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A transactional model of expressive control and inhibitory control across childhood

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Abstract

This investigation examined cross-lagged relations between expressive control (i.e., management of expressed affect) and inhibitory control (i.e., management of behavior) to elucidate the development of self-regulation across affective and behavioral domains. Regulation was assessed longitudinally at ages four, six, and eight using both observational laboratory tasks and teacher reports in a diverse sample of 250 children. Both observational and teacher-reported models produced parallel results, with consistent prospective relations between expressive control and inhibitory control. In both models, better expressive control of affect at age four predicted better inhibitory control of behavior at six whereas better inhibitory control at age six predicted better expressive control at age eight. Cross-domain longitudinal relations controlled for the stability of prior within-domain regulation and concurrent cross-domain relations. The replication of these findings across laboratory and school settings provides particularly robust evidence for these effects. This study demonstrated that clarifying developmental dynamics across domains of self-regulation may be essential to understanding the full regulatory system.

KEYWORDS
cross-lagged panel models, expressive control, inhibitory control, longitudinal, self-regulation, transactional

1 | INTRODUCTION

As the mechanism by which we modulate our responses to situational demands, self-regulation figures prominently in how children negotiate developmental challenges with profound implications for current and prospective adaptation (Graziano et al., 2007). However, the transactional relations between affective and behavioral domains of self-regulation across childhood remain poorly defined. Given the central importance of dysregulation for the development of childhood disorders (Cole, Michel, et al., 1994), research that clarifies the development of regulatory systems will inform efforts to enhance well-being by targeting intervention efforts to particular domains of skills at opportune moments in development. Guided by the tenets of an organizational perspective on development (Cicchetti & Sroufe, 1978), wherein capabilities develop in a hierarchically organized series of stage-salient issues, and subsequent elaborations in empirically validated developmental cascade models (e.g., Blandon et al., 2010), we assert that identifying prospective effects of one domain of regulatory skill on other skills will allow interventions to capitalize on potential cascade effects in the development of self-regulation by training capabilities in each domain at optimal ages. Thus, the current investigation used laboratory observations and teacher reports to examine longitudinal relations between expressive control (i.e., management of affect) and inhibitory control (i.e., management of behavior) across childhood.

1.1 | Self-regulation

Research supports a multidimensional model of self-regulation, with explicit distinctions between affective and behavioral domains of analysis (Maughan & Cicchetti, 2002; Raffaelli et al., 2005) that are reinforced by measurement models exploring the overlap and division between these domains (Egeland & Fallmyr, 2010). *Expressive control of affect* refers to the expressed component of emotion regulation, and involves up- or down-modulating one's outward emotional response to a situation in an attempt to satisfy interpersonal and intrapersonal goals (e.g., controlling anger in a frustrating situation; Thompson, 1994; Zeman et al., 2006). This affective facet of self-regulation can be distinguished from *inhibitory control of behavior*, which is a behavioral facet of self-regulation and involves modulating one's actions in accordance with situational demands and prohibitions (e.g., not playing with a toy when asked to wait). These processes, despite being exercised in distinct domains, necessarily overlap. Expressive control of affect likely involves some inhibitory control of behavior (e.g., controlling vocalizations), and inhibitory control of behavior may co-occur with expressive control of affect, particularly in emotionally charged situations (e.g., controlling excitement while awaiting one's turn). However, these domains can be differentiated based on the ultimate goal of the regulatory process (i.e., controlling affect vs. controlling prohibited behavior), and competence in one facet of self-regulation is not sufficient to develop competence in another facet. Given areas of convergence and divergence across these regulatory systems, this investigation sought to elucidate directional influences between expressive control of affect and inhibitory control of behavior across childhood while accounting for concurrent covariation, as well as intra-domain stability over time. Moreover, we evaluated these relations using distinct assessments of expressive and inhibitory control as observed in the laboratory setting and as reported by teachers in the school setting.

Given that children's behaviors can differ across contexts, and reporters do not always cohere in their assessments, experts recommend that regulation be assessed with multiple methods and informants (Cole et al., 2004). Laboratory observations allow for the systematic comparison of children's responses to equivalent regulatory challenges whereas teacher reports of self-regulation carry a distinct advantage of reflecting behavior in an ecologically valid context. Thus, comparing patterns of self-regulation across laboratory assessments and teacher reports, as in the present study, can yield substantive and methodological insights regarding the validity of each measurement approach, as well as robust evidence for obtained patterns of regulatory development.

1.1.1 | Expressive control across childhood

Expressive control represents a specific facet of the umbrella term emotion regulation. Although emotion regulation skills are thought to increase over time at the group mean level (Raffaelli et al., 2005), longitudinal research has been limited, and evidence of rank order stability of individual differences with regard to specific components of emotion regulation has been equivocal. Whereas dispositional emotionality shows moderate stability across infancy, the stability of emotion regulation is more variable, particularly outside the first few years of life (Murphy et al., 1999). Although some research suggests that rank order differences may be moderately stable across childhood (Raffaelli et al., 2005; Rydell et al., 2003), these studies have used parent reports of emotion regulation, which may conflate the stability of the child's expressive control with potential informant bias; for example, parent ratings are influenced by their perception of the child and the parent's own characteristics, such as emotional distress (Seifer et al., 2004). The current study addressed the pressing need for prospective multi-informant studies of emotion regulation skills by using longitudinal assessments of expressive control (children's expressed negative affect in response to laboratory disappointment tasks and teacher reports of children's soothability) from the preschool period (age four) through early childhood (age six) into middle childhood (age eight). These specific ages were selected for examination based on evidence that children's self-regulation begins developing in earnest at ages 4–5 (Dowsett & Livesey, 2000; Raffaelli et al., 2005) and continues through early childhood, increasing through ages 8–9, and then, plateaus between middle childhood and adolescence (Raffaelli et al., 2005). Thus, the present study sought to capture the time of greatest growth in both expressive control of affect and inhibitory control of behavior, with three evenly spaced assessments across this period.

1.1.2 | Inhibitory control of behavior across childhood

Inhibitory control refers to the suppression of a dominant response in favor of a subdominant response and is a commonly used indicator of behavioral self-regulation because it clearly captures the process of modulating actions to conform to situational/goal-oriented demands (Kochanska et al., 2000). In contrast to mixed evidence regarding patterns of emotion regulation over time, prospective longitudinal investigations using observational and parent or teacher reports of inhibitory control strongly support the rank order stability of behavior regulation across childhood (Kochanska et al., 2001; Murphy et al., 1999; Raffaelli et al., 2005).

1.2 | Transactional relations among domains of self-regulation

Few studies have examined relations between multiple domains of self-regulation, and still fewer have done so over time, despite the significant intervention implications of doing so. To address these gaps in the literature, this investigation explored if and how functioning in one domain of regulation could affect prospective functioning in the other domain of regulation. In doing so, this study contributes an integrated model of expressive control of affect and inhibitory control of behavior across childhood.

Studies that have examined concurrent relations between elements of emotion regulation and inhibitory control have yielded mixed results, with most finding a positive relation (Bridgett et al., 2013; Carlson & Wang, 2007; Hudson & Jacques, 2014; Kieras et al., 2005; Lantrip et al., 2015; Raffaelli et al., 2005; Santucci et al., 2008), others finding no significant relation (Calkins et al., 1998; Forslund et al., 2016; Hinshaw, 2003), and still others suggesting that adaptation in one domain may act as a protective factor for deficits in another (Batum & Yagmurlu, 2007; Eisenberg, Fabes, et al., 2000). However, in the absence of prospective longitudinal investigations using multiple and distinct assessments of both capabilities, such as in the current study, it is unclear if and how these regulatory abilities influence each other, or whether they develop independently at a similar rate and/or from shared contributing factors (Carlson & Wang, 2007). As noted earlier, the expectation that self-regulatory function in one domain may influence self-regulatory functioning in another domain, across time, is rooted in the organizational perspective on development (Cicchetti & Sroufe, 1978). Following this theoretical framework, it is presumed that each regulatory capacity should form a foundation for the adaptive development of other skills, including development of self-regulatory capacities in other domains. To date, only two studies have examined these capabilities longitudinally during childhood. Blankson and colleagues (2013) demonstrated unidirectional effects of emotional control at age three on inhibitory control at age four. Ferrier and colleagues (2014) conducted the only study documenting reciprocal effects in these domains, identifying effects of emotion regulation and executive functioning in both directions over a 6-month period among children aged 35–60 months. Extending these studies, the present investigation is the first to our knowledge to evaluate three competing hypotheses regarding the relation between expressive control of affect and inhibitory control of behavior across childhood.

In the first possible model, expressive control and inhibitory control may display concurrent, but not reciprocal, relations. These constructs share a number of physiological and neurobiological components, including attention, cardiac regulation, and executive functioning (Bell & Deater-Deckard, 2007; Kochanska et al., 2000). Neural models of regulation suggest that several areas in the prefrontal cortex may be involved in *both* emotional and behavioral control (Dennis et al., 2013), but longitudinal methods are necessary to determine whether this underlying structure fully explains their relations over time.

In the second competing model, expressive control and inhibitory control may share antecedent conditions and/or domain general adaptive mechanisms that contribute to their concurrent associations, but expressive control abilities may also contribute directly to inhibitory control abilities over time. Emotion often is embedded in behaviorally demanding situations, such as when a child is asked to wait in line for a reward (Calkins & Hill, 2007). Because feeling states often precede behaviors that are dictated by those states, expressive control during a challenge should preclude the need for control of behavior, thereby reducing contextual demands for inhibitory control, and facilitating its development over time. Consistent with this proposition, evidence shows that exposure to negative emotional stimuli during inhibitory control tasks can hinder performance (Xu et al., 2016), but participating in a frustration task (and actively working to control emotion) between administrations of a behavioral inhibition task predicted improvements in performance on that task over time (Walcott & Landau, 2004). Most importantly, recent work has identified the positive effects of early emotion regulation on later behavioral control (Blankson et al., 2013), as well as on related and concurrently assessed executive functioning skills (Ursache et al., 2013).

In the third competing model, inhibitory control of behavior may contribute to expressive control of affect over time. In support of this third hypothesis, research indicates that infants' emergent attentional control mechanisms influence their affect regulation (Tronick et al., 1977), that components of inhibitory control (i.e., the ability to inhibit saccadic eye movements) predict lower levels of facial expressiveness during pain (Karmann et al., 2015), and that training to improve working memory (Schweizer et al., 2013) and inhibitory control (Beauchamp et al., 2016) may improve expressive control.

1.3 | The current study

This study advanced beyond the presumption of reciprocal regulatory influences over time (Carlson & Wang, 2007), to evaluate competing models of directional effects between expressive control of affect and inhibitory control of behavior across childhood (i.e., ages 4–8). First, we hypothesized that both expressive control and inhibitory control would show modest rank order stability over time. Second, we hypothesized that expressive control and inhibitory control would show positive concurrent associations. However, we further anticipated that they would show significant cross-lagged relations over time owing to the aforementioned research supporting their mutually enhancing features. Third, we sought to extend the existing literature by evaluating the proposed model separately across both observational and teacher reports of self-regulation. Importantly, this study advanced the present literature by examining the development of self-regulation up to age eight. Although research on the independent development of these constructs exists into later childhood and adolescence, this is the first comparative longitudinal investigation of self-regulation across affective and behavioral domains past age five.

2 | METHOD

2.1 | Participants

This study assessed 250 4-year-old children (M_{age} = 4.09 years, *SD* = .24 years; 50% female, 50% male) and their primary caregivers (91.4% biological mothers, 3.6% foster/adoptive mothers, and 5% other kin caregivers). Children were identified as Latinx (46%), Black (18.4%), White (11.2%), Asian (.4%), and multiracial (24%). Within each ethnic group, 35.7%–41.3% of families resided below the poverty line, and 63.9%–73.9% were eligible to receive government aid (U.S. Census Bureau Housing and Household Economics Division, 2007). Follow-up assessments were completed by 215 families at age six (M_{age} = 6.11 years, *SD* = .21 years; 49.3% female, 50.7% male), and 211 families at age eight (M_{age} = 8.13 years, *SD* = .25 years; 49.3% female, 50.7% male). Although several families missed individual time points, 230 families (92%) completed at least two time points.

2.2 | Procedures

Families were recruited via flyers distributed to community-based childcare centers, and participants were screened to ensure the child was (1) not diagnosed with a developmental disability, (2) between 3.9 and 4.6 months of age, and (3) English proficient. At each time point, dyads completed a 3-hr laboratory assessment. Caregivers received $25/hour, children received a gift, and teachers completed questionnaires by mail for an honorarium.

2.3 | Measures

2.3.1 | Observed regulation

Assessments of expressive control of affect and inhibitory control of behavior were obtained at each time point using age-appropriate laboratory tasks. Two or more coders independently rated each participant and agreed upon consensus codes. Coders were trained to reliability by experts and rotated every 20 cases.

Expressive control of affect

Assessment of expressive control centered on the child's duration of negative affect expressed in response to a disappointment. At age four, the child was shown a bag of attractive toys they would receive but was given an empty bag to open instead. This task lasted for 2 minutes: 1 minute with the examiner absent from the room, followed by 1 minute with the examiner present but nonresponsive to the child. At age six, the disappointment task paralleled the task at age four, except that the disappointing gift was a broken version of the child's preferred gift choice, rather than an empty bag. These paradigms and associated coding schemes were adapted from Cole and colleagues' gold standard measurement of expressive control during a disappointing ranked gift task (Cole, Zahn-Waxler, et al., 1994). Although it is likely impossible to disentangle emotion activation from emotion regulation in any observational paradigm, the modification of the task away from using a ranked gift removed any possible positive interpretation of the received gift by the child and rendered the task a more universally challenging experience. This strengthens the inference that children who did not express sustained negative emotion were controlling it (whether activationally or by expression then management) during the task. At age eight, the disappointment task involved losing a prize after a game. Children engaged in an online competition (Bond & Lader, 1986) and were informed by a computer that they had lost the game and prize. The examiner absent and present segments at age eight mirrored the disappointment procedures at ages four and six. Despite minor alterations made to facilitate the elicitation of a novel emotional response at each time point and adjust for age-appropriateness, these tasks mirrored each other in procedure as well as concept (losing an expected and desired reward) across time points.

Coding

The presence or absence of any negative affect (i.e., sadness, anger, worry, and disgust) was coded during each 10-s interval using criteria set forth by Cole and colleagues (1994). Negative affect was identified by facial expressions and vocalizations and composited to yield a measure of negative affect duration at ages four (ICC = .872), six (ICC = .870), and eight (ICC = .734). As in prior works (e.g., Cole, Zahn-Waxler, et al., 1994; Eisenberg et al., 2001; Feng et al., 2008; Forbes et al., 2006), a longer duration of negative affect was used to indicate worse expressive control. Importantly, consistent with the original paradigm, the intensity of emotional experience was naturally excluded from these measurements by recording only the presence/absence of negative affect during each 10-s interval, such that negative emotion of any intensity contributed equally to the expressive control variable. In this way, the disappointment tasks appropriately measured expressive control (i.e., the degree to which negative affect is maintained vs. effectively managed during the task) rather than the intensity of emotional reactions. Scores were reversed such that higher scores indicated better expressive control (i.e., proportion of 10-s intervals *without* negative affect; range 0–1).

Inhibitory control of behavior

Assessment of inhibitory control of behavior at each time point centered on the child's capacity to inhibit a prepotent behavioral response. At age four, this was assessed during a 2-minute delay of gratification task (Bennett et al., 2005), in which the examiner played with an enticing remote-control car while forbidding the child to touch it. At age six, children completed a parallel delay of gratification task using a remote-control robot. At both ages, if children touched the object, examiners calmly repeated 'Don't touch the car/robot'. At age eight, children completed a computerized Go/No-Go paradigm, in recognition that laboratory delay paradigms may not be age-appropriate during middle childhood (Olson et al., 1999). In this task, children were asked to press a key for target images of Pokemon™ characters and refrain from pressing the key for interspersed nontarget Pokemon™ character images. Although the context of the challenge changed at each time point, the ability to inhibit a preferred response was assessed in all paradigms.

Coding. At ages four and six, coders provided a scaled rating of inhibitory control of behavior based on the number of times the child touched the toy car/robot on a scale from 1 to 5 (one [*6+ touches; very poor inhibitory control*], two [*3–5 touches; poor inhibitory control*], three [*2 touches*; *good inhibitory control*], four [*1 touch*; *very good inhibitory control*], and five [*did not touch; excellent inhibitory control*]); age four ICC = .938; age six ICC = .948. At age eight, inhibitory control was indicated by errors of commission, averaged across trials to create a proportion (range 0–1).

2.3.2 | Teacher-reported regulation

Regulation was assessed by teachers at ages four, six, and eight on the Child Behavior Questionnaire-Short Form (CBQ-SF; Putnam & Rothbart, 2006). Teachers reported on expressive control using the 6-item soothability subscale (e.g., 'When angry about something, s/he tends to stay upset for ten minutes or longer'; α_{age4} = .721;

α_{age6} = .836; α_{age8} = .739), and on inhibitory control of behavior using a 6-item subscale (e.g., 'can easily stop an activity when s/he is told "no"'; α_{age4} = .745; α_{age6} = .786; α_{age8} = .773). Each item was rated on a 7-point scale from extremely untrue (*1*) to extremely true (*7*). The CBQ demonstrates excellent reliability and validity (Putnam & Rothbart, 2006; Rothbart et al., 2001).

2.3.3 | Covariates

Child sex, IQ, and family socioeconomic status (SES) were included as covariates in all models. These variables were selected based on previously documented effects of each on regulation (Bjorklund & Kipp, 1996; Calero et al., 2007; Hackman et al., 2010). Covariates were modeled to account for direct effects on endogenous variables at each age point, given that they may exert differential effects across development.

Full scale IQ

Full scale IQ was assessed at age four using the Wechsler Preschool and Primary Scale of Intelligence-III (Wechsler, 2002) by compositing verbal and performance IQ (Sattler, 2008) according to published scoring guidelines (M_{FSIQ} = 94.76, *SD* = 13.55). Receptive vocabulary was used for children under 48 months, and expressive vocabulary was used for children 48 months or older. The age-appropriate measure was used to compute a prorated verbal IQ score for each child (M_{VIQ} = 96.89, *SD* = 15.55). The performance IQ subtest consisted of the block design subtest (M_{PIQ} = 92.33, *SD* = 17.67).

Family socioeconomic status (SES)

Family SES was scored using the Hollingshead (1975) Four-Factor Index of Social Status at age four, based on a composite of caregivers' education and occupational statuses. Scores in the sample ranged from 9 to 66 with higher scores connoting higher SES (M_{SES} = 33.22, *SD* = 13.07, which corresponds to semi-skilled employment [e.g., a salesclerk]).

2.4 | Data preparation

Nested, cross-lagged path models were estimated in MPlus v.6.12 (Muthen & Muthen, 1998–2011) using Maximum Likelihood Estimation as supported by Little's (1988) MCAR test; $\chi^2(572) = 562.203$, $p = .607$, which confirmed the data were missing completely at random. In addition to participants missing one or more follow-up assessments as described earlier, data on observed expressive control were missing at age four ($n = 3$), six ($n = 4$), and eight ($n = 7$) and observed measures of inhibitory control of behavior were missing at age four ($n = 4$), six ($n = 3$), and eight ($n = 30$), due to child noncompliance, caregiver scheduling constraints, and examiner error in administration or saving computerized data. At age four, 78 participants were missing teacher-reported data (children not in school [$n = 44$], inability to locate teacher [$n = 7$], teacher nonresponse/passive refusal [$n = 27$]). At age six, 57 participants were missing teacher-reported data (inability to locate teacher [$n = 1$], teacher nonresponse/passive refusal [$n = 54$], caregiver refusal [$n = 2$]). At age eight, 78 participants were missing teacher-reported data (inability to locate teacher [$n = 13$], teacher nonresponse/passive refusal [$n = 64$], child homeschooling [$n = 1$]). Teacher participation rates were comparable to rates in other survey-based studies (Izzo et al., 1999; Youngstrom et al., 2003). By and large teachers were unique to students, with very little nesting within classrooms. At age four, there were 101 teachers for 170 students (74 unique teachers and 27 teachers who reported on 2–8 students each). At age six, there were 142 teachers for 158 students (132 unique teachers and 10 teachers who reported on 2–4 students each). At age eight, there were 140 teachers for 146 students (134 unique teachers and 6 teachers who reported on 2 students each).

3 | RESULTS

3.1 | Preliminary analysis and measure validation

3.1.1 | Bivariate results

Table 1 displays descriptive and bivariate results. Observed expressive control of affect displayed weak to modest rank order stability from ages four through eight. Teacher-reported expressive control of affect displayed strong rank order stability from ages four through eight. Observed inhibitory control of behavior displayed moderate rank order stability from ages four through eight. Teacher-reported inhibitory control of behavior displayed strong rank order stability from ages four through eight. Observed expressive control of affect was correlated positively with observed inhibitory control of behavior at ages four and six, but not at age eight. Teacher reports of expressive and inhibitory control were correlated positively at all ages. Observed expressive control of affect was associated modestly with teacher-reported expressive control of affect at ages four, six, and eight, with the strength of the association increasing over time. Observed inhibitory control of behavior was not associated significantly with teacher-reported inhibitory control of behavior at ages four and eight, but these measurements were associated positively at age six.

3.1.2 | Model estimation

Predictors met assumptions for univariate (Afifi et al., 2007) and multivariate (Cohen et al., 2003) normality. Residuals were held equivalent across time points to preserve the assumption of homoscedasticity. Predictor variables were standardized. Chi-square tests of model fit (ns), RMSEA (<.05), and CFI (>.90; Hu & Bentler, 1999) indicated extent of model fit. Nested model comparisons with chi-square difference tests indicated the degree to which fit changed with the removal of parameters (Satorra, 2000). Standardized path coefficients are reported for all analyses.

The cross-validation of the observational models with teacher-reported data was conducted by examining two separate models. This approach was selected because the observational and teacher-reported variables, although correlated, were not overlapping enough to justify the creation of composite variables (*r*s were small to medium in size). In addition, because only two indicators were available per construct (i.e., observation and teacher report), it was not appropriate to model latent variables (Ding et al., 1995).

3.2 | Cross-lagged path analysis: Observational data

A baseline model, consisting of short-term within-domain stability paths (e.g., observed expressive control of affect at age four predicting observed expressive control of affect at age six) and concurrent cross-domain associations, yielded a good fit to the data; $\chi^2(12) = 15.128$, $p = .235$, RMSEA = .032, 90% CI [.000, .076], CFI = .929. Next, a traditional cross-lagged model evaluated the baseline model paths, as well as reciprocal associations between expressive and inhibitory control over time. The traditional cross-lagged model yielded excellent model fit [$\chi^2(8) = 3.415$, $p = .906$, RMSEA = .000, 90% CI [.000, .030], CFI = 1.000], and significant improvement over the baseline model; χ^2 difference $p = .020$. Next, an expanded cross-lagged model evaluated long-term stability and cross-domain paths (e.g., expressive control of affect at age four predicting expressive control of affect and inhibitory control of behavior at age eight) in addition to the baseline and traditional cross-lagged paths. The fit of this expanded cross-lagged model was excellent; $\chi^2(4) = 1.556$, $p = .818$, RMSEA = .000, 90% CI [.000, .058], CFI = 1.000, but it was not a significant improvement over the traditional cross-lagged model, χ^2 difference

TABLE 1 Descriptive statistics and correlations between study variables

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mean	*SD*
Observed expressive control														
1.	Age 4	–											.77	.25
2.	Age 6	.132#	–										.86	.19
3.	Age 8	.001	.111	–									.52	.26
Observed inhibitory control														
4.	Age 4	.146*	.160*	.022	–								3.76	1.11
5.	Age 6	.176*	.179**	.148*	.277***	–							4.21	.90
6.	Age 8	−.020	.085	.055	.109	.155*	–						.66	.17
Teacher-reported expressive control														
7.	Age 4	.136#	.083	.203*	.077	.204*	.065	–					4.83	1.10
8.	Age 6	.122	.180*	.304***	.182*	.277**	.101	.418***	–				4.86	1.31
9.	Age 8	.057	−.028	.248**	.226*	.235**	.110	.352**	.337**	–			5.03	1.07
Teacher-reported inhibitory control														
10.	Age 4	.047	.076	.282**	.111	.284***	.010	.565***	.368***	.394***	–		4.75	1.14
11.	Age 6	.134	.117	.160#	.212**	.302***	.206*	.405***	.691***	.484***	.373***	–	4.71	1.33
12.	Age 8	.060	−.089	.200*	.271**	.308**	.125	.338**	.351**	.629***	.537***	.567***	4.99	1.23

***$p < .001$; **$p < .01$; *$p < .05$; #$p < .10$.

p = .762, and no additional significant or marginal paths emerged, so the traditional cross-lagged model was retained as the final model (see Figure 1).

3.2.1 | Stability

In the final model, the stability of expressive control of affect was not significant from ages four to six (γ = .093, p = .147), nor from ages six to age eight (γ = .082, p = .274), though these coefficients were comparable in size. The stability of observed inhibitory control of behavior was significant from ages four to six (γ = .248, p < .001), and marginally significant from ages six to eight (γ = .130, p = .085).

3.2.2 | Covariates

Sex effects emerged at age six (γ = −.187, p = .004), such that girls displayed better expressive control of affect than boys. Higher IQ was associated with poorer expressive control of affect at age six (γ = −.149, p = .025) and marginally improved inhibitory control of behavior at age six (γ = .126, p = .056). Higher SES predicted marginally better inhibitory control of behavior at age eight (γ = .126, p = .088).

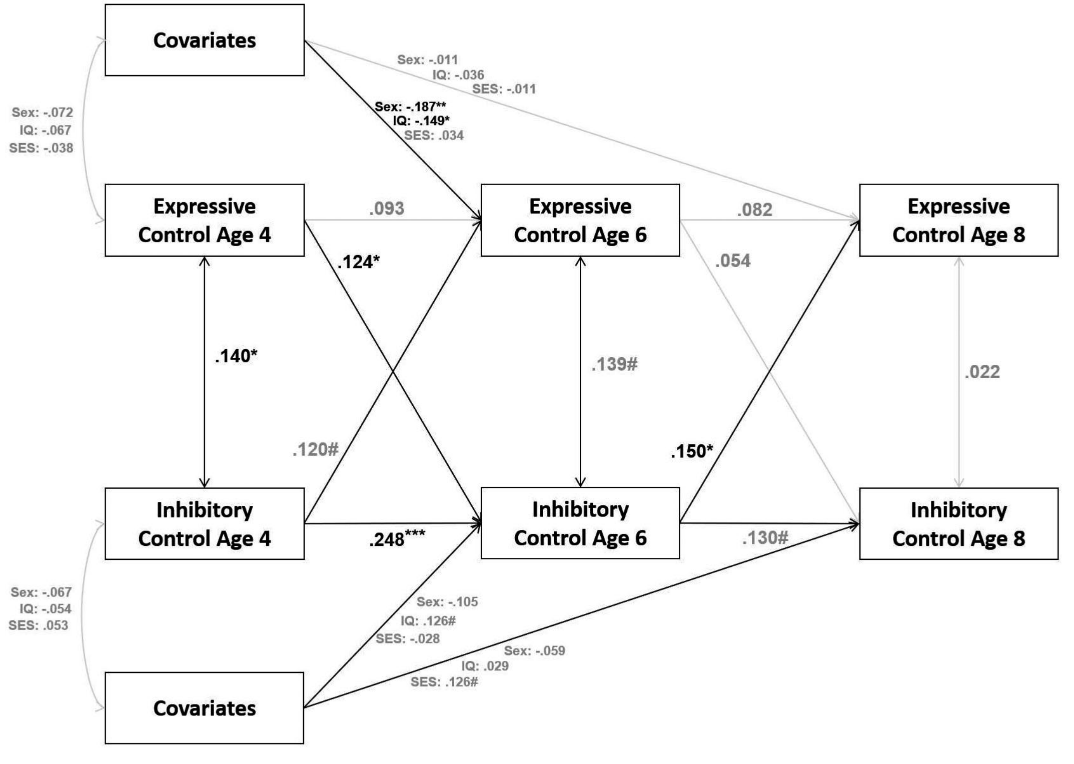

FIGURE 1 Observed expressive and inhibitory control cross-lagged path analysis (final model). *Note*. $\chi^2(8)$ = 3.415, p = .906, RMSEA = .000, 90% CI [.000, .030], CFI = 1.000. Nonsignificant effects pictured in grey for clarity. $\gamma_{sex/IQ} = -.106^{\#}$, $\gamma_{sex/SES} = -.061$, $\gamma_{IQ/SES} = .228^{***}$. Error variances modeled but not displayed. $^{***}p < .001$, $^{**}p < .01$, $^{*}p < .05$, $^{\#}p < .10$

3.2.3 | Concurrent relations

Concurrent associations between expressive control of affect and inhibitory control of behavior were significant at age four (γ = .140, p = .019), marginal at age six (γ = .139, p = .051), and not significant at age eight.

3.2.4 | Transactional effects

The final model supported significant relations between expressive control of affect and inhibitory control of behavior such that better expressive control of affect at age four predicted improved inhibitory control of behavior at age six (γ = .124, p = .048) whereas better inhibitory control of behavior at age six predicted better expressive control of affect at age eight (γ = .150, p = .042). Further, better inhibitory control of behavior at age four marginally predicted better expressive control of affect at age six (γ = .120, p = .060). Importantly, these cross-lagged paths were significant beyond within-domain stability and cross-domain concurrent associations.

To further evaluate the magnitude of these effects, the final model was compared against models in which each set of significant and marginal directional cross-lagged paths was fixed to zero. The model in which the path from expressive control of affect at age four to inhibitory control of behavior at age six was fixed to zero yielded marginally worse fit than the original model; $\chi^2(9)$ = 7.231, p = .613, RMSEA = .000, 90% CI [.000, .061], CFI = 1.000, χ^2 difference p = .051, providing tentative evidence that this path was substantively important to the model. The model in which both paths from inhibitory control of behavior to expressive control of affect were fixed to zero fit significantly worse than the original model; $\chi^2(8)$ = 10.827, p = .371, RMSEA = .018, 90% CI [.000, .072], CFI = .981, χ^2 difference p = .025, providing strong evidence that these paths were substantively important. Given the importance of these individual cross-lagged paths, all directional effects were retained in the final model.

3.3 | Cross-lagged path analysis: Teacher-reported data

The model examining laboratory-observed expressive control of affect and inhibitory control of behavior was then cross-validated using teacher-reported expressive control of affect and inhibitory control of behavior at the same ages. The baseline model, which included short-term within-domain stability paths and concurrent cross-domain associations yielded a poor fit to the data; $\chi^2(12)$ = 52.856, p < .001, RMSEA = .117, 90% CI [.086, .150], CFI = .848. However, the traditional cross-lagged model that included these baseline paths as well as cross-domain longitudinal associations between expressive control of affect and inhibitory control of behavior yielded a significant improvement; $\chi^2(8)$ = 24.864, p = .002, RMSEA = .092, 90% CI [.052, .134], CFI = .937, χ^2 difference p < .001. Finally, the expanded cross-lagged model with long-term stability and cross-domain paths did not yield a significant improvement over the traditional cross-lagged model; $\chi^2(4)$ = 17.195, p = .002, RMSEA = .115, 90% CI [.063, .173], CFI = .951, χ^2 difference p = .104. The only additional significant path to emerge in the expanded model was a stability path from inhibitory control of behavior at age four directly to inhibitory control of behavior at age eight (p = .010). Thus, the traditional cross-lagged model was retained as the final model (see Figure 2).

3.3.1 | Stability

In the final model, teacher reports of expressive control of affect showed significant stability from ages four to six (γ = .256, p = .004), but not from ages six to eight (γ = .045, p = .705). The stability of inhibitory control of behavior was marginal from ages four to six (γ = .183, p = .050), and significant from ages six to eight (γ = .488, p < .001).

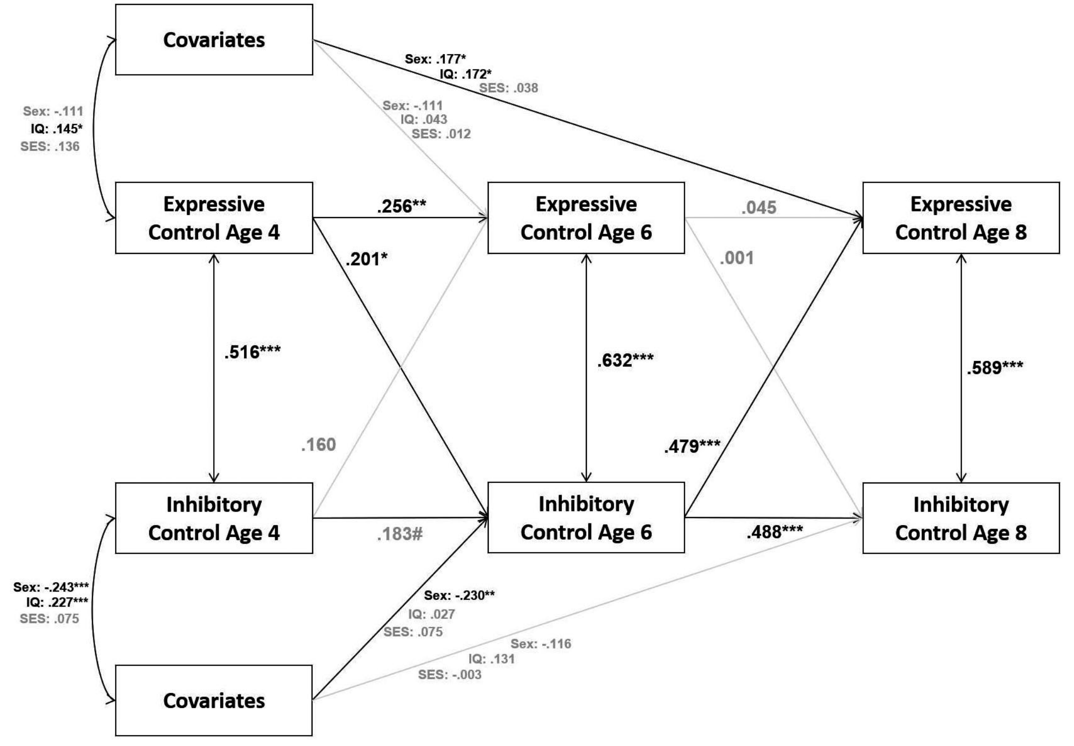

FIGURE 2 Teacher-reported expressive and inhibitory control cross-lagged path analysis (final model). *Note*. $\chi^2(8) = 24.864$, $p = .001$, RMSEA = .092, 90% CI [.052, .134], CFI = .937. Nonsignificant effects pictured in grey for clarity. $\gamma_{sex/IQ} = -.098$, $\gamma_{sex/SES} = -.058$, $\gamma_{IQ/SES} = .225^{***}$. Error variances modeled but not displayed. $^{***}p < .001$, $^{**}p < .01$, $^{*}p < .05$, $^{\#}p < .10$

3.3.2 | Covariates

Sex effects emerged on teacher-reported expressive control of affect at age eight ($\gamma = .177$, $p = .028$), such that boys were rated as better regulated than girls, and on inhibitory control of behavior at age four ($\gamma = -.243$, $p < .001$) and at age six ($\gamma = -.230$, $p = .001$), such that girls were rated as better regulated than boys. Higher IQ was associated with better expressive control of affect at age four ($\gamma = .145$, $p = .038$) and age eight ($\gamma = .172$, $p = .045$), and better inhibitory control of behavior at age four ($\gamma = .227$, $p < .001$). Higher SES was associated marginally with better expressive control of affect at age four ($\gamma = .136$, $p = .052$).

3.3.3 | Concurrent relations

Concurrent associations between teacher reports of expressive control of affect and inhibitory control of behavior were significant at age four ($\gamma = .516$, $p < .001$), age six ($\gamma = .632$, $p < .001$), and age eight ($\gamma = .589$, $p < .001$).

3.3.4 | Transactional effects

The transactional results from the teacher-reported model mirrored those revealed by the observational model. Specifically, better expressive control of affect at age four predicted better inhibitory control of behavior at age six

(γ = .201, p = .019) whereas better inhibitory control of behavior at age six significantly predicted better expressive control of affect at age eight (γ = .479, p < .001). Importantly, these cross-lagged paths were significant beyond within-domain stability and cross-domain concurrent associations.

To evaluate the magnitude of these associations further, the final model was compared against models in which each set of significant and marginal directional cross-lagged paths was fixed to zero. The model in which the path from expressive control of affect at age four to inhibitory control of behavior at age six was fixed to zero had significantly worse fit than the original model; $\chi^2(9)$ = 30.155, p < .001, RMSEA = .097, 90% CI [.060, .136], CFI = .921, χ^2 difference p = .021, providing strong evidence that this path was substantively important to the model. The model in which the path from inhibitory control of behavior at age six to expressive control of affect at age eight was fixed to zero also fit significantly worse than the original model; $\chi^2(9)$ = 39.395, p < .001, RMSEA = .116, 90% CI [.081, .155], CFI = .887, χ^2 difference p < .001, providing strong evidence that this path was substantively important to the model. Thus, the complete model was retained with all directional effects.

4 | DISCUSSION

This study makes a unique contribution to understanding relations among the integrated processes of expressive control of affect and inhibitory control of behavior across ages four through eight, and in multiple contexts. Transactional relations replicated across models using observational and teacher-reported assessments.

4.1 | Within-domain stability

Expressive control of affect did not show significant stability across time points in the observational models, but did reveal moderate stability from age four to six when examining teacher reports. These findings are consistent with prior research on emotion regulation's weak stability across childhood (Murphy et al., 1999). In addition to variability introduced by developmentally appropriate adjustments to tasks across time (i.e., changes in disappointment-eliciting stimuli), informant reports may have greater stability due to shared method bias. Inhibitory control of behavior displayed moderate stability across childhood, which is consistent with prior research noting the stability of inhibitory control in longitudinal samples (Kochanska et al., 1997, 2001; Murphy et al., 1999; Raffaelli et al., 2005). Despite modest regulatory stability, there were robust effects of early capabilities on later cross-domain capabilities, suggesting that there remains a clear independent potential for cascading influences across regulatory systems.

4.2 | Concurrent relations

In the model based on observational data, significant concurrent relations between expressive control of affect and inhibitory control of behavior emerged at age four but waned over time and were not significant at later points. One explanation may be that a domain general process, such as physiological regulation or executive functioning, may underlie both expressive control of affect and inhibitory control of behavior in early childhood (Dennis et al., 2013). However, this shared mechanism may weaken in influence over time as outside influences (e.g., parents, peers) become more salient and varied in their effects. Alternately, these early bivariate associations may reflect unmeasured early transactional effects. Unsurprisingly, concurrent relations were significant at all ages in the model based on teacher reports, which may reflect context-specific variations in response to challenging situations.

4.3 | Transactional relations

The current findings revealed specific temporal relations across domains of self-regulation. First, in both the observational and teacher-reported models, there was a significant effect of expressive control of affect at age four on inhibitory control of behavior at age six, over and above within-domain stability and concurrent cross-domain relations. This pattern is consistent with recent studies showing similar effects with related constructs such as executive functioning (Blankson et al., 2013; Ursache et al., 2013). Early abilities to control emotion may reduce subsequent contextual demands on behavior, thereby conferring an advantage for the development of children's emergent inhibitory control (Zelazo & Cunningham, 2007). Second, both the observational and teacher-reported models revealed significant effects of inhibitory control of behavior at age six on expressive control of affect at age eight. This pattern is consistent with the idea that managing expressed emotion involves controlling behaviors, such as facial expressions and vocalizations (Karmann et al., 2015), as well as engaging attentional control as a potential regulatory strategy (Eisenberg et al., 2000; Schweizer et al., 2013; Tronick et al., 1977), and that the ability to control facial expressions (e.g., masking, understanding of display rules) increases with age (Davis, 1995; Gnepp & Hess, 1986).

Significant relations between expressive control of affect and inhibitory control of behavior originating from each facet of self-regulation across both observational and teacher-reported models suggests that these regulatory capabilities do not develop in the same unidirectional sequence across time points. Instead, there may be specific contributions of early expressive control skills to the development of inhibitory control, followed by a boost from these better-developed inhibitory control skills to later improvements in expressive control. The replication of these transactional patterns across both models is particularly noteworthy given the modest correlations between observational and teacher reports of each construct, the distinct observational measure of inhibitory control used at age eight compared to ages four and six, and the potential for shared method variance in teacher reports only.

Equally important, neither model revealed significant effects of age four inhibitory control of behavior on age six expressive control of affect, though there was a trend in the observational model. It may be that inhibitory control is not sufficiently well developed at age four to provide consistent developmental support for growth in emotional domains of self-regulation. Further, neither model revealed an effect of age six expressive control of affect on age eight inhibitory control of behavior. This pattern warrants further consideration as it may reflect increased stability of inhibitory control by age eight and/or potential ceiling effects in the measures used here. Overall, these findings highlight the salience of effects of each regulatory capability on later cross-domain development, above and beyond within-domain stability, and concurrent relations. This pattern of findings provides robust support for the idea that expressive control of affect and inhibitory control of behavior are overlapping but distinct constructs.

4.4 | Strengths and limitations

The use of multi-reporter longitudinal data represents a critical advance of the current study. Perhaps most notably, the replication of obtained transactional effects across observational and teacher report measures lends tremendous confidence to the obtained results, particularly given that these assessments correlated only moderately. Further, the use of a large diverse community sample extends the generalizability of these findings beyond prior studies of small homogeneous groups.

Nevertheless, these findings are subject to several limitations. First, there was a confound between age of assessment and the specific observational task administered, making it difficult to confirm if the observational findings were due to task differences or age differences. Although the benefit of providing novel, developmentally appropriate tasks at each age constitutes a strength of this work, particularly with regard to practice/ceiling effects, these differences may have affected the results. That said, the replication of the observational model with teacher reports strengthens confidence in these effects, because they were not subject to the same limitation.

Relatedly, observational assessments of expressive control of affect were limited to disappointment paradigms, despite the potential for differentiation in expressive control capabilities across specific emotions, and across negative and positive affect. Although the use of a disappointment paradigm at each time point increased our ability to draw consistent conclusions across time points, the broader validity of our expressive control construct may have been reduced, and these findings should be extended across the spectrum of emotional expression in future work. Of note, the teacher report measure did cover a wider spectrum of emotions, with most negative items referencing ‘upset’ feelings (one specific to anger) and one positive item tapping excitement.

Further, expressive control of affect is necessarily somewhat of an umbrella construct in that it is composed of elements of both activation and management of emotions. Leading scholars posit that distinguishing between these two may be a largely academic pursuit (Thompson et al., 2008). Nevertheless, it is a persistent limitation of this work that the component processes of activation (i.e., reactivity) and management cannot be delineated further in the timeline of children's emotional responses to challenge, nor can children with separate skill sets in one but not both of these areas be distinguished from each other.

Finally, the analytic paradigm employed here represents a strong test of cross-domain effects. However, recent future studies should consider a state-trait analytic approach that can disaggregate time-varying from time-invariant effects (Berry & Willoughby, 2017; Hamaker et al., 2015). Although the variation between tasks in the present observational model precluded the ability to test an autoregressive latent trajectory model to disentangle within-person effects, such effects were not central to the questions posed in this study. The major advantage of the present approach lies in its ability to estimate transactional effects above and beyond stability coefficients to clarify whether unidirectional or reciprocal associations best characterize relations between expressive control and inhibitory control across childhood. That said, given that the cross-domain associations identified likely reflect both within- and between-person components, we caution the reader against overinterpreting these effects.

4.5 | Future directions

Expressive and inhibitory control represent just two of many discrete domains pertinent to the overarching system of self-regulation. An important area of expansion will be to integrate measures of physiological regulation across these ages into multisystem studies of self-regulation. Physiological regulation may represent a domain general process that either provides an initial set point for these abilities or supports their efficient development across time. Additionally, although the work presented here is significant and suggestive, extending this examination into adolescence will support a more comprehensive evaluation of directional effects across regulatory systems, clarify whether there is a primacy of one direction over another, and test whether these effects act across the full developmental continuum. Finally, the associations revealed here should be tested for their consistency across subgroups, such as whether these pathways operate in the same sequence and same ages for children of different genders and ethnicities.

4.6 | Conclusions and implications

The current study suggests that the development of expressive control of affect and inhibitory control of behavior likely do not represent overlapping manifestations of domain general growth, but rather separate and highly interrelated processes that involve effects in each direction at specific points in time. As such, this study demonstrates that it is not appropriate to collapse investigations of self-regulation across domains or across broad age ranges of children. Researchers must take care when combining broad age ranges of children into heterogeneous groups, as well as when generalizing findings across even brief periods of development. In addition, these findings have important implications for practice. Affect-focused interventions may be most efficiently deployed in the preschool period whereas interventions targeting control of behavior may lead to the widest ranging benefits if deployed later, in the early school-age period. Further, although behavior is often the most easily observable and attractive target of educational and clinical interventions (e.g., for conduct and attention disorders), these results suggest that it is important to support the child in a holistic manner, and to document strengths and deficits that may be building blocks for later behavioral functioning.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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