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EMPIRICAL ARTICLE

CHILD DEVELOPMENT

Emotions or cognitions first? Longitudinal relations between executive functions and emotion regulation in childhood

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Abstract
Executive functions and emotion regulation develop from early childhood to adolescence and are predictive of important psychosocial outcomes. However, despite the correlation between the two regulatory capacities, whether they are prospectively related in school-aged children remains unknown, and the direction of effects is uncertain. In this study, a sample drawn from two birth cohorts in Norway was biennially examined between the ages of 6 and 14 (n=852, 50.1% girls, 93% Norwegian). Parents completed the Emotion Regulation Checklist, and teachers completed the Behavior Rating Inventory of Executive Function. A random intercept cross-lagged panel model revealed that improved emotion regulation predicted increased executive functioning to the same extent throughout development, whereas enhanced executive functioning was unrelated to future changes in emotion regulation.

Executive functioning and emotion regulation are mechanisms through which an individual exerts self-regulation. It is believed that executive functions provide a cognitive form of self-regulation whereas emotion regulation provides an affective form (Blair & Ku, 2022). Strong executive functions and effective emotion regulation predict a variety of important positive life outcomes in children and adolescents, such as improved school achievement and enhanced quality of life (Chambers et al., 2015; Diamond, 2013; Gumora & Arsenio, 2002), and may also protect against the development of psychiatric symptoms (Halse et al., 2022; Schafer et al., 2017). As regards the constructs of executive functions and emotion regulation, which both fall under the broader definition of self-regulation, we do not yet have an understanding of the contributions of one skill to the development of the other—executive functions may be involved in the development of emotion regulation, and vice versa. Some researchers have suggested that executive functions may play a role in the development of emotion regulation (Lantrip et al., 2016), that executive functions are necessary for emotion regulation (Zelazo & Cunningham, 2007), and that children must first develop their executive functioning skills before they can fluidly apply them for emotion regulation purposes (an "executive functioning first" hypothesis; Reilly & Downer, 2019). However, other researchers have argued that emotion regulation should be viewed as a lower-level regulatory function that serves as the basis for the development of higher-order regulatory capacities, such as executive functions (an "emotion regulation first" hypothesis; Ursache et al., 2013). This contention is supported by findings from experimental studies, which suggest that highly activated emotional responses have a negative effect on the performance of executive function tasks

Abbreviations: BRIEF, Behavior Rating Inventory of Executive Function; BRIEF-T, teacher version of the BRIEF; CFI, comparative fit index; CLPM, cross-lagged panel model; ERC, Emotion Regulation Checklist; MAR, missing at random; MCAR, missing completely at random; RI-CLPM, random intercept cross-lagged panel model; RMSEA, root mean square error of approximation; SDQ, Strengths and Difficulties Questionnaire; SRMR, standardized root mean square residual; TLI, Tucker–Lewis index.

(Pessoa et al., 2012; Pnevmatikos & Trikkaliotis, 2013). Because one of the outcomes of adaptive emotion regulation is the reduction and modulation of strong negative emotions, these findings suggest that emotion regulation may have an effect on executive functions. However, the durability and ecological validity of such experimental effects are unknown, and observational studies are well suited to elucidate whether improved emotion regulation predicts enhanced executive functions and vice versa. Furthermore, the relation between the two has typically been studied by methods conflating within-person and between-person effects, and studies portraying true within-person effects are needed.

Development of executive functions and emotion regulation

Both executive functions and emotion regulation emerge early in life and continue to develop during childhood and throughout adolescence (Diamond, 2013; Macdonald et al., 2016). During this developmental period, both executive functions and emotion regulation evolve from simple to more complex forms. Throughout school years, children integrate lower-level executive functions and build upon them to develop more advanced executive functions, such as cognitive flexibility, problem-solving, and planning (Vink et al., 2020). During the same developmental period, children are increasingly less likely to use simple emotion regulation strategies, such as suppression, as they acquire more sophisticated emotion regulation skills, such as reappraisal (Gullone et al., 2010). Both executive functioning and emotion regulation depend on the prolonged and nonlinear development process of the prefrontal cortex (Reiss et al., 1996). Because both executive functions and emotion regulation undergo profound changes during development, it is plausible that their relative importance varies with age. Until now, most of the work in this area has focused on preschool-aged children, and we cannot necessarily extrapolate these findings to older children. Nor can we be certain that the relation between the two constructs stays the same from early school years to adolescence. In this study, we expand upon the few longitudinal studies that exist (Blankson et al., 2013; Feldman, 2009; Hughes et al., 2023; Reilly & Downer, 2019; Wu et al., 2021) and compare the "executive functioning first" and "emotion regulation first" hypotheses during middle childhood and early adolescence.

Cognition first: Executive functions are building blocks for emotion regulation

Executive functions are the mental abilities used to overcome impulses and automatic behavior when concentration and attention are required to achieve a goal (Diamond, 2013). Emotion regulation is the upregulation and downregulation of positive and negative emotions, respectively, to meet regulation-related goals (McRae & Gross, 2020). Some researchers have argued that executive functions are cognitive functions that are necessary for emotion regulation (Reilly & Downer, 2019; Zelazo & Cunningham, 2007). It has been stated that level of cognitive functions constrains or facilitates emotion regulation (Kopp, 2002). Specifically, some argue that the conscious forms of emotion regulation depend on executive functions (Zelazo & Cunningham, 2007). Executive functions may therefore be crucial for emotion regulation in terms of inhibiting impulses, switching between emotion regulation strategies, and monitoring and sustaining these strategies (Pruessner et al., 2020). According to some researchers, individuals with inadequate executive functioning cannot take advantage of advanced emotion regulation strategies (e.g., because they have a decreased capacity to shift their attention away from negative stimuli), and their overall ability to regulate their emotions deteriorates when the situation or their developmental level requires more advanced forms of regulation (Lantrip et al., 2016). Several cross-sectional studies have supported a positive relation between executive functions and emotion regulation in children (Groves et al., 2020; Wante et al., 2017). However, the assumption that executive functions predict improved emotion regulation has only been supported by one (Hughes et al., 2023) of the four currently available longitudinal studies (Alamos et al., 2022; Blankson et al., 2013; Reilly & Downer, 2019). Also, these studies involved preschool populations, which limits the lessons learned because the relation between executive functions and emotion regulation could differ at different ages. In addition, because of the substantial improvements observed in executive functioning and emotion regulation skills during middle childhood and adolescence (Diamond, 2013; Macdonald et al., 2016), findings from toddler and preschool years cannot be extrapolated to later developmental stages. Therefore, the purpose of this study was to investigate this aspect in a population of school-aged children.

Emotions first: Emotion regulation promotes the development of executive functions

A contrasting perspective on the relation between executive functions and emotion regulation is the "emotion regulation first" hypothesis. From a temperamental perspective, executive functions have been viewed as emerging reflective skills serving the larger concept of emotional self-regulation. Emotional self-regulation is, in this framework, believed to encompasses both reflexive (reactive) and reflective (control) systems (Liew et al., 2023). A related perspective holds that self-regulation is arranged in a hierarchical manner, where different components of self-regulation build upon each other. In this model, executive functions build on emotion regulation (Blair & Ku, 2022). According to the emotion regulation first hypothesis, the development of executive functions begins with children's rudimentary ability to regulate their emotions (Feldman, 2009). These initial forms of emotion regulation, such as avoidance, are believed to be relatively automatic (Kopp, 1989). By some accounts, such an automatic form of emotion regulation is believed to be refined later into a volitional control of attention, which subsequently develops into executive functions, such as cognitive flexibility (Ursache et al., 2013). Feldman (2009), proposed that self-regulation develops hierarchically, with lower-level regulatory functions, such as the regulation of physiological functions (e.g., sleep, alertness, and vagal tone) and emotions, laying the foundation for higher-level regulatory functions, such as attention regulation and executive functions. Consequently, if the development of rudimentary emotion regulation is delayed, the development of executive functioning is compromised. Feldman's theory was supported by a study that followed 125 premature infants from birth to the age of 5 and demonstrated that emotion regulation predicted subsequent executive functions (Feldman, 2009). However, in that study, executive functions were assessed only at the last measurement point. The study was therefore unable to rule out the possibility that rank-order stability in executive functions and a simple concurrent initial correlation between emotion regulation and executive functions may have explained the results. Studies conducted later have attempted to shed more light on this relationship. Specifically, one study indicated that emotion regulation predicted executive functioning from ages 3 to 4, but not vice versa (Blankson et al., 2013). Another study revealed no prediction from emotion regulation at 24 months to executive functions at 36 months (Wu et al., 2021).

Bidirectional relations

All but two (Blankson et al., 2013; Hughes et al., 2023) of the aforementioned longitudinal studies on the relation between executive functions and emotion regulation have assumed that emotion regulation predicts executive functioning (Feldman, 2009; Wu et al., 2021), or vice versa (Reilly & Downer, 2019). However, it has been proposed that emotion regulation develop in parallel, but intrinsically tied, to cognitive development, the two reliant on each other's development (Kopp, 1989, 2002). It is possible that children with higher emotion regulation may be better positioned to improve their executive functions, and these executive functions may simultaneously help them develop more sophisticated emotion regulation strategies and/or a more sophisticated use of these capabilities. Therefore, the relation between emotion regulation and executive functions should ideally be studied in both directions, as was done in this study, which has never been done before with school-aged children.

Between and within-person effects

All former longitudinal studies in this field have used statistical methods that conflate effects *within* a specific child with effects *between* children. However, to find out whether executive functions and emotion regulation are etiologically related, we need to know whether changes in one child's executive functions forecast changes in his/her regulatory capacity (i.e., within-person effects), and vice versa. For obvious reasons, between-person differences in executive functions cannot explain why a particular individual shows improved or declined emotion regulation abilities, or vice versa. The present study is the first to separate within- from between-person effects, using the child as his/her own control and thereby being positioned to test the prospective relation between executive functions and emotion regulation at the individual level.

By applying a within-person analytical approach, we are also positioned to take potential time-invariant confounders (i.e., third variables) into account. This is important given that executive functioning and emotion regulation do share some mutual risk factors. They are both predicted by parenting (Halse et al., 2019; Morris et al., 2017) and the family's emotional climate, as well as socioeconomic status (Bridgett et al., 2015; Morris et al., 2007). It is also possible that the two constructs share some genetic components (Macdonald et al., 2016). Many of these potential confounders are relatively stable (e.g., parenting style, socioeconomic status, and genetics) and may, to some extent, have stable effects on emotion regulation and executive functioning, at least during the study period. Thus, due to the time-invariant nature of effects, they will be accounted for by our analytical approach.

Current study

Theoretically, adaptive emotion regulation is strongly believed to facilitate the development of improved executive functioning. Improved executive functioning is also strongly believed to improve emotion regulation. However, despite these clear claims and the importance of executive functioning and emotion regulation in the development and psychosocial adaptation of children, studies supporting one or both of these hypotheses are lacking. Therefore, in this study, we tested both hypotheses in a large community sample of children, who were assessed biennially between the ages of 6 and 14, to determine whether increased emotion regulation predicts increased executive functioning, and vice versa.

METHOD

Participants and procedure

Two birth cohorts (2003 and 2004) from Trondheim, Norway, and their parents were invited by post to participate in the Trondheim Early Secure Study—a longitudinal study on children's psychosocial development and mental health. The letter of invitation was sent to parents together with the invitation to their scheduled appointments for the routine health checkup of their 4-year-olds at the local well-child clinic (N = 3456). The invitation letter included the Strengths and Difficulties Questionnaire (SDQ, version 4–16; Goodman, 1997). Almost all children from the two birth cohorts attended the health checkup (n = 3358, 97%). The well-child clinic nurse informed the parents about the study using a method approved by the Regional Committees for Medical and Health Research Ethics, Mid-Norway (approval number: 4.2008.2632, project name: "Tidlig Trygg i Trondheim"). Written consent to participate was obtained from the parents, and when the participants were 12 years old, they were directly addressed and informed about the study. The well-child clinic staff failed to ask 166 parents. In addition, parents who lacked the Nowegian proficiency required to complete the SDQ were excluded (n = 167). Of the 3016 eligible parents, 2475 provided their consent (82.1%).

To increase the variance and thus the statistical power, children with emotional and behavioral problems were oversampled by dividing the SDQ scores into four strata (cutoffs: 0–4, 5–8, 9–11, and 12–40). A random number generator was then used to draw defined proportions of parents to participate in a subsequent study. In the four strata, the drawing probabilities increased with increasing SDQ scores of .37, .48, .70, and .89, respectively. This oversampling was adjusted in the analyses in order to obtain correct population estimates.

Of the 1250 parents who were invited to participate in the first wave, 1007 were interviewed. After consent was provided at the well-child clinic, the dropout rate did not differ between the four SDQ strata (77.6, 83.2, 77.8, and 80.2%, respectively; χ^2 = 5.70, df = 3, p = .13). The participants were followed up at the ages of 6 (M = 6.66, SD = .17), 8 (M = 8.81, SD = .24), 10 (M = 10.51, SD = .15), 12 (M = 12.49, SD = .15), and 14 (M = 14.35, SD = .16). Figure 1 provides a flowchart showing participation at recruitment and at each subsequent measurement point. Measures of executive functioning were included from the second wave of data collection (6 years). Therefore, data from the first wave were not included in this report. Participants who missed one or more of the assessments were invited to subsequent assessments. In total, 852 children had usable data for at least one of the measurement points where executive functions were measured, thus constituting the analytical sample. Descriptive information from participants at enrollment (age 6) is presented in Table 1.

At the age of 8, attrition was high with increased working memory problems (OR = 1.04, 95% CI [1.00, 1.09], p = .04), inhibition difficulties (OR = 1.05, 95% CI [1.01, 1.09], p = .02), and shifting difficulties (OR = 1.11, 95% CI [1.03, 1.20], p = .01), whereas at the age of 6, attrition was low with increased emotion regulation (OR = .38, 95% CI [.18, .77], p = .01). Although all study variables predicted attrition at the age of 8, the combined effect was small (Cox and Snell R^2 = .016). At the age of 10, the same pattern of attrition was observed, with the exception of emotion regulation—namely, problems with working memory (OR = 1.08, 95% CI [1.02, 1.15], p = .01), inhibition (OR = 1.08, 95% CI [1.01, 1.16], p = .03), and shifting (OR = 1.14, 95% CI [1.02, 1.28], p = .02). However, the combined effect was also small (Cox and Snell R^2 = .010). The same study variables predicted attrition at the age of 12—namely, working memory (OR = 1.12, 95% CI [1.06, 1.19], p < .001), inhibition (OR = 1.08, 95% CI [1.01, 1.16], p = .04), and shifting (OR = 1.14, 95% CI [1.05, 1.24], p = .001). However, the combined effect was also small at this age (Cox and Snell R^2 = .023). At the age of 14, participants with more difficulties related to working memory (OR = 1.12, 95% CI [1.06, 1.18], p < .001), inhibition (OR = 1.07, 95% CI [1.00, 1.14], p = .04), and shifting (OR = 1.13, 95% CI [1.04, 1.22], p = .01) were more likely to drop out, whereas the opposite was true for those with high levels of emotion regulation (OR = .34, 95% CI [.13, .87], p = .03). However, the combined effect was also small (Cox and Snell R^2 = .021). Therefore, although attrition was predicted by the study variables, their contribution to the attrition was very small. Although Little's missing completely at random (MCAR) test (Little, 1988) confirmed that the data were not MCAR (χ^2 = 2378.366, df = 1728, p < .001), the normed test revealed a value of 1.37, indicating that the data were missing at random (MAR) (Ullman, 2001).

Measures

Executive function

Both questionnaire-based methods and laboratory tasks can be used to assess executive functions, with no significant empirical overlap between the two (Toplak et al., 2013). This is presumably because they assess executive functions engaged in very different ways, in which different motivations, knowledge, and values are activated (Doebel, 2020). Behavioral measures of cognitive functions are typically designed to capture within-person effects and maximize within-person variance at the expense of between-person variance (Hedge et al., 2018). By contrast, questionnaire-based measures

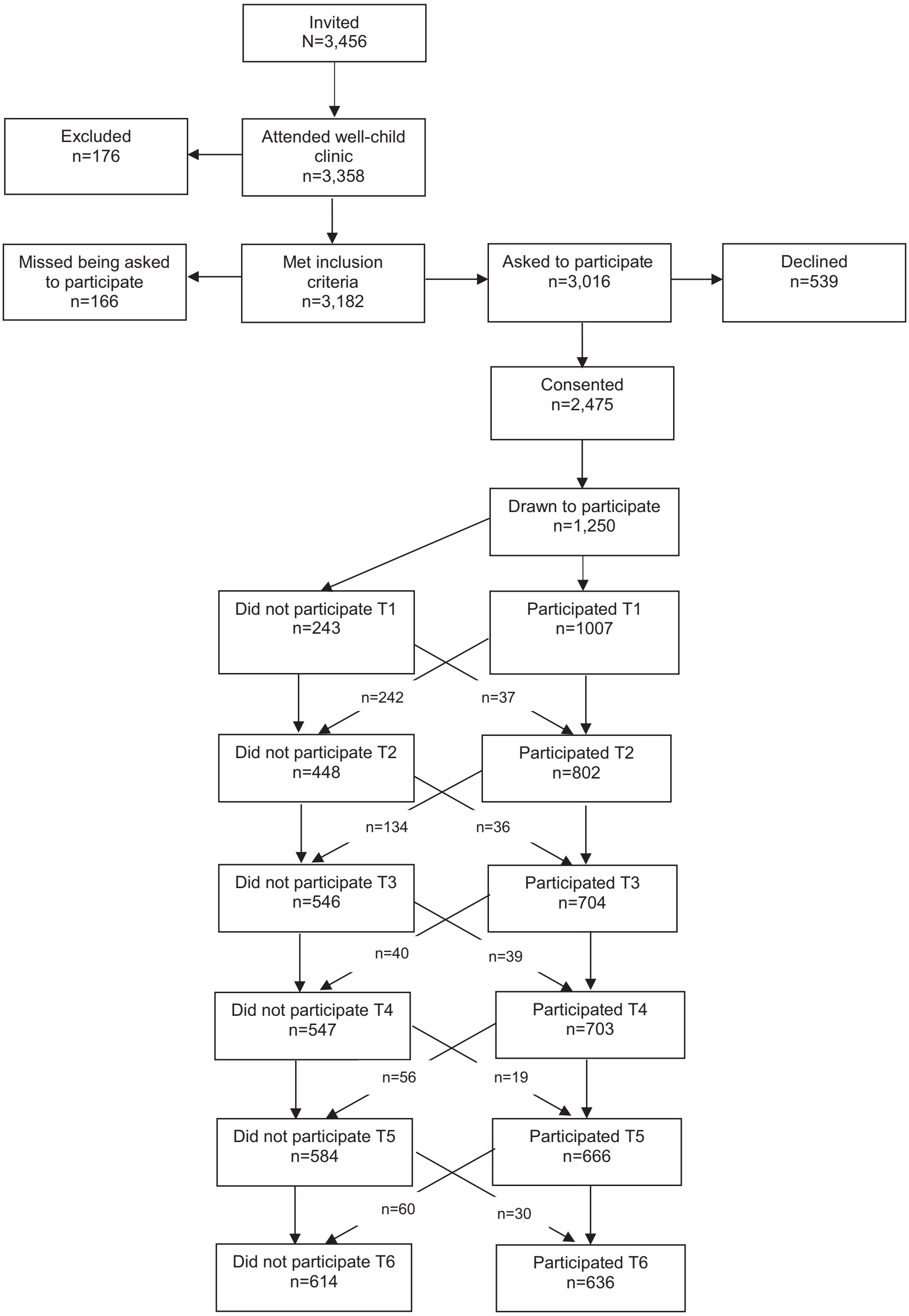

FIGURE 1 Flowchart of recruitment and follow-up.

of executive functions are designed to investigate individual differences. Because this aspect was at the core of our inquiry, we used the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000). This instrument assesses eight aspects of executive functioning: inhibition, cognitive flexibility, working memory, planning/organizing, emotional control, initiation, organization of materials, and monitoring (Gioia et al., 2010). Because inhibition, cognitive flexibility, and working memory may be viewed as core executive functions (Diamond, 2013), we focused on these aspects in our study. To reduce common method variance (i.e., parental reports of children's emotion regulation, as described below), we used the teacher version of the BRIEF (BRIEF-T; Gioia et al., 2000). The BRIEF has previously shown satisfactory internal consistency and convergent validity (Ezpeleta et al., 2015). In the present study, we found satisfactory internal consistency on the subscale of working memory (α=.91–.93), inhibition (α=.91–.94), and shifting (α=.84–.90).

TABLE 1 Sample descriptives age 6.

	%
Gender	
Boys	49.2
Girls	50.1
Gender of parent informant	
Male	15.2
Female	84.8
Ethnic origin of biological mother	
Norwegian	93.0
Western countries	6.8
Other countries	0.3
Ethnic origin of biological father	
Norwegian	93.0
Western countries	6.5
Other countries	0.5
Biological parents' cohabitating status	
Cohabitating	84.6
Not cohabitating	15.4
Inform. parent's highest completed education	
Not completed junior high school	0.0
Junior high school (10th grade)	0.3
Some education after junior high school	3.9
Senior high school (13th grade)	9.4
Some education after senior high school	2.1
Some college or university education	3.8
Bachelor's degree	4.1
College degree (3–4 years of study)	21.4
Master's degree or similar	13.7
PhD completed or ongoing	3.2
Inform. parent's occupational status	
Leader	7.8
Professional, higher level	26.3
Professional, lower level	40.5
Formally skilled worker	22.2
Farmer/fisherman	0.1
Unskilled worker	3.0

Emotion regulation

In this study, the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997) was used to assess children's emotion regulation skills. The ERC consists of 24 items that parents use to report their children's typical responses to emotional situations. The form consists of two subscales: a lability/negativity subscale and an emotion regulation subscale. The first subscale assesses inflexibility, lability, and dysregulated negative affect, whereas the second subscale assesses appropriate emotional expression, empathy, and emotional self-awareness. Although the form is divided into two subscales, both of them assess how the child regulates emotion, and because our research focused on overall emotion regulation, we used the total score in our analyses. In previous studies, concurrent validity has been established through positive correlations with observer ratings of children's proportion of expressed positive and negative affect (Shields & Cicchetti, 1997), and the internal consistency was acceptable in the present study ($\alpha = .80–.82$).

Analysis

The analyses presented represent a relatively confirmatory effort in testing specific hypotheses in a comparatively large community sample in a longitudinal framework. All analyses were conducted in Mplus version 8.5 (Muthèn & Muthèn, 1998–2015) using a robust maximum likelihood estimator, which is robust to nonnormality. Probability weights were used to correct for the oversampling of children with mental health problems, applying a sandwich estimator which provides robust standard errors. These weights were proportional to the number of children in a specific stratum of the population divided by the number of participating children in that stratum. As indicated by the attrition analyses, missing data were handled using a full information maximum likelihood procedure under the assumption that the data were MAR. Analysis was run through StatCheck and no inconsistent *p*-values were detected.

Choice of statistical model: An overview

Traditionally, regression-based data analysis techniques, such as the cross-lagged panel model (CLPM; Curran & Bauer, 2011), have been used in longitudinal studies with repeated measurements. These techniques have also been used in studies on emotion regulation and executive functions, thus posing the question: "Do children with more executive functioning problems *than other children* develop more emotion regulation problems *than other children* in the future (or vice versa) when the previous levels of these variables are adjusted for?" The answers (i.e., coefficients) to this question stem from a combination of within-person and between-person effects (Berry & Willoughby, 2017; Curran & Bauer, 2011). However, to conduct studies on causal implications (albeit with uncertainty), one must acknowledge that the executive functions and emotion regulation of other children (unacquainted) cannot be a part of the etiology of the executive functioning and emotion regulation of a specific child. Therefore, the more relevant question to ask is: "If a child's executive functioning declines, will their emotion regulation skills decline more than expected?" To answer this question, we can use a random intercept cross-lagged panel model (RI-CLPM), which separates within-person effects from between-person differences by separating out the child's overall level of executive functioning and emotion regulation, thereby resulting in true within-person effects (Hamaker et al., 2015; Usami et al., 2019). By estimating random intercepts, the RI-CLPM implicitly adjusts for unmeasured time-invariant confounding effects, regardless of whether they are known (Allison, 2009; Gunasekara et al., 2014; Usami et al., 2019). The conceptual model is presented in Figure S1. We created latent variables (i.e., random intercepts) for executive functioning (i.e., inhibition, shifting, and working memory) and emotion regulation to represent the average levels of executive functioning and emotion regulation from the age of 6 to 14—that is, the between-person part of the model. The factor loadings were set to 1. These random intercepts were allowed to correlate. We also created a latent variable for each observed variable at each time point (i.e., single indicators) with the variance in the observed variable set to 0 and the factor loading from the latent variable to its observed counterpart set to 1. The variance in the observed variable is thereby transferred to the latent one. In effect, the latent variables captured each child's time-specific deviation from their own average (i.e., the within-person part of the model), rather than deviations from the group mean (as in the CLPM), thereby allowing each individual (rather than the others) to serve as their own control (Hamaker et al., 2015). Deviations in emotion regulation, inhibition, shifting, and working memory at time point t were regressed on these variables at $t-1$. At each time point, the residuals of these latent variables were allowed to correlate and the latent variables at the first measurement point were also allowed to correlate.

Because earlier studies of the relation between executive functions and emotion regulation have typically used methods that conflate within- and between-person variance such as the CLPM, we conducted a regular CLPM before comparing the results with the results using the RI-CLPM.

Model fitting

As mentioned in the Introduction, executive functions and emotion regulation change considerably during middle childhood (Gullone et al., 2010; Vink et al., 2020), and they may develop in a nonlinear fashion (Reiss et al., 1996). This means that their relationship may differ at different ages. To examine this hypothesis, we compared a model in which the cross-lagged paths varied over time with a model in which these effects were set to remain constant over time. In the event of no fit deterioration, we chose the more constrained model, for parsimonious reasons. Specifically, we evaluated the following models or assumptions by first using a CLPM framework and then using the RI-CLPM: (1) the effects of executive functioning and emotion regulation differ by age (i.e., no constraints); (2) the effects of a specific executive function on emotion regulation are constant at all time points, as are the effects of emotion regulation on a specific executive function; and (3) the effects of emotion regulation on the three executive functions are constant. To determine which model best fits the data, we used the Satorra–Bentler scaled chi-squared test (Satorra & Bentler, 2001).

RESULTS

Table 2 lists the means, standard deviations, and bivariate associations of the study variables. By and large, executive functions were cross-sectionally correlated with emotion regulation at all timepoints.

Results of measurement invariance testing

Longitudinal measurement invariance was tested in Mplus, including configural, metric, and scalar invariance. Because Chi-sq. differences typically increase with increasing sample size, we relied on Chen's criteria for measurement invariance, which are related to changes in root mean square error of approximation (RMSEA) ($\Delta<.015$); standardized root mean square residual (SRMR) ($\Delta<.02$ for configural vs. metric; $\Delta<.01$ for metric vs. scalar); and comparative fit index (CFI) ($\Delta<.01$); Tucker–Lewis index (TLI) ($\Delta<.01$), respectively (Chen, 2007). The results (see Table S1) from these tests showed that measurement invariance was achieved for the BRIEF. As regards the ECR, full measurement invariance was indicated according to RMSEA and SRMR, and metric invariance was also suggested according to the TLI. Because emotion regulation is expected to change with age, full scalar invariance was not expected. Moreover, as we analyzed the ERC as one factor, configural invariance was considered less of a concern. Hence, the lack of metric invariance according to all criteria (i.e., also according to TLI) was considered most relevant. Setting standardized factor loadings that differed >.17 from the rest of the loadings for that item free and constraining the rest, resulted in satisfactory partial metric invariance (ΔCFI = .009, ΔTLI = .002, Δ RMSEA = .000, ΔSRMR = .002). This pertained to 7 of the 120 paths (24 items at 5 time points), specifically items 12 and 24 at age 14, items 18, 22, and 23 at age 8, and item 17 at both ages 12 and 14. Hence, scores at ages 8 and 14 seemed to diverge more than scores at other ages. In sum, measurement invariances as a requirement to conduct longitudinal analyses was considered fulfilled to a reasonable extent.

TABLE 2 Means, standard deviations, and correlations between executive functions and emotion regulation.

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 WM 6 years	12.40	3.80	-																		
2 WM 8 years	12.13	3.63	.66***	-																	
3 WM 10 years	12.13	3.57	.54***	.71***	-																
4 WM 12 years	11.87	3.41	.46***	.61***	.62***	-															
5 WM 14 years	12.20	3.50	.39***	.51***	.53***	.61***	-														
6 Inhibition 6 years	11.93	3.59	.61***	.49***	.41***	.41***	.34***	-													
7 Inhibition 8 years	11.45	3.08	.45***	.62***	.41***	.41***	.37***	.70***	-												
8 Inhibition 10 years	11.38	2.91	.43***	.54***	.56***	.42***	.37***	.57***	.69***	-											
9 Inhibition 12 years	11.26	3.00	.27***	.38***	.41***	.45***	.39***	.41***	.55***	.70***	-										
10 Inhibition 14 years	11.04	2.44	.14*	.21**	.26***	.49***	.59***	.27***	.31***	.50***	.46***	-									
11 Shifting 6 years	10.78	1.79	.49***	.38***	.27***	.33***	.36***	.62***	.45***	.34***	.32***	.14*	-								
12 Shifting 8 years	10.78	1.89	.42***	.52***	.34***	.40***	.34***	.54***	.71***	.55***	.49***	.21**	.57***	-							
13 Shifting 10 years	10.91	2.24	.32***	.35***	.43***	.39***	.36***	.39***	.47***	.62***	.48***	.27***	.38***	.55***	-						
14 Shifting 12 years	10.92	2.36	.30***	.35***	.37***	.58***	.40***	.37***	.39***	.47***	.65***	.32***	.47***	.56***	.56***	-					
15 Shifting 14 years	10.73	1.92	.16*	.17	.22**	.35***	.55***	.30***	.29**	.31***	.29***	.60***	.28**	.33**	.42***	.47***	-				
16 ER 6 years	3.42	0.26	−.13**	−.19***	−.16***	−.14**	−.12*	−.20***	−.23***	−.21***	−.21***	−.08	−.20***	−.27***	−.24***	−.20***	−.10	-			
17 ER 8 years	3.48	0.26	−.19***	−.20***	−.19***	−.19***	−.14**	−.26***	−.29***	−.21***	−.20***	−.07	−.30***	−.28***	−.27***	−.25***	−.10	.66***	-		
18 ER 10 years	3.51	0.26	−.22***	−.23***	−.28***	−.22***	−.21***	−.24***	−.23***	−.26***	−.25***	−.12**	−.25***	−.21***	−.29***	−.27***	−.20***	.61***	.71***	-	
19 ER 12 years	3.54	0.27	−.25***	−.28***	−.30***	−.31***	−.29***	−.25***	−.27***	−.27***	−.31***	−.20***	−.29***	−.25***	−.34***	−.36***	−.24***	.55***	.61***	.71***	-
20 ER 14 years	3.53	0.25	−.21***	−.23***	−.19***	−.28***	−.25***	−.23***	−.23***	−.20***	−.23***	−.11*	−.29***	−.25***	−.27***	−.34***	−.17**	.52***	.58***	.66***	.74***

Abbreviations: ER, emotion regulation; WM, working memory.
*$p<.05$; **$p<.01$; ***$p<.001$.

The relation between executive functions and emotion regulation

CLPM

We started with Model 1, which allowed for age-dependent differences in the paths between executive functions and emotion regulation, and for between-lag differences in the effects of emotion regulation on working memory, shifting, and inhibition. This model fitted the data well (see Table 3). In Model 2, we set the paths from executive functions to emotion regulation, and vice versa, to be equal at all time points. According to the Satorra–Bentler scaled chi-square test (Satorra & Bentler, 2001), Model 2 did not fit the data worse than Model 1 had (see Table 3). These results indicated that the cross-lagged effects are best described as equal across development. To determine whether a more constrained model would better fit the data, we created a restricted version of Model 2, with the effects of emotion regulation on the three executive functions set to be constant (Model 3). This model did not fit the data worse than Model 2 had (see Table 3), and it adhered to the principle of scientific parsimony and was therefore preferred. In the final and preferred CLPM, emotion regulation predicted executive functions ($B=-.88$, 95% CI [−1.17, −.60], $\beta=-.084$), and emotion regulation was predicted by working memory ($B=-.003$, 95% CI [−.006, −.001], $\beta=-.041$) and shifting ($B=-.01$, 95% CI [−.018, −.004], $\beta=-.081$) but not by inhibition ($B=.001$, 95% CI [−.004, .004], $\beta=-.001$).

RI-CLPM

Three RI-CLPMs similar to the three CLPMs described previously were created. An unrestrained model called Model 4 was first developed, in which the paths between executive functions and emotion regulation were allowed to vary over time, and the cross-lagged effects of emotion regulation on working memory, shifting, and inhibition were allowed to differ (see Table 4). Model 4 was then compared with a model in which the paths between executive functions and emotion regulation were set to be identical at all time points, whereas the effect of emotion regulation was allowed to differ across working memory, inhibition, and shifting (Model 5). This model did not fit the data worse than Model 4 had (see Table 4). Finally, a model called Model 6 was developed, in which the paths from executive functions to emotion regulation, and vice versa, were set to be equal over time. The effects of emotion regulation on working memory, shifting, and inhibition were also set to be equal over time. This model did not fit the data worse than Model 5 had (see Table 4) and was chosen for parsimonious reasons. As shown in Figure 2, the results of Model 6 revealed that the deterioration of emotion regulation predicted increased difficulties with executive functioning ($B=-1.11$, 95% CI [−1.86, −.36]), with the average standardized estimate across the different executive functions and times being $\beta=-.09$ (95% CI [−.15, −.03]). Regarding the opposite direction of paths, no changes in any of the examined executive functions predicted future changes in emotion regulation.

DISCUSSION

Efficient executive functioning and emotion regulation in children are predictive of a variety of favorable outcomes (Diamond, 2013; Gumora & Arsenio, 2002). Although a correlation exists between these constructs, the reason for their covariation remains incompletely

TABLE 3 Results of model fitting procedure cross-lagged panel model.

	χ^2	df	*p*-Value	$\Delta\chi^2$	Δdf	*p*-Value	RMSEA (90% CI)	SRMR	CFI	TLI
Model 1	286.374	96	<.001				.05	.07	.949	.901
Model 2	315.246	114	<.001	20.72	18	.29	.05	.07	.946	.912
Model 3	**318.745**	**116**	<.001	**2.04**	**2**	**.36**	**.05**	**.07**	**.945**	**.913**

Note: All models are nested and compared with the next model; $\Delta\chi^2$ is corrected according to Satorra–Bentler's scaled chi-square test; preferred model in bold.
Abbreviations: CFI, comparative fit index; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; TLI, Tucker–Lewis index.

TABLE 4 Results of model fitting procedure random intercept cross-lagged panel model.

	χ^2	df	*p*-Value	$\Delta\chi^2$	Δdf	*p*-Value	RMSEA (90% CI)	SRMR	CFI	TLI
Model 4	117.736	86	.013				.02 (.01, .03)	.06	.992	.983
Model 5	135.998	104	.019	17.38	18	.497	.02 (.01, .03)	.06	.992	.986
Model 6	**137.370**	**106**	**.022**	**1.27**	**2**	**.530**	**.02 (.01, .03)**	**.06**	**.992**	**.986**

Note: All models are nested and compared with the next model; $\Delta\chi^2$ is corrected according to Satorra–Bentler's scaled chi-squared test; preferred model in bold.
Abbreviations: CFI, comparative fit index; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; TLI, Tucker–Lewis index.

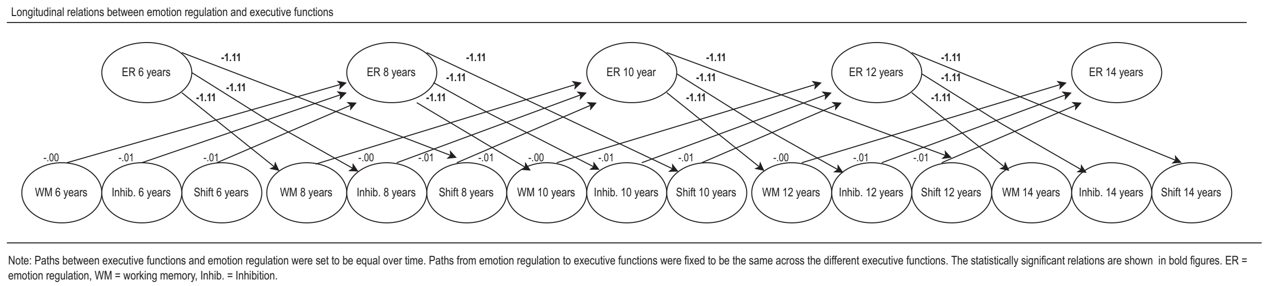

FIGURE 2 Longitudinal relations between emotion regulation and executive functions. Paths between executive functions and emotion regulation were set to be equal over time. Paths from emotion regulation to executive functions were fixed to be the same across the different executive functions. The statistically significant relations are shown in bold figures. ER, emotion regulation; Inhib., inhibition; WM = working memory.

understood. Some researchers have argued that executive functions are a prerequisite for emotion regulation (Zelazo & Cunningham, 2007)—namely, the "executive functions first" hypothesis—whereas others have contended that emotion regulation underlies the development of executive functions (Feldman, 2009; Ursache et al., 2013)—namely, the "emotion regulation first" hypothesis. However, the two hypotheses have not been compared. In this study, using a within-person approach with a large and representative community sample assessed biennially from ages 6 to 14, we discovered that improved emotion regulation predicted enhanced development of executive functioning throughout development. However, we discovered no evidence of the opposite direction of influence.

Emotion regulation predicts executive functioning

Several theoretical accounts, such as temperamental theories, hold that emotion regulation can be viewed as a fundament for the development of executive functions (Blair & Ku, 2022; Liew et al., 2023). Also, according to previous studies, improved emotion regulation during early childhood predicts enhanced executive functions during preschool age (Blankson et al., 2013; Feldman, 2009). It is important to note that these studies only studied a preschool-aged population, and that—before the present study—there were no longitudinal studies investigating whether the prediction of executive functions by emotion regulation was also evident in older children. Because both neurological and biological components, as well as the context surrounding the child, change as they grow older, and this is likely to affect how their emotion regulation and executive functions are expressed (Liew et al., 2023), it might also influence the interplay between these two constructs in different ways at different ages. Furthermore, studies have relied on methods that combine between-person differences and within-person changes, which makes it difficult to draw causal conclusions. In the present study, we extended these findings by demonstrating that improved emotion regulation predicts improved executive functioning at the within-person level when previous changes in executive functions are adjusted for and that this effect is observed across ages 6 to 14. Our findings therefore support the "emotion regulation first" hypothesis, which states that executive functioning is based on previous emotion regulation (Feldman, 2009; Ursache et al., 2013).

It has been postulated that the development of emotion regulation and cognitive processes, such as executive functions, are dependent on one another (Kopp, 1989, 2002). From a cognitive resource perspective, both executive functions and emotion regulation rely on the same limited supply (Bauer & Baumeister, 2011). Ineffective emotion regulation strategies activate the nervous system more than effective emotion regulation strategies do (Gross, 2013). Consequently, an activated nervous system consumes substantial cognitive resources, leaving the individual with fewer resources for daily tasks that rely on executive functioning. According to experimental studies, intense negative emotions impair executive functioning (Pessoa et al., 2012; Pnevmatikos & Trikkaliotis, 2013). Therefore, suboptimal emotion regulation may result in an emotional outburst, and intense emotions may consume resources that can be otherwise allocated to executive functions. Moreover, the development of executive functions requires practice (Diamond, 2013). Therefore, persistent emotional dysregulation, especially when executive functioning is required, reduces the likelihood of executive function practice and development.

Through multiple chemical pathways, both stress and negative mood (which can be the result of inadequate emotion regulation) seem to impair the prefrontal cortex, which is a crucial neural region for executive functioning (Diamond & Ling, 2016). Inadequate emotion regulation may therefore hinder the development of executive functioning by impeding the neural foundation of such development.

Emotion regulation predicts children's peer interactions and prosocial behavior (Blair et al., 2004; Cohen & Mendez, 2009) and the quality of their relationship with their teachers (Graziano et al., 2007). Interaction with peers and teachers is likely to be crucial for the development and practice of executive functions (Fuhs et al., 2013; Lecce et al., 2020). Therefore, inadequate emotion regulation may hinder positive interactions with peers and teachers, thereby reducing the likelihood of practicing and enhancing executive functioning, whereas adequate emotion regulation may facilitate positive interactions with peers and teachers, which can in turn improve executive functioning.

Executive functions do not predict emotion regulation

Although researchers have repeatedly claimed that executive functions are necessary for emotion regulation (Lantrip et al., 2016; Reilly & Downer, 2019; Zelazo & Cunningham, 2007), no longitudinal evidence for such claims has yet been discovered in school-aged children (Blankson et al., 2013; Reilly & Downer, 2019). However, in a large-scale study involving ordinary structural equation modeling, Alamos et al. (2022) reported that inhibitory control predicted improved emotion regulation in preschool children through improved interactions with teachers and peers. Our initial analysis results, which we obtained using a standard CLPM, agree with these results, indicating that improved working memory and shifting (but not inhibition) predict higher scores on emotion regulation. However, when children were used as their own controls with only within-person information in the RI-CLPM, these prospective associations disappeared. These results indicate that the apparent effect of executive functions on emotion regulation can be attributed to unmeasured time-invariant confounding effects. Although our study was not designed to identify the specifics of these effects, we draw attention to genetics and temperament, which are believed to be common underpinnings of both executive functions and emotion regulation (Blair & Ku, 2022). Furthermore, peripheral inflammation, which may result from chronic stress and is believed to affect brain function, is associated with decreased resting-state functional connectivity between the central executive network and the emotion regulation network in the brain (Nusslock et al., 2019) and can therefore serve as a confounding variable.

Although our null findings are credible, we cannot rule out the possibility that executive functions may influence emotion regulation in other contexts or when measured differently. We assessed emotion regulation at home and executive functioning at school. At school, as opposed to at home, each child is frequently evaluated and compared with other classmates, which may induce anxiety or anger (Lichtenfeld et al., 2022; Pekrun, 2017). In addition, the classroom setting requires the child to adhere to certain rules, to sit still, and to control their impulses to engage in other desired activities, significantly more than at home, at least for the majority of children. Compared with parents, teachers are arguably less likely to offer regulation assistance when internal efforts fail. In conclusion, compared with the home environment, the classroom setting is likely to exert more pressure on the emotional and cognitive regulation skills of children and provide less support. As a result, some children demonstrate poorer executive functioning at school than at home. These difficulties with executive functions may not affect emotion regulation at home, because this environment may place less pressure on both cognitive and emotional regulation. By contrast, executive function assessed at home may have some predictive power on emotion regulation at home, and, if both constructs are assessed at school, they may prove to have a bidirectional effect on each other.

Implications

Inadequate executive functioning has a variety of consequences, including cognitive, academic, emotional, and social difficulties (Diamond, 2013; Halse et al., 2022; Jacobson et al., 2011). Identifying modifiable factors that can promote the development of improved executive functions may inform efforts to enhance these capacities. Our findings suggest that assisting children in the development of emotion regulation skills may aid in the development of executive functions, which in turn may have far-reaching effects, ranging from increased academic achievement (Diamond, 2013) to improved social relationships (Jacobson et al., 2011) and reduced mental health problems (Halse et al., 2022). Emotion regulation in children is influenced by their primary caregivers (Morris et al., 2017), and preliminary evidence indicates that emotion regulation can be taught through parental interventions (England-Mason & Gonzalez, 2020). Emotional competence is also socialized by classroom teachers (Morris et al., 2013), and programs aimed at teachers may be beneficial to children's emotion regulation. However, these hypotheses require additional research.

Limitations

This study has a number of strengths, including its long-term follow-up with repeated measurements of a large representative community sample with multiple informants and robust statistical methods to disentangle within- and between-person effects. However, the study also has some limitations, which are highlighted as follows.

First, although time-invariant confounding effects were adjusted for by design, time-variant effects, such as those resulting from adverse life events (Tinajero et al., 2020), time-varying genetic effects (Wang et al., 2020), and parenting practices (Berona et al., 2022;

Fernandes et al., 2022; Halse et al., 2019), may have influenced the results.

Second, the BRIEF-T captures how children utilize their executive functions in daily life, particularly in the classroom setting, which differs from the more direct laboratory tests of executive functions. We recognize that the overlap between these indirect measures of executive functions and laboratory tests of the same construct is modest (Toplak et al., 2013). Therefore, we cannot rule out the possibility that the results may differ if laboratory tests are used instead of teacher reports. Nevertheless, measures of executive functioning in the school context must be ecologically valid, and executive functioning at school may have far-reaching implications, not only for academic achievement and its consequences (Diamond, 2013), but also for social relationships with classmates and other peers (Moriguchi, 2014).

Third, different regulatory abilities may be dominant at various stages of development (Donati et al., 2021). Although we discovered that the predictions from emotion regulation to executive functions were of equal magnitude between the ages of 6 and 14, the effects may be different before and after these ages. For example, during adolescence, the use of maladaptive emotion regulation strategies seems to increase (Rood et al., 2009), and this age is regarded as a highly crucial developmental period for executive functions (Best et al., 2009). Therefore, during this period of development, it is possible that the individual relies more on executive functions for emotion regulation than during other periods.

Fourth, full measurement invariance was not achieved for the ERC according to all indices. It is therefore possible that the importance of various items to ERC differs between ages, although there were no apparent systematic differences across ages or items. Although we cannot exclude the possibility that these differences have influenced the results, the cross-lagged effects did not differ between ages, and we have no ready explanation for why differences between ages in measurement should have produced similarities in results across ages. Therefore, given the above reasoning and the fact that two of the four indices of measurement invariance indicated full invariance of the ERC, we believe that any variance in measurement had limited impact on the results.

Finally, although our study is robust in its design, it is not an experimental study and causal conclusions cannot be drawn from it. Also, any generalization of results to other locales should consider that 93% of the parents in the sample were of Norwegian ethnicity. Thus, we cannot automatically extend our findings to populations of other ethnicities or cultures.

CONCLUSIONS

In this study, we examined the unexplored prospective relation between executive functions and emotion regulation during middle childhood and early adolescence. We discovered that improvements in emotion regulation predict enhanced executive functions in children aged 6 to 14, but not vice versa. These findings suggest that improving children's ability to regulate their emotions may promote the development of their executive functions.

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DATA AVAILABILITY STATEMENT

The data and code necessary to reproduce the analyses presented here are not publicly accessible. The analysis was not pre-registered.

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REFERENCES

Alamos, P., Williford, A. P., Downer, J. T., & Turnbull, K. L. P. (2022). How does inhibitory control predict emotion regulation in preschool? The role of individual Children's interactions with teachers and peers. *Developmental Psychology*, *58*(11), 2049–2063. https://doi.org/10.1037/dev0001415

Allison, P. D. (2009). *Fixed effects regression models* (Vol. *7–160*). Sage publications.

Bauer, I. M., & Baumeister, R. F. (2011). Self-regulatory strength. In K. D. Vohs, & R. F. Baumeister (Eds.), *Handbook of self-regulation: Research, theory, and applications* (Vol. *2*, pp. 64–82). The Guilford Press.

Berona, J., Sroka, A. W., Gelardi, K. L., Guyer, A. E., Hipwell, A. E., & Keenan, K. (2022). Maternal socialization of emotion and the development of emotion regulation in early adolescent girls. *Emotion*, *23*, 872–878.

Berry, D., & Willoughby, M. T. (2017). On the practical interpretability of cross-lagged panel models: Rethinking a developmental workhorse. *Child Development*, *88*(4), 1186–1206. https://doi.org/10.1111/cdev.12660

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review*, *29*(3), 180–200. https://doi.org/10.1016/j.dr.2009.05.002

Blair, C., & Ku, S. L. (2022). A hierarchical integrated model of self-regulation. *Frontiers in Psychology*, *13*, 1–9. https://doi.org/10.3389/fpsyg.2022.725828

Blair, K. A., Denham, S. A., Kochanoff, A., & Whipple, B. (2004). Playing it cool: Temperament, emotion regulation, and social behavior in preschoolers. *Journal of School Psychology*, *42*(6), 419–443. https://doi.org/10.1016/j.jsp.2004.10.002

Blankson, A. N., O'Brien, M., Leerkes, E. M., Marcovitch, S., Calkins, S. D., & Weaver, J. M. (2013). Developmental dynamics of emotion and cognition processes in preschoolers. *Child Development*, *84*(1), 346–360. https://doi.org/10.1111/j.1467-8624.2012.01841.x

Bridgett, D. J., Burt, N. M., Edwards, E. S., & Deater-Deckard, K. (2015). Intergenerational transmission of self-regulation: A multidisciplinary review and integrative conceptual framework. *Psychological Bulletin*, *141*(3), 602–654. https://doi.org/10.1037/a0038662

Chambers, R., Gullone, E., Hassed, C., Knight, W., Garvin, T., & Allen, N. (2015). Mindful emotion regulation predicts recovery in depressed youth. *Mindfulness*, *6*(3), 523–534.

Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, *14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Cohen, J. S., & Mendez, J. L. (2009). Emotion regulation, language ability, and the stability of preschool children's peer play behavior. *Early Education and Development*, *20*(6), 1016–1037.

Curran, P. J., & Bauer, D. J. (2011). The disaggregation of within-person and between-person effects in longitudinal models of change. *Annual Review of Psychology*, *62*(1), 583–619. https://doi.org/10.1146/annurev.psych.093008.100356

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(64), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience*, *18*, 34–48. https://doi.org/10.1016/j.dcn.2015.11.005

Doebel, S. (2020). Rethinking executive function and its development. *Perspectives on Psychological Science*, *15*(4), 942–956. https://doi.org/10.1177/1745691620904771

Donati, G., Meaburn, E., & Dumontheil, I. (2021). Internalising and externalising in early adolescence predict later executive function, not the other way around: A cross-lagged panel analysis. *Cognition & Emotion*, *35*(5), 986–998. https://doi.org/10.1080/02699931.2021.1918644

England-Mason, G., & Gonzalez, A. (2020). Intervening to shape children's emotion regulation: A review of emotion socialization parenting programs for young children. *Emotion*, *20*(1), 98–104. https://doi.org/10.1037/emo0000638

Ezpeleta, L., Granero, R., Penelo, E., de la Osa, N., & Domenech, J. M. (2015). Behavior rating inventory of executive functioning-preschool (BRIEF-P) applied to teachers: Psychometric properties and usefulness for disruptive disorders in 3-year-old preschoolers. *Journal of Attention Disorders*, *19*(6), 476–488. https://doi.org/10.1177/1087054712466439

Feldman, R. (2009). The development of regulatory functions from birth to 5 years: Insights from premature infants. *Child Development*, *80*(2), 544–561. https://doi.org/10.1111/j.1467-8624.2009.01278.x

Fernandes, C., Santos, A. F., Fernandes, M., Verissimo, M., & Santos, A. J. (2022). Caregivers' responses to children's negative emotions: Associations with preschoolers' executive functioning. *Children*, *9*(7), 1075. https://doi.org/10.3390/children9071075

Fuhs, M. W., Farran, D. C., & Nesbitt, K. T. (2013). Preschool classroom processes as predictors of children's cognitive self-regulation skills development. *School Psychology Quarterly*, *28*(4), 347–359. https://doi.org/10.1037/spq0000031

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). Behavior rating inventory of executive function. *Child Neuropsychology*, *6*(3), 235–238. https://doi.org/10.1076/chin.6.3.235.3152

Gioia, G. A., Kenworthy, L., & Isquith, P. K. (2010). Executive function in the real world: BRIEF lessons from Mark Ylvisaker. *The Journal of Head Trauma Rehabilitation*, *25*(6), 433–439. https://doi.org/10.1097/HTR.0b013e3181fbc272

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: A research note. *Journal of Child Psychology and Psychiatry*, *38*(5), 581–586.

Graziano, P. A., Reavis, R. D., Keane, S. P., & Calkins, S. D. (2007). The role of emotion regulation in children's early academic success. *Journal of School Psychology*, *45*(1), 3–19.

Gross, J. J. (2013). Emotion regulation: Taking stock and moving forward. *Emotion*, *13*(3), 359–365.

Groves, N. B., Kofler, M. J., Wells, E. L., Day, T. N., & Chan, E. S. M. (2020). An examination of relations among working memory, ADHD symptoms, and emotion regulation. *Journal of Abnormal Child Psychology*, *48*(4), 525–537. https://doi.org/10.1007/s10802-019-00612-8

Gullone, E., Hughes, E. K., King, N. J., & Tonge, B. (2010). The normative development of emotion regulation strategy use in children and adolescents: A 2-year follow-up study. *Journal of Child Psychology and Psychiatry*, *51*(5), 567–574. https://doi.org/10.1111/j.1469-7610.2009.02183.x

Gumora, G., & Arsenio, W. F. (2002). Emotionality, emotion regulation, and school performance in middle school children. *Journal of School Psychology*, *40*(5), 395–413. https://doi.org/10.1016/s0022-4405(02)00108-5

Gunasekara, F. I., Richardson, K., Carter, K., & Blakely, T. (2014). Fixed effects analysis of repeated measures data. *International Journal of Epidemiology*, *43*(1), 264–269. https://doi.org/10.1093/ije/dyt221

Halse, M., Steinsbekk, S., Hammar, A., Belsky, J., & Wichstrom, L. (2019). Parental predictors of children's executive functioning from ages 6 to 10. *British Journal of Developmental Psychology*, *37*(3), 410–426. https://doi.org/10.1111/bjdp.12282

Halse, M., Steinsbekk, S., Hammar, Å., & Wichstrøm, L. (2022). Longitudinal relations between impaired executive function and symptoms of psychiatric disorders in childhood. *Journal of Child Psychology and Psychiatry*, *63*, 1574–1582.

Hamaker, E. L., Kuiper, R. M., & Grasman, R. (2015). A critique of the cross-lagged panel model. *Psychological Methods*, *20*(1), 102–116. https://doi.org/10.1037/a0038889

Hedge, C., Powell, G., & Sumner, P. (2018). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavior Research Methods*, *50*(3), 1166–1186. https://doi.org/10.3758/s13428-017-0935-1

Hughes, C., Foley, S., Browne, W., McHarg, G., & Devine, R. T. (2023). Developmental links between executive function and emotion regulation in early toddlerhood. *Infant Behavior & Development*, *71*, 101782. https://doi.org/10.1016/j.infbeh.2022.101782

Jacobson, L. A., Williford, A. P., & Pianta, R. C. (2011). The role of executive function in children's competent adjustment to middle school. *Child Neuropsychology*, *17*(3), 255–280. https://doi.org/10.1080/09297049.2010.535654

Kopp, C. B. (1989). Regulation of distress and negative emotions: A developmental view. *Developmental Psychology*, *25*(3), 343–354. https://doi.org/10.1037/0012-1649.25.3.343

Kopp, C. B. (2002). Commentary: The codevelopments of attention and emotion regulation. *Infancy*, *3*(2), 199–208. https://doi.org/10.1207/s15327078in0302_5

Lantrip, C., Isquith, P. K., Koven, N. S., Welsh, K., & Roth, R. M. (2016). Executive function and emotion regulation strategy use in adolescents. *Applied Neuropsychology: Child*, *5*(1), 50–55. https://doi.org/10.1080/21622965.2014.960567

Lecce, S., Bianco, F., & Ronchi, L. (2020). Executive function in the school context: The role of peer relationships. *Infant and Child Development*, *29*(1), e2151. https://doi.org/10.1002/icd.2151

Lichtenfeld, S., Pekrun, R., Marsh, H. W., Nett, U. E., & Reiss, K. (2022). Achievement emotions and elementary school children's academic performance: Longitudinal models of developmental ordering. *Journal of Educational Psychology*, *115*, 552–570. https://doi.org/10.1037/edu0000748

Liew, J., Morris, A. S., & Kerr, K. L. (2023). *Emotion regulation processes as transdiagnostic in adolescence and early adulthood: A neurobioecological systems framework*. American Psychological Association.

Little, R. J. A. (1988). A test of missing completely AT random for multivariate data with missing values. *Journal of the American Statistical Association*, *83*(404), 1198–1202. https://doi.org/10.2307/2290157

Macdonald, A. N., Goines, K. B., Novacek, D. M., & Walker, E. F. (2016). Prefrontal mechanisms of comorbidity from a

transdiagnostic and ontogenic perspective. *Development and Psychopathology*, *28*(4), 1147–1175. https://doi.org/10.1017/s0954579416000742
McRae, K., & Gross, J. J. (2020). Emotion regulation introduction. *Emotion*, *20*(1), 1–9. https://doi.org/10.1037/emo0000703
Moriguchi, Y. (2014). The early development of executive function and its relation to social interaction: A brief review. *Frontiers in Psychology*, *5*, 1–6. https://doi.org/10.3389/fpsyg.2014.00388
Morris, A. S., Criss, M. M., Silk, J. S., & Houltberg, B. J. (2017). The impact of parenting on emotion regulation during childhood and adolescence. *Child Development Perspectives*, *11*(4), 233–238. https://doi.org/10.1111/cdep.12238
Morris, A. S., Denham, S. A., Bassett, H. H., & Curby, T. W. (2013). Relations among teachers' emotion socialization beliefs and practices and preschoolers' emotional competence. *Early Education and Development*, *24*(7), 979–999. https://doi.org/10.1080/10409289.2013.825186
Morris, A. S., Silk, J. S., Steinberg, L., Myers, S. S., & Robinson, L. R. (2007). The role of the family context in the development of emotion regulation. *Social Development*, *16*(2), 361–388. https://doi.org/10.1111/j.1467-9507.2007.00389.x
Muthèn, L. K., & Muthèn, B. O. (1998–2015). *Mplus user's guide* (6th ed.). Muthen & Muthen.
Nusslock, R., Brody, G. H., Armstrong, C. C., Carroll, A. L., Sweet, L. H., Yu, T. Y., Barton, A. W., Hallowell, E. S., Chen, E., Higgins, J. P., Parrish, T. B., Wang, L., & Miller, G. E. (2019). Higher peripheral inflammatory signaling associated with lower resting-state functional brain connectivity in emotion regulation and central executive networks. *Biological Psychiatry*, *86*(2), 153–162. https://doi.org/10.1016/j.biopsych.2019.03.968
Pekrun, R. (2017). Emotion and achievement during adolescence. *Child Development Perspectives*, *11*(3), 215–221. https://doi.org/10.1111/cdep.12237
Pessoa, L., Padmala, S., Kenzer, A., & Bauer, A. (2012). Interactions between cognition and emotion during response inhibition. *Emotion*, *12*(1), 192–197. https://doi.org/10.1037/a0024109
Pnevmatikos, D., & Trikkaliotis, I. (2013). Intraindividual differences in executive functions during childhood: The role of emotions. *Journal of Experimental Child Psychology*, *115*(2), 245–261. https://doi.org/10.1016/j.jecp.2013.01.010
Pruessner, L., Barnow, S., Holt, D. V., Joormann, J., & Schulze, K. (2020). A cognitive control framework for understanding emotion regulation flexibility. *Emotion*, *20*(1), 21–29. https://doi.org/10.1037/emo0000658
Reilly, S. E., & Downer, J. T. (2019). Roles of executive functioning and language in developing low-income preschoolers' behavior and emotion regulation. *Early Childhood Research Quarterly*, *49*, 229–240. https://doi.org/10.1016/j.ecresq.2019.07.006
Reiss, A. L., Abrams, M. T., Singer, H. S., Ross, J. L., & Denckla, M. B. (1996). Brain development, gender and IQ in children—A volumetric imaging study. *Brain*, *119*, 1763–1774. https://doi.org/10.1093/brain/119.5.1763
Rood, L., Roelofs, J., Bogels, S. M., Nolen-Hoeksema, S., & Schouten, E. (2009). The influence of emotion-focused rumination and distraction on depressive symptoms in non-clinical youth: A meta-analytic review. *Clinical Psychology Review*, *29*(7), 607–616. https://doi.org/10.1016/j.cpr.2009.07.001
Satorra, A., & Bentler, P. M. (2001). A scaled difference chi-square test statistic for moment structure analysis. *Psychometrika*, *66*(4), 507–514. https://doi.org/10.1007/bf02296192
Schafer, J. O., Naumann, E., Holmes, E. A., Tuschen-Caffier, B., & Samson, A. C. (2017). Emotion regulation strategies in depressive and anxiety symptoms in youth: A meta-analytic review. *Journal of Youth and Adolescence*, *46*(2), 261–276. https://doi.org/10.1007/s10964-016-0585-0
Shields, A., & Cicchetti, D. (1997). Emotion regulation among school-age children: The development and validation of a new criterion Q-sort scale. *Developmental Psychology*, *33*(6), 906–916. https://doi.org/10.1037/0012-1649.33.6.906
Tinajero, R., Williams, P. G., Cribbet, M. R., Rau, H. K., Silver, M. A., Bride, D. L., & Suchy, Y. (2020). Reported history of childhood trauma and stress-related vulnerability: Associations with emotion regulation, executive functioning, daily hassles and presleep arousal. *Stress and Health*, *36*(4), 405–418. https://doi.org/10.1002/smi.2938
Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct? *Journal of Child Psychology and Psychiatry*, *54*(2), 131–143. https://doi.org/10.1111/jcpp.12001
Ullman, J. B. (2001). Structural equation modeling. In *Using multivariate statistics* (4th ed., pp. 653–771). Allyn & Bacon.
Ursache, A., Blair, C., Stifter, C., & Voegtline, K. (2013). Emotional reactivity and regulation in infancy interact to predict executive functioning in early childhood. *Developmental Psychology*, *49*(1), 127–137. https://doi.org/10.1037/a0027728
Usami, S., Murayama, K., & Hamaker, E. L. (2019). A unified framework of longitudinal models to examine reciprocal relations. *Psychological Methods*, *24*(5), 637–657. https://doi.org/10.1037/met0000210
Vink, M., Gladwin, T. E., Geeraerts, S., Pas, P., Bos, D., Hofstee, M., Durston, S., & Vollebergh, W. (2020). Towards an integrated account of the development of self-regulation from a neurocognitive perspective: A framework for current and future longitudinal multi-modal investigations. *Developmental Cognitive Neuroscience*, *45*, 100829. https://doi.org/10.1016/j.dcn.2020.100829
Wang, H., Wu, Y., Fang, R., Sa, J., Li, Z., Cao, H., & Cui, Y. (2020). Time-varying gene network analysis of human prefrontal cortex development. *Frontiers in Genetics*, *11*, 574543.
Wante, L., Mezulis, A., Van Beveren, M. L., & Braet, C. (2017). The mediating effect of adaptive and maladaptive emotion regulation strategies on executive functioning impairment and depressive symptoms among adolescents. *Child Neuropsychology*, *23*(8), 935–953. https://doi.org/10.1080/09297049.2016.1212986
Wu, Q., Yan, J., & Cui, M. (2021). A developmental hierarchical-integrative perspective on the emergence of self-regulation: A replication and extension. *Child Development*, *92*(5), E997–E1016. https://doi.org/10.1111/cdev.13559
Zelazo, P. D., & Cunningham, W. A. (2007). Executive function: Mechanisms underlying emotion regulation. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 135–158). Guilford Press.

SUPPORTING INFORMATION

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