Developmental Dynamics of Emotion and Cognition Processes in Preschoolers

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Abstract:

Dynamic relations during the preschool years across processes of control and understanding in the domains of emotion and cognition were examined. Participants were 263 children (42% non-White) and their mothers who were seen first when the children were 3 years old and again when they were 4. Results indicated dynamic dependence among the processes studied. Specifically, change in cognitive processes of control and understanding were dependent upon initial levels of the other processes. Changes in emotion control and understanding were not predicted by earlier performance in the other processes. Findings are discussed with regard to the constructs of control and understanding and the developmental interrelations among emotion and cognitive processes.

Keywords: Child Development | Preschool Children | Cognition | Emotion | Mothers

Article:

Although there is growing recognition that examination of the interconnections between emotion and cognition processes in early childhood is likely to lead to increased understanding of children's development (Blair & Diamond, 2008; Gray, 2004), much research continues to treat the domains of emotion and cognition separately. As a result, we do not yet fully understand the developmental processes by which emotion and cognition mutually influence each other.

There is evidence from recent work in neuroscience that processes of emotion and cognition are closely related in the brain. The anterior attention system appears to play a functional role in the control of attention and in the regulation of both emotion and cognition (Davidson, Putnam, & Larson, 2000; Davis, Bruce, & Gunnar, 2002). Guiding this system is the anterior cingulate cortex, which includes two major subdivisions, one of which governs cognitive and attentional processes and the second of which governs emotional processes. It is thought that these two subdivisions have a reciprocal, or two-way, relation (Davidson et al., 2000; Davis et al., 2002), suggesting a biological foundation for the developmental integration of specific types of control and understanding processes within the domains of emotion and cognition during early childhood. The present research investigates the behavioral manifestations of these control and understanding processes early in development to identify dynamic relations between them that account for individual differences in patterns of change.

The theoretical framework of the work described here focuses on two general processes—control and understanding—that we define as operating in both domains—emotion and cognition. We have chosen to use the terms *control* and *understanding* to emphasize the similarities within these processes across domains. We use *control* to refer to processes of regulation, both the regulation of affect and of attention and executive function, and *understanding* to refer to cognitive, metacognitive, and metaemotion knowledge. Researchers focusing on emotional development typically use the term *emotion regulation* to describe what we label *emotion control*, and researchers focusing on cognitive development use the term *executive function* to describe what we label *cognitive control.* Similarly, our category of *emotion understanding* is labeled *emotion knowledge* by emotion researchers, and our category of *cognitive understanding* is labeled *theory of mind*. By using the same terms across the two domains, we emphasize their similarity as developmental processes.

Our approach to studying control and understanding processes across the domains of emotion and cognition has been tested and replicated in two samples of 3-year-old children: a diverse group of 141 children (Leerkes, Paradise, O’Brien, Calkins, & Lange, 2008) and the 3-year-old children included in the present study (Blankson, O’Brien, Leerkes, Marcovitch, & Calkins, 2012). In both cases, the four-component model, differentiating control and understanding across both emotion and cognition, was more descriptive of the relations among variables than either a model collapsing across processes within the domains of emotion and cognition or a model collapsing across domains but distinguishing control and understanding processes. These prior analyses were cross-sectional, however, and do not answer questions regarding the developmental associations across processes or domains. The present analyses go beyond this earlier work to address the extent to which age 3 performance within each component process is associated with change over time in each of the other three processes.

The present study is the first longitudinal examination of all four processes in the same sample of children across the preschool period, the time when some of these skills can first be measured. All of the processes studied in this project have been examined extensively in prior research, however, and some investigations have included longitudinal relations among the constructs of interest. These prior findings are briefly reviewed here.

Processes of Control and Interrelations Across Domains

Within the preschool period, we define *emotion control* to be the appropriate expression, use, and inhibition of emotion that allows a child to cope with positive and negative emotional, cognitive, and social situations (Calkins & Fox, 2002). We define *cognitive control* as the use of executive skills: working memory, or the ability to hold multiple pieces of information in mind and manipulate this information, and cognitive inhibitory control, an ability that allows a child to resist disruptive influences of competing stimuli (Carlson, Moses, & Claxton, 2004).

Some researchers consider children's emotion control abilities to be foundational to other domains of development (Eisenberg et al., 1995) and to play a key role in the regulation of state and of emotions and also in motor activity, attention, and cognition (Porges, 2003). Children who are better able to control their emotions have been found to be better able to engage in challenging tasks that provide opportunities for using and practicing cognitive skills (Calkins & Dedmon, 2000). Others have proposed that cognitive control, particularly attentional skills, aid in the development of emotion control (Calkins & Marcovitch, 2010; Posner & Rothbart, 2007). As attention becomes increasingly intentional throughout the 2nd and 3rd years of life, children can be seen to shift their attentional focus away from negative or emotionally arousing situations and also to deploy attention in problem-solving or cognitively demanding situations. Carlson and Wang (2007) outline three possible relations between cognitive control, specifically inhibitory control, and emotion control in early development: (a) inhibitory control underlies emotion regulation abilities, (b) emotion control allows more successful cognitive control, and (c) the two types of control are so closely integrated as to be virtually impossible to separate. The analyses in the present report allow an examination of all three of these possibilities.

Processes of Understanding and Interrelations Across Domains

We define e*motion understanding* as the ability to recognize and label one's own and others' emotions and tie them to situations, as well as the ability to understand the causes of emotions (Denham, 1998). We conceptualize c*ognitive understanding* during the preschool period as a child's ability to understand his or her own and others' mental states (Flavell, Miller, & Miller, 2002) and an awareness that perceptions do not always accurately reflect reality.

Several possibilities for the relation between emotion understanding and cognitive understanding have been raised in the literature. One is that emotion understanding emerges first and supports the development of theory of mind. Evidence indicates that very young children use emotion terms by age 2 and only later talk about beliefs (Bartsch & Wellman, 1995). Dunn (2000) has suggested that children first understand emotional states, which are typically accompanied by outward displays, and then extend that understanding to cognitive states, which are not usually visible. An alternative longitudinal hypothesis is that children need to develop an understanding of mental states to identify others' emotional states. Harwood and Farrar (2006) suggest that affective perspective taking performance, particularly the identification of emotions in others that differ from one's own feelings in those situations, depends upon the skills inherent in theory of mind tasks. In support of this idea, de Rosnay, Pons, Harris, and Morrell (2004) identified a lag between children's understanding of false belief and their ability to attribute emotions accurately. Similarly, Wellman and Liu (2004) found that children's ability to understand that an individual can feel one emotion but display another develops after an initial understanding of one's own and others' minds is acquired. A third possibility is that children's understanding of minds and of emotions develop in parallel; that is, the two areas of knowledge may be somewhat independent of each other. Support for this idea comes from studies in which children's performance on theory of mind and emotion understanding tasks are uncorrelated (e.g., Cutting & Dunn, 1999). In sum, there is a relative lack of consistent evidence regarding the developmental relation between emotion understanding and cognitive understanding. In the present study, we will examine all three possibilities: no predictive relation, emotion understanding predicts change in cognitive understanding, and cognitive understanding predicts change in emotion understanding.

Interrelations Across Control and Understanding Processes

Prior research examining developmental relations between control and understanding processes has typically focused within either the emotional or cognitive domain. The relations across various aspects of emotional competence, including emotion control and emotion understanding, have been the subject of several recent theoretical discussions (e.g., Izard et al., 2011), but there is still relatively little empirical research. It seems likely that children who are aware of their own and others' emotional states are more likely to make efforts to regulate at least the display of emotions in some situations. Using an attachment framework, Waters et al. (2010) found children's understanding of emotions to be related to their ability to handle negative emotions. Cole, Dennis, Smith-Simon, and Cohen (2009) found that children's understanding of emotion regulation strategies was related to their self-regulatory behavior.

A considerable body of research has examined relations between cognitive control, or executive function tasks, and cognitive understanding, or theory of mind. Perner and colleagues (Perner, 1998; Perner & Lang, 1999) propose that metarepresentational abilities arise from the development of mental state understanding and that this ability is necessary for successful execution of cognitive control tasks. Conversely, Russell (1996; see also Carlson & Moses, 2001) claims that children's difficulties in understanding deception and false belief stem from shortcomings in the ability to exert cognitive control. Results of several studies that have examined these links longitudinally indicate that cognitive control skills predict later performance on mental state reasoning and understanding tasks (Carlson, Mandell, & Williams, 2004; Hughes & Ensor, 2007).

Little work has been done to link cognitive control with emotion understanding or emotion control with cognitive understanding. Some authors have proposed that cognitive control skills promote understanding of emotions and affective perspective taking (Denham, Zoller, & Couchoud, 1994; Nilsen & Graham, 2009). In the few studies in which cognitive control and emotion understanding tasks have been examined together, significant relations between tasks have been found (Hughes, Dunn, & White, 1998; Nilsen & Graham, 2009). Because these studies were cross-sectional, no direction of effects could be identified. One longitudinal study included measures of both emotion regulation in a frustration task and theory of mind tasks, with results indicating no relation between the two over the preschool years (Liebermann, Giesbrecht, & Müller, 2007).

The Present Study

The goal of this study is to examine the developmental, time-lagged interconnections between four processes—emotion control, cognitive control, emotion understanding, and cognitive understanding. We use longitudinal data collected when children were 3 and 4 years old and test dynamic models to identify the extent to which each process accounts for developmental change in the others. We first examined an overall model to determine whether dynamic relations exist among these four processes, that is, whether any of the component processes predicts change over time in any other process. These analyses were followed up with tests of alternative models to identify which specific processes predict, or are leading indicators of, the others, and which are lagging indicators, in that their development is related to earlier performance in other processes. Because there is relatively little literature examining the relations among all four of these processes longitudinally within the preschool period, we took an exploratory approach and tested all possible paths. Thus, we asked the question of whether each type of process—emotion control, cognitive control, emotion understanding, and cognitive understanding—predicted change in the other processes. The resulting investigation represents a unique approach to the examination of the development of and relations between and among these four processes in the early childhood years.

Method

Participants

The sample consisted of two hundred and sixty-three 3-year-old children (M = 41.79 months, SD = 2.41, range = 37–47) and their mothers who participated in two waves of data collection of a study examining emotional and cognitive contributions to early school success. At the first wave, mothers were 33 years old on average (SD = 5.91). Approximately 51% had a 4-year college degree, 74% were married and living with their partner, and 79% were employed. Average income-to-needs ratio was 2.89 (SD = 1.73); 37% of the sample had an income-to-needs ratio below 2, 53% between 2 and 5, and 10% greater than 5. Fifty-two percent of the children were female; 58% of the children were European American, 35% African American, and 7% other ethnicities, including children of mixed ethnicity.

Of the 263 original participants, 244 returned 1 year later for Wave 2, a 93% retention rate. Mothers who participated in both visits were more likely to be White, $\chi^2(1, N = 263) = 5.13$, $p < .05$, and better educated, Welch's $t(261) = 3.14$, $p < .05$, than those who did not return for follow-up. At age 4 (M = 53.41 months, SD = 1.84, range = 49–59 months), 52% of the children were female; 60% of the children were European American, 32%

African American, and 8% other ethnicities. Mothers were 34 years old on average ($SD = 5.69$). Approximately 53% had a 4-year college degree or had completed higher levels of education, 74% were married and living with their partner, and 77% were employed.

Procedure

Participating families were recruited from preschools and child-care centers. When children were 3 and again at age 4, they participated with their mothers in a laboratory session during which they were videotaped while completing tasks assessing emotional and cognitive control and understanding. The session included a snack and play time with the mother. Mothers provided written consent and completed questionnaires during each session. Families received $40 and $60 for the 3- and 4-year visits respectively, and children selected a toy.

Measures

We take a multimethod approach to measurement by assessing each construct with several different tasks. Composites were created by standardizing and summing the relevant scores for each construct within each time point. To retain the longitudinal structure of the data for analytical purposes, the 4-year variables were standardized using the means and standard deviations of the 3-year variables prior to summing.

Emotion Control

Emotion control was measured both by maternal report and by observed behavior.

Mother report Two measures of emotion control were completed by mothers: the Children's Behavior Questionnaire short form (CBQ;Putnam & Rothbart, 2006) and the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1998). In the CBQ, mothers described their children's typical reactions to various situations on a 7-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 subscale (6 items, alphas = .73 at 3 and 4 years), which indexes regulation. In the ERC, mothers rated how frequently their child engaged in certain behaviors on a scale from 1 (*never*) to 4 (*always*). Two subscales, Lability/Negativity (15 items, alphas = .82 and .81 at 3 and 4 years) and Emotion Regulation (8 items, alphas = .60 and .56), were used in the present study. Higher scores represented more emotion control. The three parent-report measures were correlated .29 to .50 at age 3 and .29 to .55 at age 4, all ps < .01. Alphas for the composites were .67 at 3 and 4 years.

Observed regulation Expressed frustration and regulatory behaviors were coded from videotapes of frustration tasks: the Locked Box at 3 years (Calkins, 1997) and a frustrating puzzle task at 4 years. For the Locked Box task, an attractive 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. The experimenter then left the room while the child attempted to open the box. After 4 min, the experimenter re-entered and gave the child the correct key so the child could play with the toy. For the frustrating puzzle, the child was asked to untangle a string laced through a toy with many holes. The middle of the string was glued to the toy, thus making it impossible to untangle. The experimenter left the room while the child attempted to untangle the string. After 3 min, the experimenter re-entered the room, presented a second unglued puzzle to the child, and allowed the child to completely unlace the string.

Videotapes of the tasks were rated by trained coders for: *verbal frustration*, or the frequency of verbal negative expressions of frustration such as “I don’t want to do this anymore” (reversed); *physical frustration*, or the frequency of physically negative expressions, such as hitting or throwing the box or puzzle (reversed); and *global regulation*, scored on a scale of 0 (*no control of distress responses*) to 3 (*well-regulated control*). Interrater reliabilities, calculated as Pearson correlations for verbal and physical frustration and kappa for global regulation on approximately 20% of the videotapes were .96, .95, and .71, respectively, at 3 years, and .97, .63, and .58 at 4 years. Scores for observed regulation correlated .23 to .45 at age 3 and .26 to .42 at age 4, all ps < .01. Alphas were .64 and .56 at 3 and 4 years.

Cognitive Control

Working memory The number recall subtest of the Kaufman Assessment Battery for Children (K–ABC, Kaufman & Kaufman, 1983), a forward digit span task, was administered. In this task, the examiner recites a series of numbers, and the child is asked to repeat them in the same sequence. Number sequences increase in size until children miss three in a row. The possible range of scores was 0–22.

Inhibitory control In the day/night Stroop test (Gerstadt, Hong, & Diamond, 1994), 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 2 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 who failed both practice trials were not presented the test trials and received a score of 0 (3 year n = 76; 4 year n = 13). The possible range of scores was 0–16.

The two cognitive control measures were correlated at both ages: 3 year, $r(259) = .42$; 4 year, $r(242) = .24$, both ps < .01. Alphas for the composites were .48 and .38 at 3 and 4 years.

Emotion Understanding

Labeling of emotions Children were presented four felt faces, depicting the emotions happy, sad, angry, and scared, and asked to name each expression (e.g., “How is this person feeling right now?”) to assess verbal emotion labeling (Denham, 1986). Children were also asked to point to each expression when requested (e.g., “Show me the _______ face”) to assess 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., indicating sad instead of angry), and 0 if they identified an emotion of the incorrect valence (e.g., indicating happy for sad). Recognition and labeling scores were correlated: 3 year, $r(261) = .62$; 4 year, $r(244) = .42$, both ps < .01, and were summed; scores could range 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 nonequivocal emotional reactions (e.g., happiness at getting an ice cream cone). The remaining six vignettes were more equivocal situations where the protagonist puppet portrayed an emotional response that the mother had earlier reported was 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 enactedhappiness 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. The nonequivocal and equivocal scores correlated significantly: 3 year, $r(258) = .53$; 4 year, $r(244) = .43$, both ps < .01, and were summed; the possible range was 0–20.

Knowledge of emotion causes Children's ability to explain the reasons for experiencing emotions was examined using a puppet task (Denham et al., 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 up to four reasons, and their responses were recorded verbatim and coded for the number of accurate, independent causes given (possible range 0–4) 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). Interobserver reliabilities, calculated as kappas, were .76 and .83 for the 3- and 4-year assessments, respectively. The number of correct explanations was summed across all four emotions; scores could range from 0 to 16.

The three emotion understanding tasks were correlated .46 to .49 at age 3 and .30 to .44 at age 4, all ps < .01. Alphas for the composites were .71 and .53 at 3 and 4 years.

Cognitive Understanding

Appearance–reality distinction This task assesses whether children can accurately describe differences between an object's real nature and its apparent nature when modified perceptually (Flavell, Flavell, & Green, 1983). Children were shown two realistic-looking imitation objects: a candle in the shape of an apple and an egg made of wood at 3 years, and a pencil sharpener in the shape of a light bulb and an eraser that looks like a crayon at 4 years. The child was asked what is the object really (control question) and what does it look like (test question; e.g., “Does it look like a candle or an apple?”). 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. The child was asked what the object looked like while modified (e.g., “Does it look blue or red?” or “Does it look big or does it look little?”) and what the properties of the objectreally were (e.g., “Is it really, really blue or is it really, really red?”or “Is it really, really big, or is it really, really little?”). Children scored 1 point if they responded correctly to both the appearance and the reality questions for a specific property. The number of correct responses was summed across both objects and all identity, color, and size domains to yield a total score that could range from 0 to 6.

Visual perspective taking The measure of Visual Perspective Taking (Flavell, Everett, Croft, & Flavell, 1981; Taylor, 1988) is organized hierarchically into Level 1 tasks, in which children need only recognize that another person cannot always see the same things they can see, and Level 2 tasks, which require children to differentiate their own from another person’s viewpoint. Children were first presented with three Level 2 tasks in which two different pictures and a book were placed on the table in front of the child one at a time. Children were asked two questions about each stimulus that required them to consider their own perspective and that of the experimenter. Following these tasks, one Level 1 task was administered in which children were shown a card with a different picture on each side. The card was then placed vertically between the child and the experimenter so that each could see only one side. Children were asked to identify what they could see from their own perspective and what the experimenter could see. Children earned 1 point for each correct response; scores could range from 0 to 7.

Unexpected contents This task assessed children’s ability to identify accurate and false beliefs about the contents of two containers (Astington & Gopnik, 1988; Perner, Leekam, & Wimmer, 1987). At 3 years, the child was shown a BAND-AID box that contained blocks and a crayon box that contained spoons. At 4 years, the child was shown a cereal box containing pencils and a bubble jar containing straws. First, the examiner presented the box and asked the child, “What do you think is in here?” The examiner then revealed the actual contents. Children were then asked two test questions: “Before we opened this, what did you think was in here?” and 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 summed across both containers; possible scores ranged from 0 to 4.

Unexpected location The unexpected location task involved asking the child to predict a person’s behavior based on a mistaken belief about the location of a hidden object (Baron-Cohen, Leslie, & Frith, 1985; Hala & Chandler, 1996). The experimenter showed the child three boxes. A second experimenter then entered the room, placed a toy in one of the three boxes, and left the room. The child was asked to move the object from one box to another while Experimenter 2 was out of the room. Two trials were presented and for each trial the child was asked two test questions: “Where will E2 look for the toy when he comes back?” and “Where will E2 think the toy is?” Two control questions (“Where did E2 put the toy?” and “Where is the toy really?") were also asked; children received 1 point for each correct test question if they answered both control questions correctly. The number of correct responses to the test questions across both trials was summed; scores could range from 0 to 4.

The cognitive understanding tasks correlated .14 to .30 at age 3 and .34 to .44 at age 4, all *p*s < .05. Alphas for the composites were .50 and .71 at 3 and 4 years.

Child age and language At age 3, children were administered the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997). Child language was considered as a potential covariate along with child age at Time 1.

Data Analysis

The primary analytic approach was latent difference score regression models (LDS; Ferrer & McArdle, 2004; McArdle, 2009), with child age and child language considered as covariates. In an LDS model, the change between two variables is represented by a latent factor that is defined as the difference between the other two variables through the use of fixed unit-valued (= 1) coefficients (McArdle, 2009). Combining multiple univariate LDS models into one model allows tests of developmental interconnections among the variables. A complete multivariate model in which change in each variable is predicted from initial levels of all other variables can be specified and tested to provide indication of the extent to which variables are dynamically interdependent. Nested models can also be specified and compared with the complete multivariate model to provide further information about the extent to which one variable is leading or lagging in development. More technical details on LDS models can be found in Ferrer and McArdle (2004) and McArdle (2009).

Analyses included both the mother-reported and observed measures of emotion control, along with the composites representing cognitive control, emotion understanding, and cognitive understanding. In all models, parameter estimates were obtained using full information maximum likelihood (FIML) in Mplus (Muthén & Muthén, 1998–2010) and 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.

Results

Table 1 shows the means and standard deviations for the individual tasks and composites, as well as the correlations across time for individual tasks. Correlations within and across ages among the composite scores are shown in Table 2 along with the correlations with child age and language and partial correlations among the four processes controlling for 3-year language.

Table 1. ***Descriptive Statistics for Individual Measures and Composite Study Variables***

Variable	3 year	4 year	*r*

	M	*SD*	Range	*N*	*M*	*SD*	Range	*N*	
Emotion control–mother report									
Falling reactivity	5.05	0.98	1.67–6.83	258	5.09	0.88	2.33–7.00	242	.56**
Lability/negativity (rev)	2.15	0.36	1.00–2.94	261	2.29	0.34	1–3.07	242	.64**
Emotion regulation	3.38	0.34	2.13–4.00	261	3.46	0.31	2.63–4.00	242	.54**
Composite	0.00	2.32			0.65	2.14			.68**
Emotion control–observed									
Verbal frustration (rev)	28.63	5.28	1–34	260	15.48	3.28	1–18	244	.21**
Physical frustration (rev)	13.06	2.09	1–14	260	4.88	0.46	1–5	244	.04
Global regulation	2.55	0.69	0–3	260	2.83	0.42	1–3	244	.10
Composite	0.00	2.29			2.98	0.98			.18**
Cognitive control									
K–ABC number recall	2.73	2.49	0–10	260	5.17	2.48	0–12	244	.51**
Stroop	6.58	5.46	0–16	260	10.01	4.25	0–16	243	.39**
Composite	0.00	1.68			1.65	1.41			.54**
Emotion understanding									
Labeling of emotions	11.84	3.40	0–16	261	14.40	1.75	5–16	244	.51**
Affective perspective taking	12.19	4.39	0–20	258	16.77	3.15	4–20	244	.42**
Knowledge of emotion causes	3.41	2.73	0–12	262	6.80	3.76	0–15	244	.51**
Composite	0.00	2.40			3.04	2.03			.65**
Cognitive understanding									
Appearance-reality	0.99	1.09	0–6	261	2.25	1.83	0–6	242	.27**
Visual perspective taking	1.69	1.70	0–7	258	3.28	2.35	0–7	243	.35**
Unexpected contents	1.12	1.28	0–4	261	1.70	1.64	0–4	244	.21**
Unexpected location	0.58	1.04	0–4	261	2.16	1.61	0–4	244	.34**
Composite	0.00	2.35			4.06	4.33			.46**

Note. K–ABC = Kaufman Assessment Battery for Children; Stroop = day/night Stroop test; rev = reverse scored.
**$p \leq .01$.

Table 2. ***Correlations for Study Variables (*****N*****s = 242 to 262)***

	1	2	3	4	5	6	7	8	9	10	11
1. Emotion control–M report 3 year	—										
2. Emotion control–observed 3 year	−.02 (−.03)	—									
3. Cognitive control 3 year	.10 (.03)	.10 (.10)	—								

4. Emotion understanding 3 year	.21** (.12)	.10 (.12*)	.53** (.36**)	—							
5. Cognitive understanding 3 year	.11 (.05)	−.07 (−.09)	.27** (.13)	.32** (.09)	—						
6. Emotion control–M report 4 year	.68** (.67**)	.11 (.10)	.08 (.01)	.14* (−.03)	.09 (.03)	—					
7. Emotion control–observed 4 year	.15 * (.15*)	.18** (.17**)	.13 (.13*)	.05 (.05)	−.01 (−.02)	.17*	—				
8. Cognitive control 4 year	.28** (.23**)	.06 (.06)	.54** (.44**)	.46** (.26**)	.31** (.19*)	.21** (.15*)	.19* (.20**)	—			
9. Emotion understanding 4 year	.12 (.02)	.13* (.15*)	.40** (.22**)	.65** (.44**)	.27** (.08)	.13 (.04)	.16* (.18**)	.40** (.21**)	—		
10. Cognitive understanding 4 year	.19** (.12*)	.07 (.07)	.42** (.27**)	.47** (.23**)	.46** (.34**)	.19** (.13)	.05 (.04)	.50** (.38**)	.40** (.19**)	—	
11. Age 3 year	−.22**	.02	.13*	.14*	−.02	−.05	.00	.03	.15*	.01	—
12. PPVT 3 year	.18**	.02	.43**	.69**	.37**	.17**	.02	.43**	.56**	.47**	.14*

Note. Partial correlations controlling for 3-year PPVT are in parentheses.
*p ≤ .05. **p ≤ .01.

Initially, models were tested that included and excluded the covariates of child age and language. Models with age and language fit significantly worse than those excluding age and language (e.g., fit for the model that included both child age and language was: RMSEA = .22, χ^2 = 205, *df* = 15, CFI = .65). The relatively poor fits indicate that child age and language are not contributing to our understanding of change in the emotion and cognitive processes over time. Therefore, results are presented for the models excluding child age and language as direct predictors of change in the four processes over time.

The aims of the present research were addressed by fitting four multivariate LDS regression models. Model 1, depicted in Figure 1, was a full multivariate model, including all dynamic relations among the four processes. That is, the model tests whether initial levels of each control and understanding process at 3 years predict change in itself and in the other three processes, with mother reported and observed emotion control both included in the model. The solid lines in Figure 1 represent coupling parameters (γ), the dotted lines represent the auto-proportion or self-feedback parameters (β), and intercepts are represented by the triangle. For each variable, estimates were obtained for the initial deviation, slope (change score), intercept and deviation, auto-proportion, and couplings with each of the other variables.

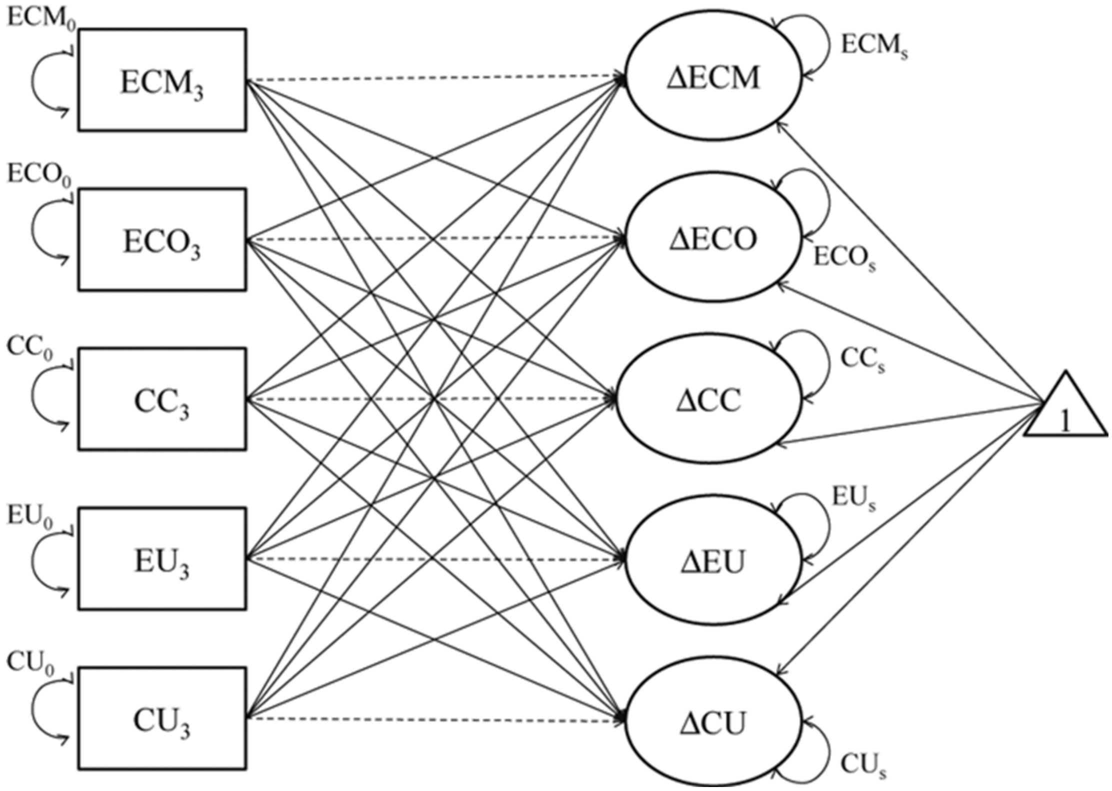

Figure 1. Dynamics of a multivariate emotion–cognition system. *Note.* ECM = emotion control–mother report; ECO = emotion control–observed; EU = emotion understanding; CC = cognitive control; CU = cognitive understanding. EC_3 = scores at 3.5 years; ΔECM = yearly changes in ECM; triangle = constant = 1; path from constant to change = slope intercept; ECM_0 = variance of initial scores; ECM_s = variance of slope scores. Solid lines represent coupling parameters (γ); dotted lines represent auto-proportion or self-feedback parameters (β). Correlations among the 3-year processes and among the difference scores are estimated but not shown.

The full dynamics model fit the data well (χ^2 = .01, *df* = 5, RMSEA = .00). Parameter estimates for this model are presented in Table 3. All auto proportion parameters (β) were significant and negative, indicating that initial levels of all processes influenced yearly changes in themselves; children with higher initial levels showed less change over time.

Table 3. ***Parameter Estimates for Full Dynamics Model***

Parameter	**ΔEmotion control–mother report**	**ΔEmotion control–observed**	**ΔCognitive control**	**ΔEmotion understanding**	**ΔCognitive understanding**
Loading α	= 1	= 1	= 1	= 1	= 1
Proportion β	−.36**	−.93**	−.66**	−.50**	−.47**
Coupling γ					

3 year emotion control-mother-report→	—	.07*	.13**	−.01	.18
3 year emotion control-observed→	.12**	—	.00	.05	.09
3 year cognitive control→	.03	.09	—	.08	.46**
3 year emotion understanding→	− .02	−.03	.10**	—	.44*
3 year cognitive understanding→	.02	−.01	.07*	.04	—
Initial mean	= 0	= 0	= 0	= 0	= 0
Slope intercept	.62**	2.97**	1.62**	3.00**	3.98**
Initial variance	5.35**	5.23**	2.82**	5.78**	6.40**
Slope variance	2.42**	.82**	1.20**	2.36**	12.15**
Note. All parameters are raw maximum-likelihood estimates fitted using Mplus. Correlations among levels and slopes are estimated but not shown here. *p ≤ .05. **p ≤ .01.					

Of primary interest was the extent to which each of the processes influenced growth and change in the others over and above the influence of a process on itself. The coupling parameters (γ) in the full multivariate model indicate that growth in cognitive processes, but not emotion processes, is predicted by age 3 scores on the other components of the model. For example, Table 3 shows that, holding initial values for all composites constant, children can be expected to increase 1.62 units in cognitive control from age 3 to age 4. This increase is accelerated by mother-reported emotion control, emotion understanding, and cognitive understanding scores at age 3 (significant coefficients of .13, .10, and .07, respectively). That is, children with better mother-reported emotion control, emotion understanding, and cognitive understanding at age 3 made greater gains in cognitive control between age 3 and 4 than other children. Likewise, cognitive understanding increased by an average of 3.98 units from age 3 to age 4, and this change was accelerated by cognitive control and emotion understanding scores at age 3 (coefficients of .46 and .44, respectively). Growth in emotion understanding was not predicted by any of the other processes.

Considering the results from the perspective of which processes are leading indicators, that is, which processes influence change in others, mother-reported emotion control, cognitive control, emotion understanding, and cognitive understanding all appear to contribute to some extent to change in other processes. Mother-reported emotion control predicts growth in cognitive control but not in emotion or cognitive understanding, cognitive control predicts cognitive understanding, emotion understanding predicts cognitive control and cognitive understanding, and cognitive understanding predicts cognitive control. Behaviorally observed emotion control was only found to predict changes in itself and mother-reported emotion control; these two approaches to the measurement of regulation are clearly differentially related to cognitive development.

Next, we conducted more rigorous tests of the dynamics among the four processes by comparing the fit of the full multivariate model with more parsimonious models specifying various processes as leading indicators, lagging indicators, or neither leading nor lagging indicators. We examined three additional sets of models, illustrated in Figure 2. These additional models were exploratory in nature.

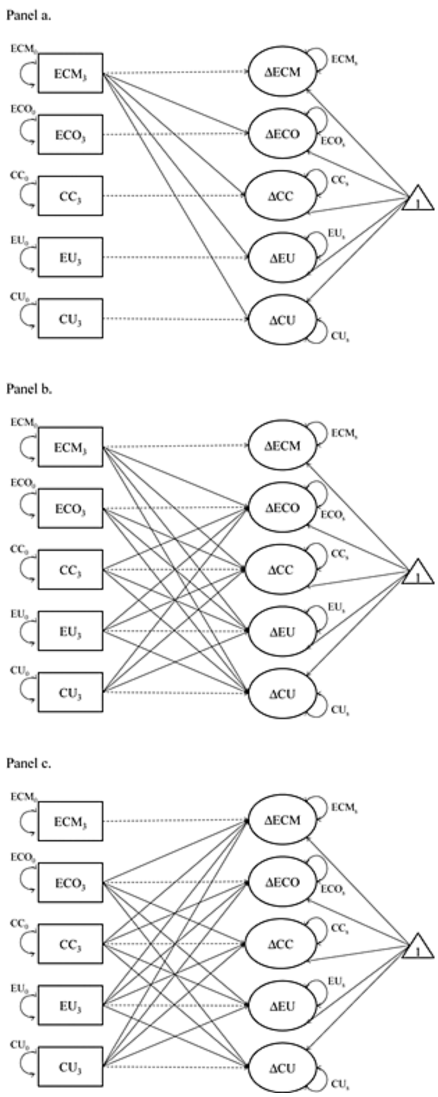

Figure 2. (a) Emotion control–mother report as the only leading indicator of development in emotion and cognitive processes. (b) Development of emotion control–mother report is independent of the other processes. (c) emotion control–mother report as the only process that does not influence development in the other processes.

In the first of these additional models, we examined whether any one of the processes is the only leading indicator of development in the other three processes. In these models, the coupling parameters (crossed coefficients) associated with only one predictor variable were estimated and all other coupling parameters were fixed at zero. Figure 2a illustrates a sample model with mother-reported emotion control as the only leading indicator of development in each of the other three processes. Each model was evaluated by comparing the chi-square fit index with the chi-square fit for the full dynamics model. As can be seen in Table 4, all five models produced significantly poorer fits in comparison to the full model, indicating that none of the processes is solely acting to accelerate development in the others.

Table 4. ***Model Fits***

Model	**RMSEA**	**CFI**	**SRMSR**	$\Delta\chi^2/\Delta df$
Full dynamics	.00	1.00	.00	.00/5
One factor is the only leading indicator				
Emotion control–mother report	.10	.91	.08	71.37/16**
Emotion control–observed	.11	.88	.10	87.70/16**
Cognitive control	.09	.92	.07	61.82/16**
Emotion understanding	.07	.95	.05	47.22/16**
Cognitive understanding	.11	.89	.09	82.44/16**
One factor is not lagging				
Emotion control–mother report	.00	1.00	.02	7.30/4
Emotion control–observed	.00	1.00	.03	8.65/4
Cognitive control	.11	.95	.05	35.46/4**
Emotion understanding	.00	1.00	.01	3.67/4
Cognitive understanding	.13	.93	.07	49.23/4**
One factor is not leading				
Emotion control–mother report	.07	.98	.04	19.76/4**
Emotion control–observed	.00	1.00	.02	8.04/4
Cognitive control	.04	.99	.02	12.53/4*
Emotion understanding	.06	.98	.03	18.58/4**
Cognitive understanding	.00	1.00	.02	6.50/4

Note. RMSEA = root mean square error of approximation; CFI = comparative fit index; SRMSR = standardized root mean square residual. All fit comparisons are in relation to the full dynamics model.*$p \leq .05$. **$p \leq .01$.

The next set of models (Figure 2b) examined “lagging hypotheses,” or whether one process is not developmentally influenced by any of the others. In these models, the coupling parameters associated with the prediction of one of the processes were fixed at zero (e.g.,Figure 2b depicts the model in which development of mother-reported emotion control is predicted only by initial values of itself and is independent of the other processes). If the fit of the model is similar to that of the full dynamics model, then we can say that change in the process of interest is not related to earlier performance in any of the other processes.

Results, shown in Table 4, indicated that the models in which yearly changes in cognitive control and cognitive understanding are predicted only from their own initial levels resulted in significantly worse fits than the full model. These results suggest that cognitive control and cognitive understanding are dynamically dependent on the other processes. This was not true for mother-reported emotion control, observed emotion control, or emotion understanding, which appear to be changing independently of the other processes.

The third set of comparison models tested whether any one process does not play a role in the development of any of the other processes (e.g., the sample model depicted in Figure 2c tests whether mother-reported emotion control is the only process that does not influence development in the other processes). In these models, the crossed coefficients for only one of the processes were fixed at zero while coupling parameters for the remaining three processes were estimated. If the fit of these models is similar to that for the full model, we can conclude that the variable with fixed coupling parameters does not influence the other variables in development. As shown in Table 4, the models for mother-reported emotion control, cognitive control, and emotion understanding fit significantly worse than the full model, indicating that there are dynamic relations between these processes and the others. The fits of the models for behaviorally observed emotion control and cognitive understanding were similar to that of the full model. Thus, observed emotion control and cognitive understanding at age 3 are not robust predictors of change from age 3 to 4 in any of the other processes.

Overall Summary

Based on the pattern of results from the sets of model comparisons in conjunction with the parameter estimates from the full dynamics model, our results indicate that: (a) no one process is accounting for change in all the others, and (b) cognitive control and cognitive understanding are dynamically dependent on each other, on emotion understanding, and on emotion control as reported by mothers, whereas emotion control and emotion understanding are independent.

Discussion

In the present research, we focus on two basic processes—control and understanding—that can be identified in the early development of both emotional and cognitive abilities. Our exploratory examination of the dynamic associations between and among emotion control, cognitive control, emotion understanding, and cognitive understanding indicate that these four processes are dynamically dependent. Specifically, growth in cognitive control and cognitive understanding appear to be dependent on each other and on emotion understanding. In addition, emotion control as reported by mothers supports growth in cognitive control, but emotion control as measured behaviorally in frustrating lab tasks is not related to growth in other processes. Growth in emotion processes is not predicted by initial levels of any of the other processes.

The early development of emotion control skills and their relation to cognitive processes has been the focus of considerable research. Investigators have tended to adopt one of two positions, with some claiming that emotion control abilities support cognitive development (Blair & Diamond, 2008) and others claiming that cognitive advances make it possible for children to monitor and control their behavior (Carlson & Wang, 2007; Perner & Lang, 1999). The results of the present study suggest that emotion control as measured by mother report and emotion understanding underlie advances in both cognitive control and cognitive understanding during the preschool years.

Gains in both cognitive control and cognitive understanding were partially accounted for by levels of these factors at age 3. These results support those of others (see Moses & Tahiroglu, 2010, for a review) who have shown executive function skills to predict mental state understanding. In the present study, mental state understanding also appeared to support the development of executive function skills, as has been proposed by Perner (1998). Our results suggest that the effect of cognitive understanding on changes in cognitive control may not be as strong as the effect of cognitive control on cognitive understanding. We did not find evidence that either cognitive control or cognitive understanding were key factors driving development of emotion processes. Because we elected to measure emotional and cognitive processes at about the earliest age children can reliably complete tasks to measure cognitive control and both emotion and cognitive understanding, our results cannot be generalized beyond the early preschool period. Our findings suggest interrelations across the domains of emotion and cognition, as has been suggested by others. As children grow and their cognitive control skills become more sophisticated, cognitive processes undoubtedly become more important to the scaffolding and organization of learning. Furthermore, processes of understanding can feed back into control skills. The present study is therefore only a starting point for researchers to examine the dynamic interplay among these four domains of development.

Our framework of dividing skills across domains into indices of *control* and indices of *understanding* adds a new dimension to past work in which emotional development and cognitive development have typically been studied separately, and similarities in processes have not been clarified. This is particularly true for control processes, which are commonly labeled emotion regulation in the social-emotional literature and executive function in the cognitive literature. Increasingly, investigators have noted the overlap in definitions of these constructs (e.g., Calkins & Bell, 2010; Liebermann et al., 2007). Attentional control, inhibitory control, and self-regulation are difficult to separate and are often needed within the same tasks.

Another key issue involves the measurement of processes of control and understanding. Measures of cognitive control are perhaps most well developed and standardized (Garon, Bryson, & Smith, 2008) although there continue to be differences of opinion about the components of executive function (e.g., Zelazo, Carlson, & Kesek, 2008). By contrast, measurement issues in the study of emotion control continue to be widely discussed and debated (e.g., Zeman, Klimes-Dougan, Cassano, & Adrian, 2007). Emotion control is most often measured using parent or teacher report to capture the child’s typical responses across a wide range of situations. Frustrating laboratory tasks have also been developed to allow direct observation of regulatory strategies. These approaches are limited in the range of intensity that can ethically be elicited and also because it is known that even very young children can hide negative emotions (Zeman et al., 2007), making it difficult to observe and code regulation accurately. In the present investigation, the global regulation measure had low reliability, which may have affected the results.

We followed past studies in considering emotion understanding to include recognition of emotional expressions and knowledge of appropriate emotional displays in specific situations (Denham, 1998). Given the young age of the children in our study, we defined cognitive understanding as understanding of mental states and used perspective taking, appearance-reality, and theory of mind tasks as indicators. Some recent work suggests that children understand desires and variation in desires prior to understanding that people may hold differing beliefs (Wellman, Fang, & Peterson, 2011; Wellman & Liu, 2004); inclusion of tasks involving desires may have expanded the range of performance. Some investigators studying theory of mind consider understanding of emotions to be a component part of this construct (Ketelaars, van Weerdenburg, Verhoeven, Cuperus, & Jansonius, 2010; Pears & Moses, 2003) whereas others believe the dimensions are separable (Cassidy, Werner, Rourke, Zubernis, & Balaraman, 2003; Cutting & Dunn, 1999). Some research indicates that different factors predict emotion and cognitive understanding as we define them (Dunn, Brown, Slomkowski, Tesla, & Youngblade, 1991), and these constructs also have been shown to relate to different outcomes (Dunn, 2000). Nevertheless, there are clear similarities between one’s understanding of others’ emotional states and of mental states.

It is possible that the emotion understanding tasks we used were more straightforward than the cognitive understanding tasks and that this difference in complexity contributed to the developmental relations we identified. We expect that as children’s understanding of their own and others’ emotional and mental states develops into the early school years and beyond, there are reciprocal relations between these domains. Longer term longitudinal research is needed to disentangle these transactional relations over time.

Prior research has examined some aspects of the relations between the processes considered in the present study, but no previous work has included all of them in a large and diverse sample of children studied longitudinally. The developmental dynamics approach allowed us to examine the contributions of all four processes to one another. This is a novel way to look at developmental change and offers the advantage that we are able to study the effects of the four processes simultaneously. A further advantage of the use of latent difference score models over traditional difference score analyses is that measurement error is taken into account, such that more reliable estimates of effects are obtained.

An additional strength of the present research was the use of a multimethod approach to measure emotion control. The differences in our results from analyses using maternal report of emotion control compared with those using behavioral observation of emotion control suggest that laboratory observations are not tapping the same range of individual differences in emotion control as maternal report. Future research could take a multimethod developmental approach to the assessment of all four processes. Such an approach would allow us to better untangle the structural overlaps and distinctions among the processes and assess convergence and divergence in the dynamics among the four processes.

Understanding the developmental dynamics among emotional and cognitive processes can enhance our understanding of the complex interplay across domains that are often investigated as if they were independent. Longer term longitudinal work that includes measures of both cognitive and emotional functioning assessed using different methodological approaches is likely to unravel more of the reciprocal relations among these processes.

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