior during six mother-child interactions at 2 years of age were coded according to global indices of *warmth/positive affect* (displaying positive affect and warmth toward the child), s*ensitivity/responsiveness* (promptly and appropriately responding to the child's bids to her), and *overcontrol/intrusiveness* (exerting influence toward completion of the child's activity using directive methods; displaying a no-nonsense attitude; constantly and aversively guiding the child and creating a structured environment). These global codes were adapted from the Early Parenting Coding System (Winslow, Shaw, Bruns, & Kiebler, 1995). Each behavior was coded once for each episode on a 4-point scale (1 = low to 4 = high). Four coders trained on 10% of the videotaped sessions and independently coded another 10% for reliability. The adjusted Kappas for global codes were all above .70.

Emotion Regulation—Emotion regulation at 2 years of age was coded from videotapes of the frustration task (High Chair). The task was coded for global regulation and the frequency and effectiveness of various strategies such as self-stimulation, self-soothing, distraction, and help seeking. Global regulation was coded on a scale from 0, meaning dysregulated or no control of distress, to 4, meaning well regulated or when the child seemed to completely regulate his/her distress during most of the task. The various regulation strategies were also coded globally on a scale from 0, not used at all, to 2, often used throughout the task. The effectiveness of each strategy was coded globally on a scale from 0, never used, to 4, strategy use was always effective in regulating distress. Four coders trained on 10% of the videotaped sessions and independently coded another 10% for reliability. Reliability Kappas across codings were all above .72 (range = .72 to 1.0). The current study only used the *global regulation* code as it was thought to best index a child's level of appropriate regulation skills during the High Chair task.

Reactive Control

To obtain a parent measure of children's reactive control, the three impulsivity items from the AD/HD Rating Scale (DuPaul, Power, Anastopoulos, & Reid, 1998) were used. The impulsivity items include “blurts out answers,” “difficulty awaiting turn,” and “interrupts/intrudes on others.” Mothers rate the frequency (ranging from 0 = never to 3 = always) with which they observe their children engage in each item asked. The three items were summed and reversed score to create a reactive control score with higher numbers indicating higher levels of control. The alpha reliability for the reactive control score was .66. This measure was obtained at ages 2, 4.5, and 5.5.

Effortful Control

At 5.5-years of age, a Stroop task was used to measure children's effortful control abilities. In this task, children were presented with large pictures representing large shapes (animals, geometric figures). Within the larger pictures, smaller shapes were depicted. In half of the trials the small shapes were consistent with the large shape (e.g., a large cat was made up of identical smaller cats) and in the other half the shapes were inconsistent (e.g., large circles made up of small squares). The child was asked to recognize only the smaller shapes in the pictures presented and were instructed to answer as fast as possible. Prior to the start of the task examiners made sure that children understood the task via a practice trial. Children could receive a maximum of 48 points: 2 points for each correct answer, 1 point if they initially got it wrong but corrected themselves, and 0 points if they did not get it right. This *total score*, while controlling for the child's response speed, was used as this study's measure of cognitive inhibition at age 5.5.

Data analytic strategy

First, preliminary analyses (data reduction, descriptive statistics, and correlations among predictors) were computed. Next, growth curve analyses were conducted to examine the trajectory of reactive control across early childhood using hierarchical linear modeling (HLM; Raudenbush & Byrk, 2002). An advantage of growth curve modeling and HLM is the ability to account for missing data longitudinally with longitudinal sets that vary in terms of participants per waves as it allows for unbalanced designs so those children with incomplete outcome data could be included in the analyses (Singer & Willett, 2003). In the current study 341 children had some data (e.g., parent report and/or lab measure) at each time point; an additional 47 children had some data in two time points, while another 47 children had data on only one time point. Thus, a total of 435 children, who had at least one wave of data, were included in the analyses. This final sample of 435 children (225 girls) was racially (67% Caucasian) and economically diverse (Hollingshead scores ranging from 14 to 66 with a mean of 39.48). There were no significant differences in sex, race, or SES between children who provided 1, 2, or 3 waves of data. Additionally, there were no significant demographic differences between this study's sample and the original recruitment sample.

Measures of reactive control were obtained when children were 2, 4.5, and 5.5 years of age. All other variables (i.e., predictors such as maternal behaviors and emotion regulation as well as demographic variables) were assessed when children were 2-years of age. Age was centered at 2-years so that the intercept indicated initial levels of reactive control. The reactive control scores were converted into proportion scores and multiplied by 100 (with higher numbers indicating better behavioral inhibition) to facilitate HLM interpretation. Linear growth trajectories were fit using full maximum likelihood estimation and the results reported were based on the robust standard errors. Based on our hypotheses, we expected: a) growth in reactive control across time as evidenced by a significant Unconditional Growth Model and b) that children with better emotion regulation skills at age 2 would have higher initial levels of reactive control (i.e., less behavioral impulsivity) at age 2, as evidenced by a significant initial status effect, and would experience greater improvement over time as evidenced by a significant slope effect.

Lastly, because the laboratory measure for effortful control was only measured at age 5.5, it could not be examined via HLM. In addition, the laboratory measure of effortful control (Stroop task) was skewed (-1.68) with a large number of children obtaining perfect or close to perfect scores. As a result, a quartile split was performed and a Multivariate Analysis of Variance (MANOVA) was conducted to determine whether children in the high scoring group ($\geq 75^{th}$ percentile, n = 108) differed from the low scoring group ($\leq 25^{th}$ percentile, n =

80) in terms of maternal behaviors and emotion regulation. Based on our hypotheses, we expected that children in the high effortful control group to have had significantly higher levels of emotion regulation at age 2, as well as experienced greater levels of positive maternal behavior (i.e., warmth/responsiveness) and lower levels of negative maternal behavior (i.e., overcontrol/intrusiveness) compared to children in the low effortful control group.

Results

Preliminary analyses

Preliminary analyses focused on reducing the number of predictors. First, the global codes for the maternal behaviors were averaged across the six mother-child interactions as their alphas were highly reliable (.90 for warmth, .81 for overcontrol/intrusiveness, and .82 for responsiveness). Second, an examination of the relations between the maternal behavior composites indicated that maternal warmth and responsiveness were high related (r = .80, p<.001) and thus were averaged into a single maternal warmth/responsiveness composite. Next, the associations among predictors were examined. Maternal warmth/responsiveness was negatively associated with maternal overcontrol/intrusiveness (r = -.29, p<.001). This indicates that mothers who use a warm and responsiveness interaction style are less likely to interact with their children in an intrusive manner. Children's emotion regulation skills were negatively associated with maternal overcontrol/intrusiveness (r = -.12, p<.05). This indicates that children with better emotion regulation skills were less likely to have mothers who interacted with them in an intrusive manner compared to children with weaker emotion regulation skills. Finally, maternal education was positively related to maternal responsiveness/warmth (r = .35, p<.001) and negatively related to maternal overcontrol/intrusiveness (r = -.26, p<.001). Hence, this indicates that mothers with higher levels of education were more likely to interact with their children in a warm and responsive manner and less likely to interact with them in an intrusive manner compared to mothers with lower levels of education. Descriptive statistics for all of the study's variables are presented in Table 1.

Hierarchical linear modeling for reactive control

The unconditional means model (UMM) was first tested to determine whether there was sufficient variability in individuals' average scores on the dependent variable (i.e., reactive control) averaged over time. A significant UMM suggests that examining predictors in the model is warranted. Next, the unconditional growth model (UGM) was tested to determine if there is sufficient variability in the data over time. The UGM also addresses whether reactive control increases from the toddlerhood to early childhood period. Next, the variability in interindividual change in reactive control was examined by adding 2-year factors (demographic variables, emotion regulation, and maternal behaviors) to predict initial levels of reactive control and to predict increases or decreases in reactive control from 2-years to 5.5-years. The predictors of reactive control (emotion regulation and maternal behaviors) were placed in the model in a step wise fashion. The addition of each predictor that is placed in the model was compared to the previous model using the deviance statistic (when the model was nested within another model) or the Akaike information criterion (AIC) and/or the Bayesian Information Criterion (BIC) when the model was non-nested. The model with smaller deviance or the smaller AIC and/or BIC numbers fits the data better and should be preferred. Differences greater than 10 are considered to provide very strong evidence for favoring the model with the lower AIC and/or BIC score (Kass & Raftery, 1995). This index has been shown to be helpful in comparing non-nested models and penalizes the model for the number of parameters which helps prevent problems with overspecification (Singer & Willet, 2003).

The UMM and UGM for the maternal report of behavioral inhibition are presented as Models A and B in Tables 2 and 3. As indicated in Model A, the grand mean or fixed effect (table 2) for reactive control is significantly different from zero along with the estimated within-person variances (table 3). The dependent variable also had significant between-person variances (table 3) that differed from zero, indicating significant individual differences in average reactive control as reported by mothers. Because both variance components were not zero, additional predictors may improve model fit. The UGM in Model B shows that both initial status and slope were significantly different from zero (table 2). Specifically, it is estimated that children's reactive control abilities increase from 2 to 5.5-years of age. Graphically depicted in Figure 1, it is estimated that the average child (depicted by the thick grey line) has a reactive control score of 71.41 at 2-years with an increase in reactive control of .11 per month. This finding indicates that children's reactive control as reported by mothers show a significant increase from the toddlerhood to early childhood period. Moreover, 26% of within-person variation in reactive control is explained by age. However, as seen in Figure 1, there is significant variability in children's reactive control development. Further examination of the significant Level 2 residual variances (table 3) for the maternal report of reactive control, which summarize the between-person variability in initial status and rate of change, indicate that additional Level 2 predictors may improve model fit. Additionally, to determine whether the addition of time as a Level 1 predictor improved the model, the fit statistics were compared. Because the UMM is nested within the UGM, the deviance statistic can be used. The reduction in deviance due to the addition of time was statistically significant (χ^2 (3) = 9323 - 8937 = 386, $p<.001$).

Predicting reactive control development

Demographic variables—No initial status or slope effects were observed in regards to sex, race, socioeconomic level, or maternal education. This indicates that boys and girls alike as well as children from various racial and socioeconomic statuses have similar initial levels of reactive control as well as similar levels of reactive control growth over time.

Effect of Emotion Regulation and Maternal Behaviors—A significant effect of emotion regulation skills on children's initial levels of reactive control was found ($\Pi 0i$ = 1.88, $p<.05$). Children with higher levels of emotion regulation skills had higher levels of reactive control (i.e., lower levels of behavioral impulsivity) at age 2, as reported by mothers, compared to children with lower levels of emotion regulation skills. Emotion regulation skills did not significantly predict improvement in reactive control across time ($\Pi 1i$ = -.02, $p>.05$). In terms of the maternal behaviors, there was a marginal effect of maternal overcontrol/intrusiveness on children's initial levels of reactive control ($\Pi 0i$ = -2.35, $p<.08$) and growth over time ($\Pi 1i$ = -.10, $p<.08$). Thus, children whose mothers interacted with them in an overcontrolling/intrusive manner had lower levels of reactive control (i.e., higher levels of behavioral impulsivity) at age 2 and showed less improvement in reactive control across time compared to children whose mothers interacted with them in a less overcontrolling/intrusive manner. Maternal warmth did not have a significant effect on the initial status or slope of children's reactive control. No interactions were found among maternal behaviors or emotion regulation and the demographic variables.

Final Model—Table 2 contains the parameter estimates for the final model in the prediction of children's reactive control development. It combines the significant parameters found within models 1 and 2. Additionally, it tests the unique contribution of each predictor to ensure, for example, that the effect of maternal behavior on children's reactive control is not better explained by only having the emotion regulation variable. Lastly, the final model tests any potential interactions between predictors. Thus, Model C examined the joint main effects of emotion regulation and maternal overcontrol/intrusiveness. This model revealed that children's emotion regulation skills continued to significantly predict initial levels of reactive control, even after accounting for maternal overcontrol/intrusiveness. Maternal overcontrol/intrusiveness, on the other hand, no longer had a significant effect on children's initial levels of reactive control but continued to exert a marginal effect on reactive control growth across time. Model D examined the potential interaction between children's emotion regulation skills and maternal overcontrol/intrusiveness. The interaction between emotion regulation skills and maternal overcontrol/intrusiveness was not significantly related to the initial status or slope of reactive control in this final model. As seen in Table 3, comparison of the goodness-of-fit statistics between the model that included emotion regulation and maternal overcontrol/intrusiveness (Model C) and Model B (unconditional growth model) revealed a lower AIC and BIC statistic suggesting a better fit. Thus, the best fitting model for the prediction of children's reactive control was Model C.

Predicting effortful control

Before conducting the MANOVA, demographic/control variables were examined to determine possible covariates. These analyses found that children in the high effortful control group (i.e., high scores on the Stroop) had significantly higher levels of maternal education ($M = 3.66$, $SD = .88$, $t(204) = 4.75$, $p<.001$) and socioeconomic levels ($M = 41.56$, $SD = 11.08$, $t(199) = 2.81$, $p<.01$) compared to children in the low effortful control group ($M = 3.08$, $SD = .87$ and $M = 37.28$, $SD = 10.05$, respectively). No other differences were noted. As a result of such differences, both SES and maternal education were covaried in the MANOVA. The child's response speed during the stroop task was also covaried. The initial MANOVA was significant ($F(3, 181) = 9.97$, $p<.001$, partial eta squared = .14) with significant follow up ANOVAs for maternal warmth/responsiveness ($F(1, 183) = 15.42$, $p<.001$, partial eta squared = .08) and maternal overcontrol/intrusiveness ($F(1,183) = 14.03$, $p<.001$, partial eta squared = .07). These results, which are depicted in Figure 1, indicate that children in the high effortful control group at age 5.5 had mothers who interacted with them at age 2 with significantly more warmth/responsiveness (estimated marginal $M = .17$ $SE = .09$) and were less overcontrolling/intrusiveness (estimated marginal $M = -.22$ $SE = .10$) compared to mothers from children in the low effortful control group (estimated marginal $M = -.40$, $SE = .11$, estimated marginal $M = .37$, $SE = .11$, respectively). No effect was noted for emotion regulation.

Discussion

The purpose of the current study was to examine the role of maternal behavior and children's early emotion regulation skills in the development of children's reactive control, specifically behavioral impulsivity, and later effortful control. This study attempted to address several gaps in the literature to determine whether socialization factors (e.g., maternal behavior) and temperamental/individual factors (e.g., emotion regulation) differentially predict reactive and effortful control processes. First, it is important to note that the current study found significant growth in children's reactive control (i.e., a decrease in behavioral impulsivity across time) from the toddlerhood to early childhood period. While previous studies (Berwid et al., 2005; Kochanska, Murray, Jacques, & Koenig, 1996; Kochanska, Murray, & Harlan, 2000; Olson et al., 2002) had documented increases in various self-regulation processes over this period, this marks the first study to date that has longitudinally examined the development of a reactive control process (i.e., behavioral impulsivity) utilizing growth curve modeling. The significant growth in reactive control between toddlerhood and early childhood found in this study indicates a reduction in children's behavioral impulsivity across time and is consistent with recent findings showing increases in children's other self-regulation and executive functioning skills between the ages of 3 and 5 that are thought to be crucial in regulating impulsivity (Stahl & Pry, 2005; Zelazo, 2006; Zelazo & Muller, 2003).

Previous neuroscience work has established relative distinct neural pathways for reactive and effortful control processes (Posner & Rothbart, 2007). The unique contributions of both reactive and effortful control processes to various developmental outcomes (e.g., social competence, externalizing and internalizing symptoms) have also been established (Eisenberg et al., 2004; 2009). Our study extends such work by providing support that these related yet distinct control processes may also have different etiological factors that contribute to their development as we found partial support for the notion that maternal behavior and children's early emotion regulation skills differentially predict children's reactive control development and later effortful control abilities. It is also important to point out that we found no sex differences in any of these associations suggesting that boys and girls show relatively similar levels of reactive and effortful control from toddlerhood to early childhood. Past research has found that boys tend to exhibit greater levels of behavioral impulsivity (i.e., worse reactive control) and poorer effortful control compared to girls (Chapple & Johnson, 2007; Eisenberg et al., 2003; 2005). However, these studies tended to focus on school age children. Hence, it appears that sex differences in these self-regulation domains may become more evident as children enter school. These emerging sex differences may be due to the fact that deficits in self-regulation are more readily seen in the school environment, which has been documented as being particularly challenging for children as they must now independently use their self-regulation skills to adapt to novel demands of learning and interpersonal skills (Rimm-Kaufman & Pianta, 2000).

Maternal behavior as a predictor of children's reactive and effortful control

Maternal behavior characterized by high levels of overcontrol/intrusiveness at age 2 was found to negatively predict children's effortful control at age 5.5 while maternal behavior characterized by high levels of warmth/responsiveness was found to positively predict children's effortful control at age 5.5. Maternal behavior characterized by high levels of overcontrol/intrusiveness at age 2 was marginally related to lower levels of reactive control growth. While the role of the caregiver in children's self-regulation development has been widely documented (Calkins, 2007), it remained unclear the extent to which caregiver behavior affects various self-regulation abilities. Given the strong biological basis and emotional driven aspect of reactive control processes as well as research from the ADHD and animal literature suggesting that maternal behaviors do not have a direct influence on behavioral impulsivity (Barkley, 1997; Groot et al., 2004), we predicted that maternal behavior would not have a direct effect on children's reactive control development. However, we did find that maternal behavior characterized by high levels of overcontrol/intrusiveness at age 2 was marginally related to lower levels of reactive control growth. Maternal behavior also predicted children's effortful control abilities.

These findings add to recent literature documenting the effects of caregiving on behavioral, cognitive, and physiological indices of self-regulation in humans (Calkins, Graziano, Berdan, Keane, & Degnan, 2008; Crockenberg & Leerkes, 2006; Eisenberg et al., 2005) and on animal work demonstrating the multiple levels of influence of early caregiving (Polan & Hofer, 1999). It also extends the literature by demonstrating that maternal behavior is associated with multiple aspects of children's control processes (i.e., reactive and effortful control). However, it is important to note that there was a stronger association between maternal behaviors and effortful control. This stronger association between maternal behavior and effortful control rather than reactive control is consistent with previous research (Derryberry & Rothbart, 1997; Eisenberg & Morris, 2002; Olson et al., 2002) suggesting that socialization factors have a stronger influence on effortful control versus more involuntary reactive control processes. In addition, it appears that the link between maternal behaviors and children's self-regulation skills occur across situations and not necessarily only during teaching moments.

Although the current study did not test any mechanisms by which maternal behaviors facilitates children's reactive and effortful control skills, it may be that maternal behavior that is intrusive and hostile elevates children's stress levels which have been shown to affect various neurological systems associated with self-regulation (Francis, Caldji, Champagne, Plotsky, & Meaney, 1999). On the other hand and consistent with the notion of scaffolding, maternal behavior characterized by positive affect and appropriate responsiveness encourages children not only to respond to the demands of the situation but also allows them to independently learn how to solve problems. These maternal behaviors may in turn not only either foster or hinder the toddlers' ability to integrate environmental experiences into their emerging repertoire of self-regulatory skills but may also affect physiological systems that are important for the development of higher order cognitive skills. For example, more recent work has found that a high quality mother-child relationship is associated with better physiological functioning (i.e., respiratory sinus arrhythmia [RSA] suppression, a physiological regulation construct frequently linked to emotion regulation) that is thought to promote children's higher order coping skills such as attentional disengagement (Calkins et al., 2008). Similar links between caregiver behavior and offspring's physiological functioning has been documented in the animal literature (Caldji et al., 1998; Hofer, 1994; Lovic & Fleming, 2004).

Children's early emotion regulation skills as a predictor of reactive and effortful control

We expected that children's early emotion regulation skills at age 2 would predict the development of reactive control, specifically behavioral impulsivity, (i.e., predict initial level of reactive control and greater improvement over time) as well as later effortful control abilities at age 5.5. Consistent with this hypothesis, toddlers with better emotion regulation skills did display higher initial levels of reactive control (i.e., lower behavioral impulsivity) as reported by mothers at 2 years of age. No effects were found in terms of the rate of change of reactive control. This indicates that although children's initial levels of reactive control varied as a function of their emotion regulation skills, the rate at which their reactive control skills grew over time were similar. Counter to our hypothesis, toddlers' emotion regulation skills did not predict effortful control abilities in early childhood.

The link between early emotion regulation skills and reactive control (i.e., lower behavioral impulsivity) was not surprising given previous work suggesting a strong link between emotion regulation and emotional reactivity, a reactive control process (Eisenberg & Morris, 2002; Fox & Calkins, 2003). Thus, a child who has early and successful experiences modulating their emotions to lower their emotional reactivity appears to also be more likely to modulate other reactive control dimensions such as behavioral impulsivity. This type of generalization makes sense from a self-regulation framework. For example, it is well established that as early as the neonatal period, infants show individual differences in the ability to regulate distress (Kopp, 1982; Rothbart, Ziaie, & Boyle, 1992). Successful modulation of such distress allows infants to build their behavioral and physiological repertoire of self-regulatory skills (Calkins, 2007). Significant increases in motor and language development during the toddlerhood period along with greater external demands placed by the caregiver, place the toddler at an increase need to be able to modulate their motor and verbal behaviors (Fox and Calkins, 2003). Not surprisingly, then, infants and toddlers who have built a repertoire of self-regulatory skills based on regulating past distress/emotions have an easier time applying such self-regulatory skills to modulate their newly occurring motor and verbal behaviors, thus appearing to be less impulsive.

It is also important to note that children with better emotion regulation skills in toddlerhood had higher initial rates of reactive control, but contrary to expectations did not have higher rates of growth across time. Reactive control processes such as emotional reactivity tend to be relatively stable across development (Rothbart & Bates, 2006). The influence of self-regulation strategies on reactive control processes such as emotional reactivity and behavioral inhibition have also been documented as occurring rapidly during the first 2 years of life (Fox & Calkins, 2003; Kochanska, 1997). Thus, it may also be the case that individual differences in reactive undercontrol (i.e., behavioral impulsivity) are most readily seen within the first two years. Our finding highlights not only the importance of examining early emotion regulation skills as predictors of other reactive control processes such as behavioral impulsivity but also suggests that toddlerhood may be an important period for interventions, especially for toddlers who are having difficulty regulating distress.

The lack of association between children's early emotion regulation skills and later effortful control was surprising given that effortful control has been widely documented as having an important role in children's emotion regulation development (Fox & Calkins, 2003; Eisenberg et al., 2009; Rothbart & Bates, 2006). Thus, it appears that having early success in regulating one's emotions via basic behavioral strategies (e.g., self-soothing, self-stimulation) in toddlerhood does not necessarily generalize to more advanced cognitive self-regulation strategies (i.e., effortful control) in later childhood. It is important to point out that the effortful control task that was used in the current study was a more cognitively based task (stroop). Thus, it is possible that children's early successful experiences in regulating emotions can facilitate the use of more advanced self-regulation strategies during similar emotional situations. Lastly, given the well documented bidirectional association between caregiver behavior and child temperament (Calkins, 2007), a more indirect link between early emotion regulation skills and later effortful control may exist in which toddlers with better emotion regulation skills elicit more supportive caregiver behaviors and less negative behaviors, which in turn promote the development of more complex self-regulation (i.e., effortful control).

Limitations and future directions

In terms of this study's limitations, a couple of methodological issues need to be acknowledged. First, the lab measure of effortful control was not available at all time points preventing a trajectory analysis. Second, the predictors (emotion regulation and maternal behaviors) were time invariant meaning that they were assessed at the initial time point. For the HLM analysis this assumes that such constructs are stable across time. Since emotion regulation abilities are also growing during this developmental period, a model that takes into account such dynamic changes by having multiple measures of emotion regulation across time would provide answers to other potentially interesting questions. For example, does emotion regulation growth or stability predict better reactive control development? Another important limitation to acknowledge of having time invariant predictors is the inability to determine the directionality of their associations. Thus, it may also be the case that toddlers with lower levels of reactive control (i.e., higher levels of behavioral impulsivity) were more likely to elicit negative maternal behaviors. Future studies may be able to address the directionality of their associations by examining whether changes in the trajectories of maternal behavior or emotion regulation overtime directly map onto changes in reactive control. Lastly, it is important to note that a child's reactive and effortful control abilities along with his or her ability to regulate distress/emotions all contribute to the multi-facet aspect of self-regulation development. It will be important for future research to not only continue to examine how all three facets of self-regulation develop, relate to each other, and predict outcomes, but also to examine whether and how socialization factors can change these aspects of self-regulation as it may have tremendous implications for treatment/early interventions.

References

Achenbach, TM. Manual for the Child Behavior Checklist/2-3 & 1992 Profile. Burlington, VT: University of VT Department of Psychiatry; 1992.

Archibald S, Kerns K. Identification and description of new tests of executive functioning in children. Child Neuropsychology. 1999; 5(2):115–129.

Aron A, Poldrack R. The cognitive neuroscience of response inhibition: relevance for genetic research in ADHD. Biological Psychiatry. 2005; 57:1285–92. [PubMed: 15950000]

Avila C, Cuenca I, Felix V, Parcet M, Miranda A. Measuring impulsivity in school-aged boys and examining its relationship with ADHD and ODD ratings. Journal of Abnormal Child Psychology. 2004; 32(3):295–304. [PubMed: 15228178]

Barkley R. Attention-deficit/hyperactivity disorder, self-regulation, and time: Toward a more comprehensive theory. Journal of Developmental & Behavioral Pediatrics. 1997; 18:271–279. [PubMed: 9276836]

Berwid O, Kera E, Marks D, Santra A, Bender H, Halperin J. Sustained attention and response inhibition in young children at risk for attention deficit-hyperactivity disorder. Journal of Child Psychology and Psychiatry. 2005; 46:1219–129. [PubMed: 16238669]

Caldji C, Tannenbaum B, Sharma S, Francis D, Plotsky PM, Meaney MJ. Maternal care during infancy regulates the development of neural systems mediating the expression of fearfulness in the rat. Neurobiology. 1998; 9:5335–5340.

Calkins, S. The Emergence of Self-regulation: Biological and Behavioral Control Mechanisms Supporting Toddler Competencies. In: Brownell, C.; Kopp, C., editors. Socioemotional Development in the Toddler Years. New York: The Guilford Press; 2007. p. 261-284.

Calkins S, Graziano P, Berdan L, Keane S, Degnan K. Predicting cardiac vagal regulation in early childhood from maternal-child relationship quality during toddlerhood. Developmental Psychobiology. 2008; 50:751–766. [PubMed: 18814182]

Calkins, SD.; Hill, AL. Caregiver influences on emerging emotion regulation: Biological and environmental transactions in early development. In: Gross, J., editor. Handbook of emotion regulation. New York: The Guilford Press; 2007. p. 229-248.

Cassidy J. Emotion regulation: influences of attachment relationships. Monographs of the Society of Research in Child Development. 1994; 59:228–249.

Chapple C, Johnson K. Gender differences in impulsivity. Youth Violence and Juvenile Justice. 2007; 5(3):221–234.

Crockenberg S, Leerkes E. Infant and maternal behavior moderate reactivity to novelty to predict anxious behavior at 2.5 years. Development and Psychopathology. 2006; 18:17–34. [PubMed: 16478550]

Cumberland-Li A, Eisenberg N, Reiser M. Relations of Young Children's Agreeableness and Resiliency to Effortful Control and Impulsivity. Social Development. 2004; 13(2):193–212.

Degnan K, Calkins S, Keane S, Hill-Soderlund A. Profiles of disruptive behavior across early childhood: Contributions of frustration reactivity, physiological regulation, and maternal behavior. Child Development. 2008; 79(5):1357–1376. [PubMed: 18826530]

Derryberry D, Rothbart M. Reactive and effortful processes in the organization of temperament. Development and Psychopathology. 1997; 9(4):633–652. [PubMed: 9448999]

Dubow E, Boxer P, Huesmann L. Childhood and adolescent predictors of early and middle adulthood alcohol use and problem drinking: The Columbia County Longitudinal Study. Addiction. 2008; 103:36–47. [PubMed: 18426539]

DuPaul, GJ.; Power, TJ.; Anastopoulos, AD.; Reid, R. ADHD Rating Scale-IV. New York: Guilford Press; 1998.

Eisenberg N, Cumberland A, Spinrad T, Fabes R, Shepard S, Reiser M, et al. The relations of regulation and emotionality to children's externalizing and internalizing problem behavior. Child Development. 2001; 72(4):1112–1134. [PubMed: 11480937]

Eisenberg N, Guthrie I, Fabes R, Reiser M, Murphy B, Holgren R, et al. The relations of regulation and emotionality to resiliency and competent social functioning in elementary school children. Child Development. 1997; 68(2):295–311. [PubMed: 9180003]

Eisenberg, N.; Morris, A. Advances in child development and behavior. Vol. 30. San Diego, CA US: Academic Press; 2002. Children's emotion-related regulation; p. 189-229.

Eisenberg N, Spinrad T, Fabes R, Reiser M, Cumberland A, Shepard S, et al. The Relations of Effortful Control and Impulsivity to Children's Resiliency and Adjustment. Child Development. 2004; 75(1):25–46. [PubMed: 15015673]

Eisenberg N, Valiente C, Spinrad T, Cumberland A, Liew J, Reiser M, et al. Longitudinal relations of children's effortful control, impulsivity, and negative emotionality to their externalizing, internalizing, and co-occurring behavior problems. Developmental Psychology. 2009; 45(4):988–1008. [PubMed: 19586175]

Eisenberg N, Zhou Q, Spinrad T, Valiente C, Fabes R, Liew J. Relations Among Positive Parenting, Children's Effortful Control, and Externalizing Problems: A Three-Wave Longitudinal Study. Child Development. 2005; 76(5):1055–1071. [PubMed: 16150002]

Fairbanks L, Newman T, Bailey J, Jorgensen M, Breidenthal S, Ophoff R, et al. Genetic contributions to social impulsivity and aggressiveness in vervet monkeys. Biological Psychiatry. 2004; 55(6): 642–647. [PubMed: 15013834]

Francis DD, Caldji C, Champagne F, Plotsky PM, Meaney MJ. The role of cortcotropin-releasing factor-norepinephrine systems in mediating the effects of early experience on the development of behavioral and endocrine responses to stress. Biological Psychiatry. 1999; 46:1153–1166. [PubMed: 10560022]

Fox N, Calkins S. The development of self-control of emotion: intrinsic and extrinsic influences. Motivation and Emotion. 2003; 27:7–26.

Fox N, Henderson H, Marshall P, Nichols K, Ghera M. Behavioral inhibition: linking biology and behavior within a developmental framework. Annual Review of Psychology. 2005; 56:235–262.

Gartstein M, Fagot B. Parental depression, parenting and family adjustment, and child effortful control: Explaining externalizing behaviors for preschool children. Journal of Applied Developmental Psychology. 2003; 24(2):143–177.

Gilliom M, Shaw D. Codevelopment of externalizing and internalizing problems in early childhood. Development and Psychopathology. 2004; 16(2):313–333. [PubMed: 15487598]

Goldsmith, HH.; Rothbart, MK. The laboratory temperament assessment battery (LAB-TAB). University of Wisconsin; 1993.

Graziano P, Keane S, Calkins S. Cardiac Vagal Regulation and Early Peer Status. Child Development. 2007; 78(1):264–278. [PubMed: 17328704]

Greenberg M, Speltz M, DeKlyen M. The role of attachment in the early development of disruptive behavior problems. Development and Psychopathology. 1993; 5(1):191–213.

Groot AS, Sonneville LMJ, Stins JF, Boomsma DI. Familial influences on sustained attention and inhibition in preschoolers. Journal of Child Psychology and Psychiatry. 2004; 45:306–314. [PubMed: 14982244]

Gunnar, MR. Social regulation of stress in early child development. In: McCartney, K.; Phillips, D., editors. Blackwell handbook of early childhood development. Blackwell Publishing; 2006. p. 106-125.

Herba C, Tranah T, Rubia K, Yule W. Conduct Problems in Adolescence: Three Domains of Inhibition and Effect of Gender. Developmental Neuropsychology. 2006; 30(2):659–695. [PubMed: 16995831]

Hinshaw S. Academic underachievement, attention deficits, and aggression: Comorbidity and implications for intervention. Journal of Consulting and Clinical Psychology. 1992; 60(6):893–903. [PubMed: 1460150]

Hinshaw S, Melnick S. Peer relationships in boys with attention-deficit hyperactivity disorder with and without comorbid aggression. Development and Psychopathology. 1995; 7(4):627–647.

Hofer MA. Early relationships as regulators of infant physiology and behavior. Acta Paediatric Supplement. 1994; 397:9–18.

Kagan, J. Extreme fear, shyness, and social phobia: Origins, biological mechanisms, and clinical outcomes. New York, NY US: Oxford University Press; 1999. The concept of behavioral inhibition; p. 3-13.

Kass RE, Raftery AE. Bayes factors. Journal of the American Statistical Association. 1995; 90:773–795.

Keenan K. Emotion dysregulation as a risk factor for child psychopathology. Clinical Psychology: Science and Practice. 2000; 7(4):418–434.

Kochanska G. Multiple pathways to conscience for children with different temperaments: From toddlerhood to age 5. Developmental Psychology. 1997; 33:228–240. [PubMed: 9147832]

Kochanska G, Murray K, Harlan E. Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. Developmental Psychology. 2000; 36:220–232. [PubMed: 10749079]

Kochanska G, Murray K, Jacques T, Koenig A. Inhibitory control in young children and its role in emerging internalization. Child Development. 1996; 67(2):490–507. [PubMed: 8625724]

Kopp C. Antecedents of self-regulation: A developmental perspective. Developmental Psychology. 1982; 18:199–214.

Landry S, Miller-Loncar C, Smith K, Swank P. The role of early parenting in children's development of executive processes. Developmental Neuropsychology. 2002; 21:15–41. [PubMed: 12058834]

Lengua L, Honorado E, Bush N. Contextual risk and parenting as predictors of effortful control and social competence in preschool children. Journal of Applied Developmental Psychology. 2007; 28(1):40–55.

Livesey D, Keen J, Rouse J, White F. The relationship between measures of executive function, motor performance and externalising behaviour in 5- and 6-year-old children. Human Movement Science. 2006; 25(1):50–64. [PubMed: 16442172]

Loesch D, Bui Q, Grigsby J, Butler E, Epstein J, Huggins R, et al. Effect of the fragile X status categories and the fragile X mental retardation protein levels on executive functioning in males and females with fragile X. Neuropsychology. 2003; 17:646–657. [PubMed: 14599277]

Logan, G. On the ability to inhibit thought and action: A user's guide to the stop-signal paradigm. In: Dagenbach, D.; Carr, T., editors. Inhibitory processes in attention, memory, and language. New York: Academic; 1994. p. 189-239.

Lovic V, Fleming A. Artificially-reared female rats show reduced prepulse inhibition and deficits in the attentional set shifting task—reversal of effects with maternal-like licking stimulation. Behavioral Brain Research. 2004; 148:209–219.

Moffitt TE. Adolescence-limited and life-course-persistent antisocial behavior: A developmental taxonomy. Psychological Review. 1993; 100(4):674–701. [PubMed: 8255953]

Moffitt T, Caspi A, Rutter M, Silva P. Review of Sex Differences in Antisocial Behaviour: Conduct Disorder, Delinquency and Violence in the Dunedin Longitudinal Study. Psychological Medicine. 2002; 32(8):1475–1476.

Murphy B, Eisenberg N, Fabes R, Shepard S, Guthrie I. Consistency and change in children's emotionality and regulation: A longitudinal study. Merrill-Palmer Quarterly. 1999; 45(3):413–444.

Oades R, Lasky-Su J, Christiansen H, Faraone S, Sonuga-Barke E, Banaschewski T, et al. The influence of serotonin- and other genes on impulsive behavioral aggression and cognitive impulsivity in children with attention-deficit/hyperactivity disorder (ADHD): Findings from a family-based association test (FBAT) analysis. Behavioral and Brain Functions. 2008; 4

Olson S, Bates J, Bayles K. Early antecedents of childhood impulsivity: the role of parent-child interaction, cognitive competence, and temperament. Journal of Abnormal Child Psychology. 1990; 18:317–334. [PubMed: 2376656]

Olson S, Bates J, Sandy J, Schilling E. Early developmental precursors of impulsive and inattentive behavior: From infancy to middle childhood. Journal of Child Psychology and Psychiatry. 2002; 43(4):435–448. [PubMed: 12030590]

Olson S, Schilling E, Bates J. Measurement of impulsivity: Construct coherence, longitudinal stability, and relationship with externalizing problems in middle childhood and adolescence. Journal of Abnormal Child Psychology. 1999; 27(2):151–165. [PubMed: 10400061]

Polan, HJ.; Hofer, MA. Psychobiological origins of infant attachment and separation responses. In: Cassidy, J.; Shaver, PR., editors. Handbook of attachment: Theory, research, and clinical applications. New York: Guilford Press; 1999. p. 162-180.

Posner, M. Progress in attention research. In: Posner, M., editor. Cognitive neuroscience of attention. New York: The Guilford Press; 2004. p. 3-9.

Posner M, Rothbart M. Research on Attention Networks as a Model for the Integration of Psychological Science. Annual Review of Psychology. 2007; 58:1–23.

Putnam S, Rothbart M, Gartstein M. Homotypic and heterotypic continuity of fine-grained temperament during infancy, toddlerhood, and early childhood. Infant and Child Development. 2008; 17(4):387–405.

Raudenbush, SW.; Bryk, AS. Hierarchical linear models: Applications and data analysis methods. 2nd. Newbury Park, CA: Sage; 2002.

Rice D, Barone S Jr. Critical periods of vulnerability for the developing nervous system: Evidence from humans and animal models. Environmental Health Perspectives. 2000; 108:511–33. [PubMed: 10852851]

Rimm-Kaufman S, Pianta R. An ecological perspective on the transition to kindergarten: A theoretical framework to guide empirical research. Journal of Applied Developmental Psychology. 2000; 21:491–511.

Rothbart MK, Ahadi SA, Hershey KL, Fisher P. Investigations of temperament at three to seven years: The Children's Behavior Questionnaire. Child Development. 2001; 72(5):1394–1408. [PubMed: 11699677]

Rothbart, M.; Bates, J. Handbook of child psychology: Vol 3, Social, emotional, and personality development. 6th. Hoboken, NJ, US: John Wiley & Sons Inc.; 2006. Temperament; p. 99-166.

Rothbart M, Ziaie H, Boyle C. Self-regulation and emotion in infancy. New Directions for Child Development. 1992; 55:7–23. [PubMed: 1608516]

Rubia K, Smith A, Brammer M, Toone B, Taylor E. Abnormal Brain Activation During Inhibition and Error Detection in Medication-Naive Adolescents With ADHD. American Journal of Psychiatry. 2005; 162(6):1067–1075. [PubMed: 15930054]

Saudino K. Special Article: Behavioral Genetics and Child Temperament. Journal of Developmental & Behavioral Pediatrics. 2005; 26(3):214–223. [PubMed: 15956873]

Sergeant J. The cognitive-energetic model: An empirical approach to attention-deficit hyperactivity disorder. Neuroscience & Biobehavioral Reviews. 2000; 24(1):7–12. [PubMed: 10654654]

Singer, J.; Willet, J. Applied longitudinal data analysis. New York: Oxford University Press; 2003.

Smith C, Calkins S, Keane SP, Anastopoulos A, Shelton T. Predicting stability and change in toddler behavior problems: Contributions of maternal behavior and child gender. Developmental Psychology. 2004; 40:29–42. [PubMed: 14700462]

Sroufe L. Early relationships and the development of children. Infant Mental Health Journal. 2000; 21:67–74.

Stahl L, Pry R. Attentional flexibility and perseveration: Developmental aspects in young children. Child Neuropsychology. 2005; 11:175–189. [PubMed: 16036443]

Vygotsky, LS. Mind in society: The development of higher mental processes. Cole, M.; John-Steiner, V.; Scribner, S.; Souberman, E., editors. Cambridge, MA: Harvard University Press; 1978.

Wassenberg R, Hendriksen J, Hurks P, Feron F, Keulers E, Vles J, et al. Development of inattention, impulsivity, and processing speed as measured by the d2 Test: Results of a large cross-sectional study in children aged 7-13. Child Neuropsychology. 2008; 14(3):195–210. [PubMed: 17852129]

White JL, Moffitt TE, Caspi A, Bartusch DJ, Needles DJ, Stouthamer-Loeber M. Measuring impulsivity and examining its relationship to delinquency. Journal of Abnormal Psychology. 1994; 103:192–205. [PubMed: 8040489]

Winsler A, Diaz R, McCarthy E, Atencio D, Chabay L. Mother-child interaction, private speech, and task performance in preschool children with behavior problems. Journal of Child Psychology and Psychiatry. 1999; 40(6):891–904. [PubMed: 10509884]

Winslow, EB.; Shaw, DS.; Bruns, H.; Kiebler, K. Parenting as a mediator of child behavior problems and maternal stress, support, and adjustment. Paper presented at the biennial meeting of the Society for Research in Child Development; Indianapolis, IN. 1995.

Wood D, Middleton D. A study of assisted problem-solving. British Journal of Psychology. 1975; 66:181–191.

Zelazo, P.; Muller, U. Executive function in typical and atypical development. In: Goswami, U., editor. Blackwell Handbook of Childhood Cognitive Development. Blackwell Publishing; 2003. p. 445-469.

Zelazo P. The dimensional change card sort (DCCS): A method of assessing executive function in children. Nature Protocols. 2006; 1:297–301.

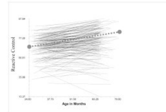

Figure 1.
Unconditional growth model. Black lines indicate individual growth trajectories using ordinary least squares (OLS; Singer & Willet, 2003). Grey line depicts average growth trajectory.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

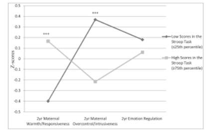

Figure 2.
Profiles of children with low vs. high effortful control abilities at 5.5yrs of age.
*** indicates a significant difference at p<.001 between the groups while controlling for maternal education, SES, and speed of response on the stroop task.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 1

Descriptive statistics for all variables

	M	SD	Min	Max	N
2yr Measures					
Maternal warmth (L)	3.07	.75	1.17	4	428
Maternal responsiveness (L)	3.18	.67	1.17	4	428
Maternal overcontrol/intrusiveness (L)	2.36	.61	1	4	428
Emotion regulation (L)	3.27	.89	0	4	423
Reactive Control (P)	70	18	0	100	394
4.5yr Measures					
Reactive Control (P)	71	19	0	100	372
5.5yr Measures					
Reactive Control (P)	73	21	0	100	321
Effortful Control (L)	42.55	7.31	19	48	333

(P) = parent report, (L) = laboratory measure

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 2

Results of best fitting hierarchical linear models for change in reactive control from toddlerhood to early childhood (N = 435)

Fixed effects	Par	Model A (UMM)	Model B (UGM)	Model C	Model D
Initial Status Π0i					
Intercept	γ00	71.22*** (.77)	71.41*** (.77)	71.07*** (.82)	71.18*** (.82)
Emotion regulation	γ01			1.72* (.84)	1.73* (.84)
Maternal overcontrol/intrusiveness	γ02			-1.91 (1.35)	-1.79 (1.35)
Maternal overcontrol/intrusiveness * Emotion regulation	γ03				1.48 (1.39)
Slope Π1i (age)					
Intercept	γ10		.11*** (.03)	.09** (.03)	.10** (.03)
Emotion regulation	γ11			-.02 (.04)	-.03 (.04)
Maternal overcontrol/intrusiveness	γ12			-.10+ (.06)	-.10+ (.06)
Maternal overcontrol/intrusiveness * Emotion regulation	γ13				.06 (.06)

Note.

+ $p<.08$,

* $p<.05$,

** $p<.01$,

*** $p<.001$.

UMM = Unconditional means model, UGM = Unconditional growth model

Table 3

Variance components and fit statistics for hierarchical linear modeling models for change in reactive control from toddlerhood to early childhood (N = 435)

	Par	Model A (UMM)	Model B (UGM)	Model C	Model D
Random Effects (Variance Components)					
Level 1					
Within person	$\sigma^2 e$	201.14*** (10.88)	149.79*** (12.44)	157.09*** (13.73)	157.34*** (13.71)
Level 2					
In initial status	$\sigma^2 0$	166.33*** (17.25)	177.89*** (17.64)	181.12*** (19.05)	178.86*** (18.93)
In slope (age)	$\sigma^2 1$		.14*** (.04)	.14*** (.04)	.14*** (.04)
Fit Statistics					
Deviance		9323.38	8936.66	8208.67	8207.00
AIC		9329.38	8948.66	8228.67	8231.00
BIC		9344.36	8978.39	8277.33	8289.40

Note.

* $p < .05$,

** $p < .01$,

*** $p < .001$.

UMM = Unconditional means model, UGM = Unconditional growth model