Differentiating Processes of Control and Understanding in the Early Development of Emotion and Cognition

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Abstract:

In this study, we examined the hypothesis that preschoolers' performance on emotion and cognitive tasks is organized into discrete processes of control and understanding within the domains of emotion and cognition. Additionally, we examined the relations among component processes using mother report, behavioral observation, and physiological measures of emotion control. Participants were 263 children (42 percent non-White) and their mothers. Results indicated that the three approaches of measuring emotion control were unrelated. Regardless of the measurement method, a four-factor solution differentiating emotion control and understanding and cognitive control and understanding fits the data better than did either of two two-factor models, one based on domains of emotion and cognition across processes, and one based on processes of control and understanding across domains. Results of this research replicate those of Leerkes et al. in describing a differentiated underlying structure of emotion and cognition processes in early childhood while also extending these conclusions across samples and across measurement approaches for assessing emotion control.

Keywords: emotion | theory of mind | executive function | preschool

Article:

Introduction

In early child development research, the domains of emotion and cognition have often been treated independently. Only recently has research been conducted to address the contributions of emotional processes to academic performance (e.g., Trentacosta & Izard, 2007), or cognitive processes to social skills (e.g., Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008). Additionally, the interconnections between emotion and cognition have not been thoroughly explored, although there is increasing recognition that integration across these areas would lead to increases in our understanding of early development in home, school, and peer contexts (Blair & Diamond, 2008;Gray, 2004). The principal aim of the present research was to examine a hypothesized underlying organization of emerging skills in emotion and cognition. A second aim was to take a multi-method approach to the assessment of emotion control to determine whether the hypothesized underlying relations among various emotion and cognitive processes are similar across methods of assessing emotion control. The rationale for each of these aims is described below.

Structural Relations among Emotion and Cognition Processes

Several areas of research have emerged that examine both emotion and cognition processes simultaneously. Firstly, recent work in the area of self-regulation in both children and adults suggests that both emotional *and* cognitive processes are involved in the successful regulation of thought and behavior (Blair & Diamond, 2008; Gray, 2004). Secondly, research examining early childhood psychopathology emphasizes that children who experience adjustment difficulties (e.g., externalizing or internalizing problems) often show deficits in both emotion and cognitive processing (Martel et al., 2007; Nigg & Huang-Pollock, 2003). Thirdly, recent reports highlight the benefits of incorporating both cognition and emotion in childhood interventions to promote positive socioemotional functioning (Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006). Finally, recent developmental neuroscience research suggests that two separate but closely related subdivisions within the anterior cingulate cortex govern both cognitive and emotional processes (Davidson, Putnam, & Larson, 2000; Davis, Bruce, & Gunnar, 2002; Lewis & Todd, 2007). These specific brain regions may play a functional role in the deployment of attention and in the processing and regulation of emotion and cognition, and may become integrated early in development (Posner & Rothbart, 1994).

Thus, several growing bodies of literature provide a rationale for examining emotion–cognition relations in early development, and there is evidence to suggest that these relations may be observable as early as the preschool period (e.g., Calkins & Dedmon, 2000; Walden & Smith, 1997). Although recent theoretical work clearly suggests that emotional and cognitive processes influence, and perhaps support, one another during the preschool years (Blair & Diamond, 2008; Nigg & Huang-Pollock, 2003), there has been little empirical investigation of the underlying structure of these processes. Increased empirical investigation of distinctions and relations between different processes in emotion and cognition would be valuable to enhancing our understanding of the links between these processes in early childhood, and would have implications for intervention and treatment efforts targeted at enhancing emotion and cognitive skills in young children. In the current study, we focus on emotion control and understanding and cognitive control and understanding.

Emotion control is the production and inhibition of emotion that allow an individual to cope during positive or negative emotional, cognitive, and social situations (Buss & Goldsmith, 1998; Kopp, 1989). Emotion understanding includes the ability to recognize and label one's own and others' emotions, tie them to situations, understand their causes, identify familial and cultural display rules, and recognize disparity between outward displays and felt emotions (Campos & Barrett, 1984; Denham, 1998). Cognitive control processes include the set of skills often referred to as executive function, including inhibitory control and working memory (Carlson, Moses, & Claxton, 2004; National Institute of Child Health and Human Development Early Child Care Research Network [NICHD ECCRN], 2005). Finally, cognitive understanding includes children's understanding of their own and others' mental states, and in preschoolers is typically referred to as theory of mind (Flavell, Miller, & Miller, 2002).

Three alternative models that describe the interrelations among these processes are apparent. One model is that emotion and cognitive skills are separate but related, and can be distinguished as such. Alternatively, skills in emotion involve elements of control, such as regulation of emotions, as well as understanding of one's own and others' emotions. Similarly, cognitive processes involve control abilities, such as regulation of attention toward task-relevant information, and understanding, such as the ability to understand one's own and others' minds. Because control processes appear to be similar in function across emotion and cognition in that both require regulation (of feelings or attention) and the inhibition of dominant responses, they may fall along a single control dimension. Likewise, as understanding processes share a common function in that both emotion understanding and cognitive understanding involve knowledge or awareness of self and other, they may fall along a single understanding dimension. Thus, a two-factor control and understanding model is possible. A third alternative is that the domains of emotion and cognition in early childhood each include separable, but related, processes of control (regulation) and understanding (knowledge), such that four factors can be identified in the preschool years. We posit that this four-factor model is most plausible, as full integration of control and understanding across the domains of emotion and cognition is unlikely at this stage of development, a view supported by evidence that emotion control emerges earlier in development than cognitive control or understanding (Blair, 2002; Posner & Rothbart, 2000).

In recent work conducted to test this hypothesis, the four-factor model was found to fit better than two alternative two-factor models described above (i.e., emotion and cognition model; control and understanding model) (Leerkes, Paradise, O'Brien, Calkins, & Lange, 2008). In this prior study, however, emotion control was based exclusively on maternal reports, thus leaving open the possibility of potential biases in how mothers rate elements of children's emotion control (Seifer, 2002; Seifer, Sameroff, Dickstein, Schiller, & Hayden, 2004). The present analyses go beyond previous work in incorporating three methods of assessing emotion control: mother report, observations during laboratory tasks, and physiological indices.

Measurement of Emotion Control

Emotion control is a key dimension of early childhood functioning that is important for success in social (Calkins & Keane, 2004) and academic (Graziano, Reavis, Keane, & Calkins, 2007; Raver, 2004) settings. Despite the demonstrated significance of emotion control to early development, its measurement continues to be difficult and sometimes controversial (Cole, Martin, & Dennis, 2004; Eisenberg & Spinrad, 2004). Recent conceptualizations of the construct emphasize the multifaceted nature of emotion control. Emotion control involves both emotional reactivity as well as emotion regulation (Thompson, Lewis, & Calkins, 2008). Emotion control draws on fundamental neurological, physiological, cognitive, and behavioral processes of both reactivity and regulation (Thompson et al., 2008) that interact dynamically over time and within contexts. Consistent with this view, we conceptualize emotion control as a process that includes both emotional reactivity and emotional regulation, each of which can be observed behaviorally and physiologically.

In young children, common methods used to obtain indices of emotion control behaviors include parent reports of reactive and regulatory dimensions of temperament, as measured by questionnaires such as those developed by Rothbart (e.g., Putnam & Rothbart, 2006), and specific measures of emotion regulation, such as the emotion regulation checklist (Shields & Cicchetti, 1998). Laboratory tasks can also be used. Such tasks are usually designed to elicit frustration or fear, and children's responses to the tasks are rated by trained coders. In these assessments, emotion control is often indexed by the intensity and frequency of negative emotional displays and by the ease with which a child is able to cope with the emotionally challenging situation (Calkins & Johnson, 1998).

Research on the physiological substrates of emotion control—children's physiological capacity to experience and modulate arousal—has focused on the influence of the parasympathetic branch of the autonomic nervous system on adaptive behavior. Studying such influences is important because the parasympathetic branch modulates metabolic output from internal homeostasis demands to external or environmental demands. These environmental demands require internal processing that creates coping strategies aimed at controlling affective arousal (Porges, 2007). Parasympathetic influences on heart rate can be easily quantified by measuring heart rate variability. Variability in heart rate that occurs at the frequency of spontaneous respiration (respiratory sinus arrhythmia, RSA) can be measured non-invasively, and is considered a good estimate of the parasympathetic influence on heart rate variability via the vagus nerve. Porges and colleagues developed a method that measures the amplitude and period of the oscillations associated with inhalation and exhalation, referred to as vagal tone (Porges, 1985, 1991). Of particular interest to researchers studying self-regulation, though, has been measurement of vagal *regulation* of the heart when the organism is challenged. Such regulation is indexed by a decrease in RSA or vagal tone (vagal withdrawal) during situations where coping or emotional and behavioral regulation is required (Porges, 2007). During demanding tasks, a decrease, or *withdrawal*, in vagal input to the heart has the effect of stimulating increases in heart rate. Such a response reflects physiological processes that allow the child to shift focus from internal homeostatic demands to demands that require internal processing or the generation of coping strategies to control affective or behavioral arousal. Thus, vagal withdrawal is thought to be a physiological strategy that results in greater cardiac output in the form of HR acceleration, and that supports behaviors indicative of active coping (Calkins, Graziano, & Keane, 2007; Porges, 1991).

Although there is evidence that these various measurement approaches reflect emotion control, the extent to which they correlate with one another is somewhat unclear. For example, some studies demonstrate associations between vagal measures of emotion control and behavioral processes and strategies used in regulating emotions, as measured by direct observation or parent reports (El-Sheikh & Buckhalt, 2005; Huffman et al., 1998; Stifter & Jain, 1996), but others do not (Blair & Peters, 2003; Roberts, Boccia, Hatton, Skinner, & Sideris, 2006). Some evidence suggests that parent reports, behavioral observations, and physiological indicators might provide different information about emotion control processes. For example, Santucci et al. (2008) found that both parent-rated temperament and vagal recovery predicted subsequent observed emotion regulation strategies during a frustration task, even though the two were unrelated. One explanation for this lack of convergence is that observable behavior and physiological responding represent different levels of a larger system of skills. Emotion regulation and other behavioral and cognitive control processes may be part of a differentiated self-regulatory system (Calkins & Marcovitch, 2010). As part of this multilevel system, these behavioral processes are linked in fundamental ways to more basic biological and attentional processes, which makes a one-to-one mapping of emotion control behaviors and physiological responding less likely. That is, physiological processes that are observable during an emotion eliciting task are not exclusive to the process of emotion control, and may be indexing more general abilities (Calkins, 2009).

In general, recent research has highlighted the importance of a multi-method approach to the assessment of the multifaceted construct of emotion control (Cole et al., 2004; Thompson et al., 2008), particularly given the possibility that different methods may tap into different aspects of emotion control. This need can be addressed by simultaneously measuring both the reactivity and regulation aspects of emotion control using different methods. Therefore, in the present study, we examined the structure of emotional and cognitive processes using parent report, behavioral observations, and physiological measures of emotion control, with emotion control encompassing both reactivity and regulation, consistent with current theoretical perspectives.

The Current Study

The goal of the present research was to investigate the structure of early emotional and cognitive functioning in a large and diverse sample of preschool children. Specifically, we examined whether the patterns of performance displayed by children could be organized into discrete factors of emotion control, emotion understanding, cognitive control, and cognitive understanding, and whether a four-factor model would fit the data significantly better than the simpler two-factor models. In the present research, we took a multi-measure approach to the assessment of emotion control. Additionally, we tested competing structural models that took into account the source of information (i.e., method) to rule out method effects as explanations for our findings. That is, we compared our best-fitting theoretically based structural model with alternative method factor models.

Thus, the specific questions addressed in the present study were: (1) Do indicators of emotional control obtained by parent report, behavioral observation, and physiological measures fit a single common factor model, or are they indicators of distinct aspects of emotion control? and (2) Can control and understanding processes be differentiated within the emotional and cognitive domains? This study makes an important contribution to the literature because not only does it allow for replication of previous findings on the nature of associations among emotion and cognition, but it advances the definition and operationalization of emotion control in the preschool years.

Method

Participants

The sample was comprised of 263 3.5-year-old children (*M*= 41.79 months; *SD*= 2.41) and their mothers who participated in the first wave of data collection of a study examining emotional and cognitive contributions to early school success. Mothers in the study sample were 33 years of age on average (*SD*= 5.91). Approximately 51 percent had a four-year college degree or had completed higher levels of education, 74 percent of the respondents were married and living with their partner, and 79 percent were currently working outside the home. Average income-to-needs ratio, derived by dividing the total family income by the poverty threshold for that family size, was 2.89 (*SD*= 1.73). Fifty-two percent of the children were female; 58 percent of the children were European American, 35 percent African American, and 7 percent other ethnicities, including children of mixed ethnicity.

Procedures and Measures

Participating families were recruited from preschools and childcare centers in a small southeastern city through letters sent home with the children. Families interested in participating returned contact information to the researchers who then called the families to schedule a laboratory visit that lasted approximately two hours. During the lab session, children were videotaped while completing tasks assessing emotional and cognitive control and understanding, with task order held constant across children. Mothers provided written consent and completed questionnaires during the session. Families received $40 and children selected a toy as thanks for their participation.

Emotion Control

Parent Report. Two measures of emotion control were completed by mothers, the children's behavior questionnaire short form (CBQ-short, Putnam & Rothbart, 2006), which assesses temperamental dimensions, and the emotion regulation checklist (ERC; Shields & Cicchetti, 1998), which assesses children's emotional reactivity and regulation. In the CBQ-short, mothers described their children's typical reactions to various situations on a seven-point Likert scale ranging from 1 (extremely untrue of your child) to 7 (extremely true of your child). Of interest in the present analyses was the *falling reactivity/ soothability* (e.g., '. . . is easy to soothe when upset') subscale (six items, alpha = .73), which indexes regulation. In the ERC, mothers rated how frequently their children engaged in certain behaviors on a scale from 1 (never) to 4 (always). The ERC includes two subscales: reactivity is indicated by *lability/negativity* (15 items, alpha = .82, e.g., 'is easily frustrated') and regulation by *emotion regulation* (eight items, alpha = .60, e.g., 'can modulate excitement in emotionally arousing contexts'). Items within each subscale were summed.

Behavioral Observations. Measures of expressed frustration and emotion regulatory behaviors were coded during a frustration task, the locked box task. The child was seated at a small table and offered a choice of two highly desirable toys. After the child made a selection, the toy was placed in a transparent box that was locked with a padlock. After ensuring that the child knew how to open a lock with a key, the experimenter supplied the child with a large ring of keys, none of which was the correct key, and instructed the child to find the right key to open the box in order to play with the toy. The experimenter then left the room while the child attempted to open the box. After four minutes, the experimenter re-entered and presented the child with the correct key. The child then opened the box and played with the toy. The locked box task was videotaped and rated by a trained coder for verbal and physical expressions of frustration and global regulation. *Verbal frustration* represents the frequency of the child's verbal negative expressions of frustration, such as 'I don't want to do this anymore', and 'This is too hard'. *Physical frustration* represents the frequency of the child's physically negative expressions, such as hitting or throwing the box. *Global regulation* was rated on a scale of 0 (unregulated) to 3 (well-regulated). Unregulated represents no demonstrated control of distress responses to stimuli, whereas well-regulated represents demonstrated regulation of distress responses by engaging in such things as verbal or physical distractions. Inter-rater reliability, calculated as Pearson correlations for verbal and physical frustration and kappa for global regulation on approximately 20 percent of the videotapes, was .96, .95, and .71, respectively.

Physiological Indices. Physiological indices of emotion control were collected during the locked box (described previously) and the green circles tasks. For the green circles task (adapted from Goldsmith & Reilly, 1993), the experimenter repeatedly (for four minutes) asked the child to draw circles with a green marker on an 11″× 14″ sheet of white paper. The experimenter criticized the child's circles but did not provide information on how to do better. The experimenter continued to prompt, 'I need the *perfect* green circle' for the duration of the task.

To measure baseline vagal tone and vagal withdrawal during the frustration tasks, two disposable pediatric electrodes placed on the child's chest were connected to a preamplifier, the output of which was processed through a vagal tone monitor (Series 2000 Mini-Logger, Mini Mitter Co., Inc., Bend, OR) for R-wave detection. Baseline EKG was recorded while the child was watching a five-minute video about a puppy, and EKG recording was continued during the lab session. A data file containing the inter-beat intervals (IBIs) for the entire period of collection was transferred to a laptop computer for later artifact editing (resulting from child movement) and analysis. Data files were analyzed using the software program MXEDIT (Delta Biometrics, Inc, Bethesda, MD). Vagal withdrawal was calculated by subtracting vagal tone during each frustration task from baseline vagal tone. A positive difference score indicates that there is a decrease in vagal tone during the task, reflecting greater emotion control (Calkins, 1997). High baseline vagal tone reflects greater emotional reactivity, a view supported by evidence that it correlates positively with observed frustration (Calkins & Johnson, 1998). The measures of interest for the present study were *baseline vagal tone*, *locked box vagal withdrawal*, and *green circles vagal withdrawal*.

Emotion Understanding

Labeling of Emotions. Following the procedure used by Denham (1986), children were presented four felt faces, drawn to depict the emotions happy, sad, angry, and scared, and asked to name each expression (e.g., ‘How is this person feeling right now?’) to assess accuracy of verbal emotion labeling. Children were also asked to point to each expression when requested (e.g., ‘Show me the ______ face.’) to assess non-verbal emotion recognition. For each emotion, children received a score of 2 if they identified the correct emotion, 1 if they identified an incorrect emotion of the correct valence (e.g., sad instead of angry), and 0 if they identified an emotion of the incorrect valence (e.g., happy instead of sad). Recognition and labeling scores correlated, $r(261) = .62$, $p < .01$, and were summed to yield one measure of *labeling of emotions* with scores ranging from 0 to 16.

Affective Perspective Taking. The vignettes of emotion-eliciting situations developed by Denham (1986) were used to assess children's understanding of others' emotions. Vignettes were presented as puppet tasks; the children were asked to indicate how the puppet felt by affixing a felt face depicting happiness, sadness, anger, or fear to the puppet. The first four vignettes involved situations that evoke non-equivocal emotional reactions (e.g., happiness at getting an ice cream cone). The remaining six vignettes were more equivocal situations in which the protagonist puppet portrayed an emotional response that the mother had earlier reported as atypical for her child. For example, if a mother indicated that her child would feel scared about being approached by a large, friendly dog, the puppet enacted happiness using standardized verbal and visual cues. For each vignette, children received a 0, 1, or 2 for the face they selected using the same criteria as the labeling of emotions scoring described above. Separate scores were calculated for non-equivocal (possible range 0 to 8) and equivocal affective perspective taking (possible range 0 to 12) by summing scores across the appropriate vignettes. The two measures correlated significantly, $r(258) = .53$, $p < .01$, and were summed to yield one index of *affective perspective taking*.

Knowledge of Emotion Causes. Children's ability to explain the reasons for experiencing emotions was examined using a puppet task developed by Denham, Zoller, and Couchoud (1994). One of four emotion faces (happiness, sadness, anger, or fear) was placed on a puppet, and children were asked to identify the emotion. Then the examiner asked, ‘What made the puppet feel this way?’ Children were encouraged to report as many as four possible reasons, and their responses were recorded verbatim and coded for the number of accurate, independent causes given (possible range 0 to 4) for each of the four emotions. Accuracy was defined using criteria established in past research (Barrett & Campos, 1987; Stein & Jewett, 1986; e.g., correct causes of anger involve goal blockage. Inter-observer reliability, calculated as kappa, was .76. The number of correct explanations was summed across all four emotions to yield a total score for *knowledge of emotion causes* that could range from 0 to 16.

Cognitive Control

Working Memory. The *number recall* subtest of the Kaufman assessment battery for children (K-ABC, Kaufman & Kaufman, 1983) was administered to children to assess working memory capacity. In this forward digit span task, children repeat a sequence of numbers after the examiner. Each sequence is scored as correct (1) or incorrect (0). The raw score was calculated as the total number of sequences repeated correctly. Forward digit span is a measure of working memory to the extent that children must actively maintain storage of ‘end-string’ numerals while at the same time verbally producing earlier-appearing numerals, and has been described as a simple working memory task (Garon, Bryson, & Smith, 2008).

Inhibitory Control. The day/night Stroop test (Gerstadt, Hong, & Diamond, 1994) was developed from the classic task (Stroop, 1935), which is widely used to index cognitive inhibitory control. Children were presented with a deck of cards, half of which were black with a yellow moon and several stars, and half white with a bright sun, and were instructed to say ‘day’ in response to the black cards and ‘night’ to the white cards. Following two practice trials, each type of card was presented eight times in a fixed order. The child's score was the number of correct responses to the 16 test trials. Children were administered the test trials only if they answered at least one question correctly in two practice trials. Children who failed both practice trials ($N = 74$) received a score of zero. The possible range of scores was 0 to 16, with higher scores indicating stronger cognitive control or inhibition.

Cognitive Understanding

Appearance-reality Distinction. This task, developed by Flavell, Flavell, and Green (1983), assesses whether children can accurately describe differences between an object's real nature and its apparent nature when modified perceptually. To do so correctly, children must understand that their current perception of the object is inaccurate. Children were shown two realistic-looking imitation objects: a candle in the shape of an apple and an egg made of wood. Then the color was modified by placing a sheet of blue-tinted plastic in front of each of the objects, and the size was modified by using a large magnifying lens. Children were asked a series of questions about what the object looked like while modified (e.g., ‘Does it look blue or red?’ and ‘Does it look big or does it look little?’), and what the properties of the object really were (e.g., ‘Is it really, really blue or is it really, really red?’ and ‘Is it really, really big, or is it really, really little?’). Children received a score of 1 for each correct answer for each of these questions. The number of correct responses was summed separately across color and size domains to yield two scores: *appearance reality color* and *appearance reality size* each ranging from 0 to 4.

Unexpected Contents. This task, developed by Astington and Gopnik (1988), assessed children's false belief reasoning by asking them to identify their own and another character's belief about the contents of two containers. Children were shown a band-aid box that contained blocks and a crayon box that contained spoons. First, the examiner presented the box and asked, ‘What do you think is in here?’ The examiner then revealed the actual contents and asked, ‘Before we opened this, what did you think was in here?’ Then, the examiner asked the child what a friend, who had not seen the actual contents of the box, would think was inside. Children earned a score of 1 for each correct answer, and scores were summed across both trials; possible scores range from 0 to 4.

Results

Preliminary Analyses: Examining Measures of Emotion Control

All analyses were conducted using the Mplus 5.0 (Muthén & Muthén, 1998–2007) statistical software, and full information maximum likelihood (FIML) was used to treat missingness, under the assumption that data are missing at random (MAR; Little & Rubin, 1987). The proportion of missing values was small (<5 percent overall). Given the small amount of missing data, FIML was appropriate (Widaman, 2006).

Prior to examining the structural relations among the emotion and cognitive processes, we examined the underlying relations among the different indicators of emotion control using structural equation modeling. Various hierarchically nested multi-trait multi-method (MTMM) models, derived by cross-classifying various method structures with various trait structures (0 traits, 1 trait, 2 uncorrelated traits, 2 correlated traits), were fit to the data (Widaman, 1985). The primary question that was addressed in these MTMM analyses was whether the emotion control variables measure one common construct, two constructs (reactivity and regulation), or three constructs based on method of assessment. Results indicated support for the three-factor solution over the two-factor and single factor solutions.

Subsequently, two additional models were tested and compared to determine whether the three types of measures (parent report, behavioral, physiological) were separate but correlated, or separate and uncorrelated, respectively. The root mean square error of approximation (RMSEA; Steiger & Lind, 1980), comparative fit index (CFI; Bentler, 1990), and standardized root mean square residual (SRMSR) were consulted to estimate the relative goodness of fit of the models. The correlated three-factor model (i.e., parent report, behavioral, physiological) fit the data well, $\chi^2(24) = 34.35$; RMSEA = .04; CFI = .98; SRMSR = .04, but the fit was not significantly better than the uncorrelated three method factor model, which has three fewer estimated parameters and is therefore a more parsimonious model ($\Delta\chi^2 = .95$, $\Delta df = 3$).

A final alternative model was tested that specified four factors, namely, a single-trait factor (emotion control) and three uncorrelated method factors (parent report, behavioral, physiological). Although this alternative model fit the data well, the estimated factor loadings on the single trait factor were all non-significant, while the loadings on the three method factors were significant. When considered jointly, these results suggest that the parent report, behavioral observation, and physiological indices of emotion control measure three uncorrelated factors.

Substantive Analyses: Differentiating Processes of Control and Understanding

Table 1 shows the means and standard deviations for the raw study variables, as well as the estimates using maximum likelihood estimation for incomplete data (Muthén & Muthén, 1998–2007). Inter-correlations among the variables are shown in Table 2.

Table 1. Raw and Maximum Likelihood Estimated Means and Standard Deviations for Study Variables

Variable	**Raw**		**Maximum Likelihood**	
	Mean	***SD***	**Mean**	***SD***
Emotion control: parent report				
Falling reactivity/soothability	5.05	.98	5.04	.98
Negativity	28.81	5.47	28.81	5.46
Emotion regulation	27.04	2.69	27.04	2.68
Emotion control: behavioral observation				
LB global regulation	2.55	.70	2.55	.70
LB verbal frustration	5.37	5.28	5.36	5.27
LB physical frustration	.94	2.09	.94	2.08

Variable	Raw		Maximum Likelihood	
	Mean	***SD***	**Mean**	***SD***
Emotion control: physiological indices				
Baseline vagal tone	6.41	1.32	6.40	1.31
LB vagal withdrawal	1.25	.84	1.25	.84
GC vagal withdrawal	.67	.69	.66	.70
Emotion understanding				
Labeling of emotions	11.84	3.40	11.82	3.40
Affective perspective taking	12.19	4.39	12.07	4.46
Knowledge of emotion causes	3.41	2.73	3.41	2.73
Cognitive control				
K-ABC number recall	2.73	2.49	2.72	2.49
Day/night Stroop	6.58	5.46	6.55	5.46
Cognitive understanding				
Appearance reality color	2.02	.81	2.02	.82
Appearance reality size	2.02	.72	2.01	.72
Unexpected contents	1.12	1.28	1.12	1.27

Notes: LB = locked box; GC = green circles; K-ABC = Kaufman assessment battery for children.

Table 2. Maximum Likelihood Estimated Zero-order Correlations among Study Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Falling reactivity/soothability	1.00															
2. Negativity	−.50	1.00														
3. Emotion regulation	.29	−.41	1.00													
4. LB global regulation	−.08	−.04	−.03	1.00												
5. LB verbal frustration	.05	−.01	.03	−.45	1.00											
6. LB physical frustration	.00	.04	.01	−.43	.23	1.00										
7. Baseline vagal tone	.06	−.05	−.02	.10	−.05	.07	1.00									
8. LB vagal withdrawal	.10	−.04	.03	.02	.10	.04	.62	1.00								
9. GC vagal withdrawal	−.03	.03	.04	.14	.11	−.01	.45	.60	1.00							
10. Labeling of emotions	.07	−.14	.24	.15	.03	−.15	.11	.05	.18	1.00						
11. Affective perspective taking	.04	−.17	.25	.08	.09	−.13	.03	.05	.09	.53	1.00					
12. Knowledge of emotion causes	.03	−.09	.20	.08	−.01	−.06	.10	.05	.08	.49	.47	1.00				
13. K-ABC number recall	.02	−.05	.04	.14	−.02	−.10	.06	.03	.07	.38	.37	.40	1.00			
14. Day/night Stroop	.08	−.11	.14	.11	.03	−.03	.19	.11	.07	.36	.35	.34	.42	1.00		
15. Appearance reality color	−.05	.08	.12	−.01	.00	.03	.00	.05	.05	.14	.14	.25	.09	.16	1.00	

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16. Appearance reality size	−.04	−.09	.10	.05	.05	.02	.07	.00	.08	.25	.26	.21	.19	.12	.26	1.00
17. Unexpected contents	.04	−.06	.13	.04	.10	.15	.03	.02	.18	.05	.10	.10	.07	.08	.07	.20

Notes: $p \leq .05$ for $|r| \geq .13$, $p \leq .01$ for $|r| \geq .16$.
LB = locked box; GC = green circles; K-ABC = Kaufman assessment battery for children.

To examine the question involving the structure of control and understanding processes within the domains of emotion and cognition, we tested three structural equation models. Model 1 tested emotion control, emotion understanding, cognitive control, and cognitive understanding as four oblique factors; Model 2 tested emotion processes and cognition processes as separate but related domains; and Model 3 tested control and understanding as separate but related processes. Because Models 2 and 3 are nested within Model 1, each was compared with Model 1 using the chi-square difference test ($\Delta\chi^2$) to assess the relative fit of these models.
The three models were tested once each for emotion control as measured by parent report, behavioral observation, and physiological indices; thus, nine models were tested in all. The models including parent report of emotion control were an exact replication of the Leerkes et al. (2008) analyses. All models were estimated using FIML, and the RMSEA (Steiger & Lind, 1980), CFI (Bentler, 1990), SRMSR, and chi-square were examined. We expected that the four-factor model would not only provide a good fit to the data, but would show a statistically significantly better fit when compared with either of the two-factor models, regardless of the method for measuring emotion control.

Results of these analyses are presented in Table 3. The results support the four-factor model as a significantly better fit than either of the two-factor models. That is, separation of emotion and cognition into control and understanding processes was a better description of the relations among measures than either of the other two models. This finding held for parent report, behavioral observation, and physiological measures of emotion control.

Table 3. Model Comparisons

Model	RMSEA [95% CI]	CFI	SRMSR	χ^2	*df*
Parent report					
Four factors	.03 [.00, .05]	.98	.05	46.25	38
Emotion and cognition	.11 [.09, .12]	.74	.09	168.32	43

Model	RMSEA [95% CI]	CFI	SRMSR	χ^2	*df*
Understanding and control	.11 [.09, .12]	.74	.09	169.66	43
Behavioral observation					
Four factors	.02 [.00, .05]	.99	.04	43.81	38
Emotion and cognition	.11 [.09, .12]	.73	.09	171.95	43
Understanding and control	.11 [.09, .12]	.74	.09	166.75	43
Physiological indices					
Four factors	.03 [.00, .05]	.99	.04	45.22	38
Emotion and cognition	.14 [.13, .16]	.60	.11	266.09	43
Understanding and control	.11 [.10, .13]	.74	.12	190.19	43

Notes: RMSEA = root mean square error of approximation; CFI = comparative fit index; SRMSR = standardized root mean square residual.

The standardized parameter estimates are given in Table 4. The estimated loadings were significant for all variables on their respective factors, suggesting that the variables are significant indicators of the processes in which they were hypothesized to measure. The inter-correlations among the four factors are depicted in Figure 1. Correlations were similar for the three approaches to measuring emotion control, with two exceptions: (1) emotion control and emotion understanding were significantly correlated in the model using parent report and behavioral indices, but not in the model using physiological indices; and (2) emotion control and cognitive control were significantly correlated for the behavioral observations measure, but not for the parent report and physiological measure of emotion control.

Table 4. Standardized Parameter Estimates for Four-factor Model

Variable	Parent report	Behavioral observation	Physiological indices
Emotion control: parent report			

Variable	**Parent report**	**Behavioral observation**	**Physiological indices**
Falling reactivity/soothability	.60	—	—
Negativity	−.81	—	—
Emotion regulation	.52	—	—
Emotion control: behavioral observation			
LB global regulation	—	.94	—
LB verbal frustration	—	−.46	—
LB physical frustration	—	−.48	—
Emotion control: physiological indices			
Baseline vagal tone	—	—	.69
LB vagal withdrawal	—	—	.89
GC vagal withdrawal	—	—	.67
Emotion understanding			
Labeling of emotions	.72	.73	.73
Affective perspective taking	.71	.70	.70
Knowledge of emotion causes	.68	.68	.68
Cognitive control			
K-ABC number recall	.68	.68	.67

Variable	**Parent report**	**Behavioral observation**	**Physiological indices**
Day/night Stroop	.62	.61	.62
Cognitive understanding			
Appearance reality color	.41	.41	.41
Appearance reality size	.66	.66	.65
Unexpected contents	.26	.26	.26

Notes: LB = locked box; GC = green circles; K-ABC = Kaufman assessment battery for children.

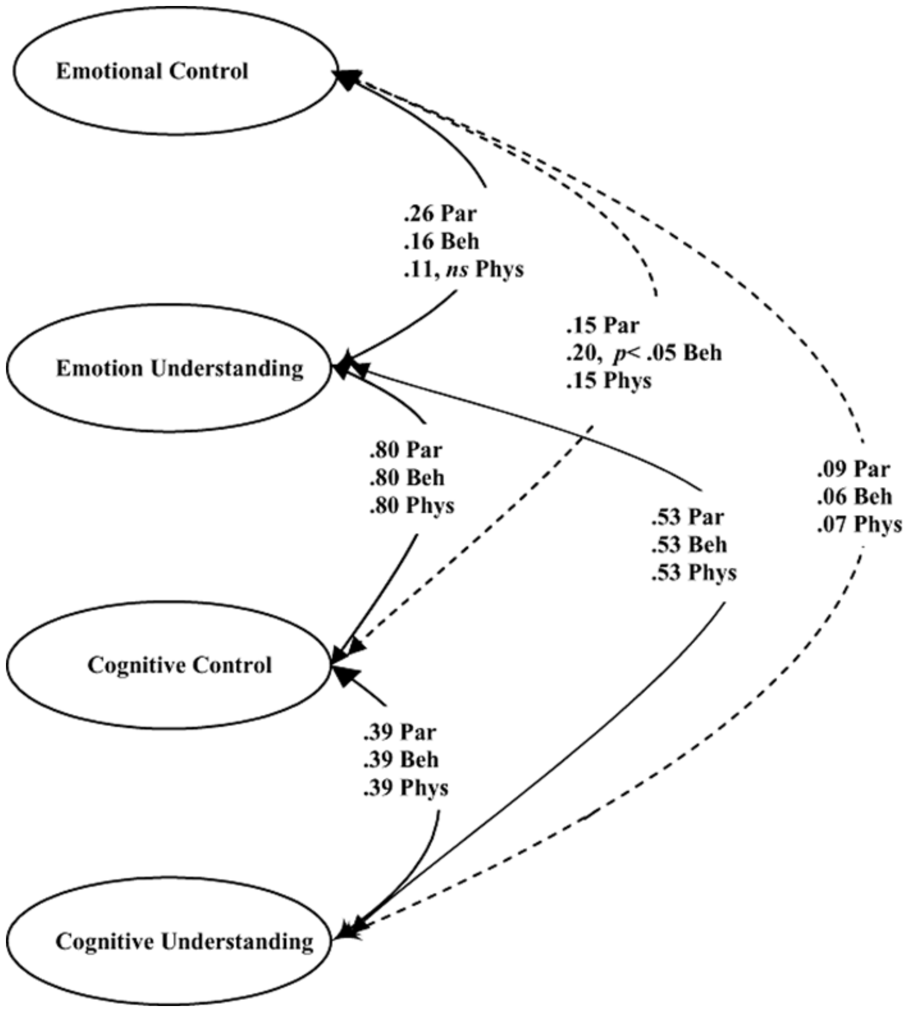

Figure 1. Inter-correlations among Four Factors for Various Methods of Measuring Emotion Control. *Notes*: Par indicates parent report emotion control, Beh indicates behaviorally observed emotion control, and Phys indicates physiological measurement of emotion control. Dashed lines indicate non-significant paths; solid lines indicate paths significant at $p < .05$. Exceptions to the pattern of significance are noted.

To alleviate the concern of shared method variance as an explanation for the associations among the variables in the analyses, two additional models were tested. The first was a model in which all behavioral measures (behavioral observation and child tasks) were required to load on one factor, and the physiological and parent report measures on a second factor. The second was a three-factor model, with all behavioral measures on one factor and physiological and parent report on two separate factors. Neither of these models fit the data well (RMSEA = .10 and .07; CFI = .65 and .81, respectively).

Discussion

Recently, there has been increasing attention to the importance of both emotional and cognitive processes in early childhood development, and interest in examining the interrelations across these domains. To date, however, our understanding of the nature of the underlying processes contributing to emotional and cognitive functioning has been limited. To delineate the interrelations among emotional and cognitive processes in early childhood, it is important to clarify the fundamental structure of early emotional and cognitive development. The present research had the goal of defining component processes within the domains of emotion and cognition in early development. Results indicated that control and understanding are separable processes, and that they operate within both domains. The four-factor solution in which emotion control, emotion understanding, cognitive control, and cognitive understanding are viewed as separate processes fit the data better than did either of two two-factor models based on domains of emotion and cognition or processes of control and understanding. This structure was replicated across different methods of assessing emotion control.

By identifying component processes of early emotional and cognitive development, we can begin to unravel the complexities involved in the interrelations among them. Theoretical support for the potential interdependence of emotional and cognitive processes is emerging (Blair & Diamond, 2008; Nigg & Huang-Pollock, 2003), but empirical evidence requires that the component processes be more clearly differentiated. The present research is a step toward that differentiation.

Because we assessed emotion control in three ways—using parent report, behavioral observation, and physiological indices—we were able to examine the extent to which these three measurement approaches provide overlapping or independent information. Our results are similar to earlier work showing a lack of concurrent correlation across these types of measures (e.g., Blair & Peters, 2003; Roberts et al., 2006). That physiological and behavioral aspects of emotion control were unrelated may be a function of the different processes they are able to access, with physiological indicators perhaps being a more general indicator of focused attention (Calkins & Marcovitch, 2010), which may either support or undermine adaptive emotion control behavior. That the parent report and trained observer ratings of emotion control did not converge may be a function of the different contexts in which they were assessed (Rothbart & Bates, 1998). That is, parent reports are presumably based on their observations of their children in typical daily life, which include a range of frustrating situations that are both social and task oriented, and likely often involve the parent. In contrast, the laboratory observation was based on a single task-oriented frustration elicitor in which the parent was not actively involved. Finally, we must consider the extent to which these three types of measures might be expected to cohere at this point in development. As emotion control becomes more sophisticated and less observable, convergence may be more difficult to observe (Calkins, 2009). We do not yet fully understand this multifaceted construct, and the findings of this research highlight the need for future studies of emotion control to take a multi-method approach to assessment. Such methods will allow us to begin to unravel the complexity of this construct.

Both parent reported and behaviorally observed emotion control were found to be significantly related to emotion understanding in this study, although the two measures were themselves uncorrelated. This finding is consistent with prior research showing similar patterns of relations of different emotion control measures to other variables despite their lack of association with one another (Santucci et al., 2008), and is also consistent with a multilevel or multi-system view of emotion regulation (Thompson et al., 2008). Thus, in this study, observable aspects of emotion control operated similarly with regard to their relation to emotion understanding, whereas the internal/physiological aspect did not. Children with higher levels of emotion understanding are better able to recognize their own emotions, to label these emotions, to understand their causes, and to identify familial and cultural display rules. Such children may therefore be able to display culturally acceptable emotions (i.e., emotion control) when faced with challenging situations, which may or may not correspond to their internal emotional responses that would be detected by physiological measures in the moment. Alternatively, the association between some measures of emotion control and emotion understanding may be a function of parental behavior. That is, when a child appears to have his/her emotions under control during a challenging or frustrating task, the parent may be better able to focus on helping the child understand his/her emotions as opposed to focusing on calming or soothing the child (Eisenberg, Cumberland, & Spinrad, 1998). Thus, a child with good emotion control may elicit more sophisticated emotion socialization, which in turn enhances emotion knowledge. To the extent that children's physiological emotion control and behavioral emotion control are not coupled in time or are indexing distinct processes (Calkins, 2009), children's physiological control is unlikely to elicit parent's more sophisticated emotion socialization behaviors.

These results suggest that the different methods for assessing emotion control may be tapping into different aspects of a similar construct, highlighting the need to assess these variables in different ways in research to increase understanding of the development of emotion control in the early childhood years. In the present study, whether assessed by parent report, behavioral observation, or physiology, emotion control appears to be a construct that is distinguishable from the constructs of emotion understanding, cognitive control, and cognitive understanding. Moreover, the pattern of associations among each of the other three factors (emotion understanding, cognitive control, and cognitive understanding) remained similar across each of the models that were fit. It is well understood that results of factor analyses (which can be conducted using structural equation modeling) can differ when variables are included or excluded from an analysis. That the four-factor structure replicated regardless of which emotion control variables were included demonstrates the robustness of these four factors.

Similar to findings by Leerkes et al. (2008), the strongest observed correlation among the four factors was between emotion understanding and cognitive control. This finding seems counterintuitive, as the two factors do not share a domain. However, it may be that the ability to hold information in short-term awareness, along with the ability to inhibit dominant information in favor of subdominant information, may assist a child in focusing on relevant information during emotion-learning events. Children who are able to regulate their attention in emotion-learning events may be better able to focus on others' emotions, increasing their awareness of others emotions and strengthening their ability to identify their own and others' emotions. Thus, the development of cognitive control processes may foster the development of emotion understanding. Alternatively, it may be that children with good cognitive control processes performed better on the set of emotion-understanding tasks given task demands. In particular, the affective perspective-taking task requires children to attend to and remember a story, and the unequivocal vignettes may require inhibition of the child's own feelings in the given situation (e.g., dogs make me scared) in order to correctly answer about the protagonist in the vignette (e.g., dogs make the puppet happy). A possible explanation for why emotion understanding would influence the development of cognitive control may be that having the ability to understand one's own and others' emotions helps one to focus attention on specific tasks at hand rather than on the emotions accompanying the tasks. However, the empirical literature on the associations between these two variables is scant. The results of this research highlight the need for further investigation on the interplay between emotion and cognition in the early childhood years.

One strength of this study is that the participants were diverse in family income and ethnicity. Also, the analyses relied heavily on directly observed child performance rather than parent or teacher report. Additionally, we included both reactivity and regulation as indicators of emotion control. Often in past research, reactivity and regulation have been examined as separate constructs. In other cases, only reactivity has been measured, particularly in research with children due to challenges in being able to observe the actual regulation process. However, emotion control is a process that involves both an emotional reaction as well as regulation of that emotion (Thompson et al., 2008). Therefore, examination of both components simultaneously can more fully address the multifaceted nature of emotion control. Relatedly, a further strength of the present study is that we examined emotion control processes using multiple sources of information, again addressing the complexity of the construct. Future research should adopt a similar strategy to provide greater insight into the construct. Although direct child performance is the most meaningful way to measure emotion understanding, cognitive understanding, and cognitive control, which was done in the present investigation, nevertheless, future research can be conducted in which diverse measurement approaches are used within and across all four processes.

Overall, the findings of the present study stimulate further avenues for research to address important questions about the structure of and relations among emotional and cognitive processes. By understanding the structural relations among emotional control, emotional understanding, cognitive control, and cognitive understanding in the early childhood years, we can begin to explore longitudinal questions regarding the stability or change in the structure of early abilities. Questions regarding the dynamic interrelations among the four processes remain to be answered. It is important to determine whether development of one component process of emotion or cognition is basic to development of other processes, either within or across domains, so that we can more accurately identify potential difficulties and intervene very early to prevent secondary effects of such difficulties. Without knowledge of the basic structure of early emotional and cognitive processes and their interrelations, we must continue to rely on behavioral manifestations of social–emotional or academic problems as indicators of the need for intervention.

There is growing consensus that emotion and cognition are linked across development (Calkins & Bell, 2009). How they are linked and the significance of developmental change in each component process for change in the others remains to be explored. Thus, future research is needed that focuses on the dynamic, longitudinal associations between emotional and cognitive processes over time and their links with social–emotional adjustment and cognitive functioning.

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