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EMPIRICAL ARTICLE

CHILD DEVELOPMENT

Does early child negative emotionality moderate the association between maternal stimulation and academic readiness and achievement?

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Abstract

We investigated whether child temperament (negative emotionality, 5 months) moderated the association between maternal stimulation (5 months–2½ years) and academic readiness and achievement (vocabulary, mathematics, and reading). We applied structural equation modeling to the data from the Quebec Longitudinal Study of Child Development ($N = 1121–1448$; mostly Whites; 47% girls). Compared to children with low negative emotionality, those with high negative emotionality had higher levels of academic readiness (6 years) and mathematics achievement (7 years) when exposed to high levels of maternal stimulation ($\beta = 3.17$, $p < .01$ and $\beta = 2.91$, $p < .01$, respectively). The results support the differential susceptibility model whereby highly emotionally negative children were more susceptible to the influences of low and high levels of maternal stimulation in academic readiness and mathematics achievement's developments.

Early childhood represents a critical period during which children develop an array of pre-academic skills and social-emotional abilities (Barbarin et al., 2008; Boivin & Bierman, 2013). For example, they acquire nominal knowledge (e.g., letter, number, and color recognition), cognitive skills (e.g., inferential thinking, ability to follow instructions), and social, attentional, and emotional competences (Barbarin et al., 2008; Li-Grining et al., 2010; Nix et al., 2013). There is much variability in the extent to which children have acquired these skills at school entry. Those with poor pre-academic skills are at risk of short- and long-term academic problems, including dropping out of school (Jimerson et al., 2000). Although environmental factors such as parenting are important determinants of academic outcomes (Chazan-Cohen et al., 2009), children's temperament

Abbreviations: FIML, full information maximum likelihood; k-ABC, Kaufman Assessment Battery for children; NKT, Number Knowledge Test; PA, proportion affected; PPVT-R, Peabody Picture Vocabulary Test-Revised; RoS, region of significance.

also contributes to academic readiness and achievement (Blair & Razza, 2007; Liew, 2012; Valiente et al., 2010). Thus, understanding the interaction between parenting and temperament is crucial to promote children's academic success.

Temperament refers to early individual characteristics underlying basic reactions in various situations, including social interactions (Rothbart & Bates, 1998). Temperamental characteristics are the result of the complex interplay between biological and environmental factors initiated from the beginning of the pregnancy (Räikkönen et al., 2004; Shiner et al., 2012; Takegata et al., 2021). Notably, temperament characteristics have neurological (DiPietro et al., 1996) and genetic roots (Rothbart & Bates, 1998, 2006). Individual differences in central nervous system functioning have been observed before birth and seem to be associated with infant temperament (DiPietro et al., 1996; Dipietro et al., 2018). Several taxonomies of temperament have been proposed (Bates, 1980; Rothbart et al., 2001; Thomas & Chess, 1977). In this study, we used a commonly accepted classification of temperament according to which it is composed of several dimensions, such as self-regulatory capacities (i.e., inhibitory and attentional control capacities), rhythmicity-activity (i.e., impulsivity and activity level), and negative emotionality (i.e., irritability and negative emotional reactivity) (Bates et al., 1979; Rothbart et al., 2001).

Extensive research has been conducted on the association between temperamental dimensions, academic readiness, and achievement (Blair & Razza, 2007; Liew, 2012; Valiente et al., 2010). Children expressing a difficult temperament tend to have low adaptability to new situations, irregular habits, and irregular biological rhythms (e.g., sleeping, reaction time, daily performance) (Thomas & Chess, 1977). Especially, negative emotionality is a core aspect of temperament that is expressed with frequent, intense, or lasting episodes of anger, sadness, and frustration. These negative emotions often interfere with behaviors critical to academic success, such as motivation, concentration, and social interactions (Rice et al., 2007; Valiente et al., 2010). These emotions may also impede one's ability to recall relevant cues, to elaborate plans, and to solve problems, thus impacting cognitive performance (Blair, 2002). Furthermore, frequent expression of anger might negatively affect children's relationships with peers (Rothbart & Bates, 1998), which are important for academic achievement (Ladd, 1990). Thus, negative emotionality has been associated with low academic readiness and achievement levels (Checa & Abundis-Gutierrez, 2017; Gumora & Arsenio, 2002; Potmesilova & Potmesil, 2021; Valiente et al., 2010).

According to the social development theory of cognitive development, providing a nurturing and stimulating environment during early childhood is essential to support cognitive development (Belsky & De Haan, 2011), which, in turn, may be associated with better academic achievement (Forget-Dubois et al., 2009; Lemelin et al., 2007). An optimal parenting style to support children's academic competencies is characterized by warmth and support (Neitzel & Stright, 2003). Indeed, appropriate levels of maternal warmth, support, and stimulation have been associated with greater vocabulary development (Akhtar et al., 1991). In addition, age-appropriate levels of maternal stimulation (e.g., availability for interaction, promotion of cognitive development) may provide the child with increased opportunities for learning and cognitive development (Landry et al., 2006). Similarly, authoritative parenting styles (e.g., high level of support and demand) has been associated with higher cognitive development, possibly because of enhancing child's interest and regulating their opportunities for development (Gauvain et al., 2013; Pinquart, 2016). In turn, these experiences may increase children's interest in exploring their environment (Landry et al., 1996), as well as their acceptance of parental scaffolding (Grusec & Goodnow, 1994). Furthermore, being involved in reciprocal dyadic interactions provides opportunities for children to understand that they can affect their environment and regulate their behavior (Kochanska, 2002). A mother who demonstrates competence in managing emotions will promote coping skills and contribute to the emotional development of her child (Power, 2004; Spinrad & Stifter, 2006). In contrast, less nurturing parenting styles are associated with worse cognitive developmental outcomes during childhood (Blair, 2002).

As postulated by the bioecological system theory (Bronfenbrenner et al., 1998), child characteristics interact with proximal processes (i.e., parent–child interactions) to frame child development. Thus, to understand how children develop, it is imperative to understand parent–child interactions, that is how the association between parenting and child development may be moderated by child characteristics. To date, few studies have specifically focused on the role of child negative emotionality. Negative emotionality is a key dimension of temperament that can be observed early on and has been associated with academic achievement (Checa & Abundis-Gutierrez, 2017; Gumora & Arsenio, 2002; Potmesilova & Potmesil, 2021; Valiente et al., 2010). Thus, understanding the interplay between child negative emotionality and maternal stimulation could refine the understanding of child development. Some studies on parent–child interactions found that children with high negative emotionality when exposed to inefficient or unresponsive parenting were more likely to experience behavior problems than children with low negative emotionality (Lengua et al., 2000; Morris et al., 2002). This form of interaction supports the diathesis-stress model (Monroe & Simons, 1991; Zuckerman, 1999). It posits that vulnerable children

(i.e., children with nigh negative emotionality) are more likely to be negatively affected by an adverse environment, but develop normally and similarly to non-vulnerable children in an adequate environment (e.g., when exposed to adequate parental stimulation) (Monroe & Simons, 1991; Zuckerman, 1999). However, some studies on parent–child interactions found that children with high negative emotionality, when exposed to efficient or responsive parenting, were more likely to experience less behavior problems than children expressing low negative emotionality (Rioux et al., 2018; Slagt et al., 2016). This form of interaction supports the differential susceptibility model (Belsky, 2005). It posits children with high negative emotionality are not necessarily vulnerable, but are especially sensitive to environmental influences during development, 'for better and for worse' (Belsky et al., 2007). This model suggests that children with high negative emotionality may be negatively affected by a suboptimal environment (e.g., inadequate parental stimulation), but benefit from a positive environment (e.g., appropriate parental stimulation). Notably, the model suggests that children with high negative emotionality may outperform their peers with low negative emotionality in terms of academic achievements when exposed to a positive environment, whereas children with low negative emotionality may be less sensitive to their environment and develop similarly in most environments (Belsky et al., 2007). Indeed, negative emotionality can be seen as a biologically based sensitive factor due to the proneness of the nervous or biological systems of some children to react to stimuli in the environment, including parenting (Boyce & Ellis, 2005; Ellis et al., 2011).

A growing body of research supports the differential susceptibility model when studying interactions between child temperament and parenting in predicting child behavior (Belsky et al., 1998; Kochanska et al., 2011; Mesman et al., 2009; Park et al., 1997; Rioux et al., 2018; Slagt et al., 2016), as well as academic performance (Poehlmann et al., 2012; Stright et al., 2008). In addition, recent studies found evidence for the role of gene–environment interactions in various developmental outcomes, which supports the differential susceptibility model for behavior (Bakermans-Kranenburg & van Ijzendoorn, 2006; Kochanska et al., 2011; Sheese et al., 2007) and cognitive development (Jimenez et al., 2020; Plak et al., 2015). However, only two studies have specifically focused on the interaction between child temperament and maternal stimulation as a predictor of academic readiness and academic achievement (Poehlmann et al., 2012; Stright et al., 2008). Among them, only one study specifically focused on child negative emotionality (Stright et al., 2008), creating the need for further studies investigating this question.

Since many academic difficulties begin early in the elementary school years (Jimerson et al., 2000), understanding the interplay between emotional negativity and parenting practices prior to school entry could be a promising avenue to help prevent academic underachievement. Using a 7-year prospective longitudinal design, the aim of the present exploratory study was to confirm the interplay between early negative emotionality (5 months) and maternal stimulation (5 months–2½ years) in the prediction of academic readiness and achievement at school entry (6 and 7 years). We hypothesized that child negative emotionality would moderate the association between maternal stimulation and academic outcomes. Specifically, in line with the differential susceptibility model, we expected that highly emotionally negative children would present higher academic readiness and performance levels than low emotionally negative children when their mothers provide higher levels of stimulation.

METHOD

Participants

Data were drawn from the Quebec Longitudinal Study of Child Development Study (QLSCD), a representative cohort of infants born in the Canadian province of Quebec, between October 1997 and July 1998 and conducted by the Quebec Statistic Institute. The initial sample was selected from the Quebec Master Birth Registry of the Ministry of Health and Social Services based on living area and birth rate. Exclusion criteria included multiple pregnancies, birth before 24 or after 42 weeks of amenorrhea, and illiteracy in French and English. A total of 2120 families were recruited and followed up by trained interviewers at ages 5 months, 1½, 2½, 3½, 4, 5, 6, and 7 years. Ethics approval and written informed consent were obtained from the primary caregiver at each data collection wave. The study protocol was approved by the Quebec Statistic Institute and the Sainte Justine Hospital Research Center ethics committees. Further details on participant recruitment, selection, and attrition are available elsewhere (Orri et al., 2020).

Measures

Child negative emotionality

Child negative emotionality was assessed by mothers at 5 months using the Infancy Difficult Temperament subscale from the validated Infant Characteristics Questionnaire (Bates et al., 1979). The difficultness subscale was used to capture the degree of difficulty a child presents to his parents when compared to typical or 'average' babies (e.g., "how easily does he/she get upset?", "how much does he/she cry and fuss in general?") and used as an indicator of negative

emotionality (Vitaro et al., 2006). Response categories ranged from 1 (low negative emotionality) to 7 (high negative emotionality). The Cronbach α was .79 at 5 months.

Maternal stimulation level

Age-appropriate maternal stimulation (e.g., organization of the temporal environment of the child, number and quality of appropriate toys, involvement with the child, opportunities taken to diversify the stimulation) level was assessed by a trained interviewer after family home visits at 5 months, 1½, and 2½ years using a standardized subscale of the Home Observation for Measurement of the Environment Inventory Short-Form (Bradley, 1993). This 5-item subscale measured the frequency with which the mother spoke to her infant while working or performing her daily activities, encouraged her infant's developmental progress, provided him/her with toys that motivated his/her development, encouraged playing with toys stimulating his/her development, encouraged playing with educational toys, and structured her child's play periods. Response categories ranged from 1 (never) to 5 (always). Because parenting behaviors are relatively stable during childhood (Holden & Miller, 1999), and to maximize our repeated measurements as well as use the most reliable estimation of maternal stimulation level, a mean score over the three assessment points was calculated. There was moderate stability of the scores over the assessment points: 5 months to 1½ years, $r = .38$ ($p < .001$) and 1½ to 2½ years, $r = .36$ ($p < .001$). The Cronbach's α was .86 at 5 months, 1½, and 2½ years.

Academic readiness and achievement

Preschool assessments were done by a trained interviewer during the spring of 2004. Academic readiness was assessed using the Lollipop Test-Revised Edition, a validated test (Venet et al., 2003) evaluating children's cognitive skills with four subtests: identification of colors and shapes, spatial recognition, identification of numbers and counting, and identification of letters and writing (Chew & Chew, 1989). Receptive vocabulary was assessed using the Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981; Dunn et al., 1993) which measures receptive vocabulary in children, in either French or English.

First-grade assessments were done by the teacher during the spring of 2005. Mathematics achievement was assessed using the Number Knowledge Test (NKT), which measures basic knowledge and understanding of numerical concepts (Case & Okamoto, 1996; Garon-Carrier et al., 2018). Reading achievement was assessed using the reading comprehension and decoding subtests of the Kaufman Assessment Battery for children (k-ABC; Kaufman & Kaufman, 1983). As the scores of these two subtests were highly correlated ($r = .78$), they were averaged to create a reading score. All outcome measures were converted into an IQ-type scale for further analyses (i.e., $M = 100$, SD = 15).

Covariates

Child sex and family socioeconomic differences in temperament and academic outcomes were expected (Olino et al., 2013). Family socioeconomic status was estimated using five items concerning annual gross income, parental educational level, and parental occupation. The score ranged from −3 to 3 and was centered at 0, with higher scores indicating higher socioeconomic status. In addition, we controlled our analyses for child age at the time of test administration (in years; for all the outcomes) and language of test administration (French or English) for tests with a language component (i.e., PPVT-R and k-ABC), since it may be related to test scores.

Data analyses

Statistical analyses aimed at testing the moderating effect of child negative emotionality on the association between maternal stimulation and child academic readiness and achievement at 6 and 7 years. We followed Belsky et al.'s (2007) recommendation to test the differential susceptibility model. Thus, for each outcome, a serie of two-step regression analyses (path analyses) were conducted. The first set of models included child sex, family socioeconomic status, child age at the time of test administration, language of test administration (for tests with a language component), child negative emotionality, and maternal stimulation level. The second set of models included the interaction term between child negative emotionality and maternal stimulation level. Both child negative emotionality and maternal stimulation were standardized before inclusion in the analyses. Models were estimated using maximum likelihood with robust standard error estimations to account for non-normal distribution (Kaplan et al., 2009). The full information maximum likelihood (FIML) method was used to account for missing data. We examined model fit using the comparative fit index (adequate if ≥.95), root mean square error of approximation (adequate if ≤.05), and the standardized root mean square residual (adequate if ≤.08) (Tabachnick & Fidell, 2012). The Benjamini–Hochberg correction (Benjamini, 2010) was applied to take into account multiple testing in our analyses.

The effects of maternal stimulation on the outcomes were plotted as a function of child negative emotionality. Whenever a significant interaction was found, simple slope analyses were conducted to determine the

nature of the interaction (i.e., ordinal or disordinal) between maternal stimulation and the outcome at relatively high (+1 SD) or low (−1 SD) child negative emotionality scores.

To further evaluate if the significant interactions were consistent with the differential-susceptibility model, we identified their 'region of significance' (RoS) on X (Kochanska et al., 2011). The RoS on X identified, within the range of maternal stimulation level values, where children who had high and low negative emotionality scores significantly differed in academic readiness or achievement. When they differed at only low levels of maternal stimulation, then the RoS supported a diathesis-stress model (i.e., an ordinal interaction). When they differed at both low and high levels of maternal stimulation, it supported a differential susceptibility model (i.e., a disordinal interaction). We also presented the Johnson–Neyman plots to visualize the values of the moderator for which the slope of maternal stimulation was significant. Because the RoS is influenced by sample size, we also estimated the "proportion affected (PA) index" (Roisman et al., 2012). It allowed us to quantify the degree to which an interaction is consistent with the differential susceptibility model by estimating the proportion of the sample differentially influenced by child negative emotionality, that is, the proportion of the sample above the cross-over point and benefiting from maternal stimulation (Roisman et al., 2012). Values around 0.50 support the differential susceptibility model, while values around 0 support the diathesis-stress model. However, as suggested by Roisman et al. (2012), a PA index above 0.16 might suggest a differential susceptibility model (Roisman et al., 2012). Finally, we examined the linearity of the relation to ascertain that the highlighted differential susceptibility models were not nonlinear relations, which would support the diathesis-stress model (Roisman et al., 2012).

All analyses were weighted using sampling weights to handle sample attrition and approximate the initial target population with regard to sociodemographic characteristics at 5 months. However, we conducted sensitivity analyses to appraise the impact of missing data by rerunning the regression analyses without the inverse probability weights. We also conducted sensitivity analyses investigating each Lollipop subtest score separately.

RESULTS

Participants

Of the 2120 participants included at baseline, 2081 (98.16%) provided information on child negative emotionality at 5 months and on maternal stimulation level from 5 months to 2½ years. Of those, sample sizes varied for academic outcomes: $n=1188$ (56.04%) for academic readiness, $n=1121$ (52.88%) for receptive vocabulary test, $n=1448$ (68.30%) for mathematics achievement, and $n=1404$ (66.23%) for reading skills. Those participants differed slightly from the original sample on socio-demographic characteristics (Table S1). There was a tendency for boys and underprivileged families to be lost to follow-up.

Descriptive statistics

The sample included slightly less boys (47%) than girls (53%). Child negative emotionality mean score was 2.70 (SD = 1.60, skewness = 0.63, kurtosis = 0.11) and maternal stimulation level mean score was 4.49 (SD = 1.68, skewness = 0.11, kurtosis = −0.19). The mean ages at the time of test administration were 6.24 years (SD = 0.26) for the academic readiness test, 6.14 (0.25) for the receptive vocabulary test, 7.15 years (SD = 0.04) for the mathematics test, and 7.15 (0.26) for the reading achievement test. The average score was 57.78 (SD = 6.95, skewness = −1.43, kurtosis = 3.21) for academic readiness, 80.35 (SD = 17.15, skewness = −0.78, kurtosis = 1.04) for receptive vocabulary, 19.71 (SD = 3.93, skewness = −0.58, kurtosis = 0.31) for mathematics achievement, and 22.81 (SD = 10.65, skewness = −0.20, kurtosis = −0.88) for reading achievement. Pearson correlation coefficients between outcomes ranged from .40 to .57 with all p-values < .01. It should be noted that a small proportion of the children took the receptive vocabulary test (7.05%) and the reading achievement test (6.13%) in English.

Table 1 presents correlations between variables which were used in regression analyses for each outcome. Maternal stimulation level was positively correlated with family socioeconomic level and child's age at the time of test administration; mothers with higher socioeconomic status were reported to have higher levels of maternal stimulation. All outcomes were positively correlated with family socioeconomic status, child's age at the time of test administration, and maternal stimulation level. Thus, children of mothers with a higher stimulation level had higher academic readiness and achievement scores. Language of test administration was correlated with receptive vocabulary and reading achievement scores, with higher scores for tests taken in French. Child sex was correlated with academic readiness at 6 years: girls had higher scores. There were no significant correlations between child negative emotionality, academic readiness, and achievement.

In addition, there were no significant correlations between child negative emotionality and maternal stimulation level. Indeed, within the differential susceptibility model, they are required to be independent (Belsky & Pluess, 2009). Thus, to respect this assumption and to control for any potential correlation, maternal stimulation level was regressed on child negative emotionality,

TABLE 1 Correlations[a] among the study variables for each outcome, QLSCD[b] cohort.

Variable	1	2	3	4	5	6
	Academic readiness (Lollipop) at 6 years, *n* = 1188					
1. Sex	–					
2. Socioeconomic status	.02	–				
3. Child's age at the time of test administration	−.006	.005	–			
4. Language of test administration (English)	–	–	–	–		
5. Maternal stimulation	.02	.18***	.07**	–	–	
6. Child negative emotionality	.006	.02	−.10***	–	−.03	–
7. Academic readiness (Lollipop)	.17***	.30***	.12***	–	.14***	−.03
	Receptive vocabulary (PPVT) at 6 years, *n* = 1121					
Variable	**1**	**2**	**3**	**4**	**5**	**6**
1. Sex	–					
2. Socioeconomic status	.01	–				
3. Child's age at the time of test administration	−.01	.01	–			
4. Language of test administration (English)	−.02	−.05	−.02	–		
5. Maternal stimulation	.02	.18***	.08**	−.03	–	
6. Child negative emotionality	.01	.04	−.08**	.02	−.03	–
7. Receptive vocabulary (PPVT)	.003	.28***	.12***	.21***	.17***	.02
	Mathematics achievement (NKT) at 7 years, *n* = 1448					
Variable	**1**	**2**	**3**	**4**	**5**	**6**
1. Sex	–					
2. Socioeconomic status	.02	–				
3. Child's age at the time of test administration	−.02	−.01	–			
4. Language of test administration (English)	–	–	–	–		
5. Maternal stimulation	.05	.21***	.08**	–	–	
6. Child negative emotionality	−.007	.05	−.07	–	−.02	–
7. Mathematics achievement (NKT)	−.04	.31***	.10***	–	.14***	.03
	Reading achievement (k-ABC) at 7 years, *n* = 1404					
Variable	**1**	**2**	**3**	**4**	**5**	**6**
1. Sex	–					
2. Socioeconomic status	.03	–				
3. Child's age at the time of test administration	−.02	.004	–			
4. Language of test administration (English)	−.01	−.03	.008	–		
5. Maternal stimulation	.05	.21***	.09**	−.02	–	
6. Child negative emotionality	.008	.05	−.07**	−.008**	−.02	–
7. Reading achievement (k-ABC)	.01	.28***	.11***	.15***	.17***	.04

Abbreviations: k-ABC, Kaufman Assessment Battery for children; NKT, Number Knowledge Test; PPVT, Peabody Picture Vocabulary Test.

[a]Calculated as Pearson correlation coefficient for correlation between continuous variables, as point biserial correlation coefficient for correlation between dichotomous and continuous variables, and as phi correlation coefficient between dichotomous variables.

[b]Data were compiled from the final master file of the Quebec Longitudinal Study of Child Development (1998–2005), ©Gouvernement du Québec, Institut de la Statistique du Québec.

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

saving the residuals for inclusion in subsequent sensitivity analyses, as it has been done in previous studies (Ramchandani et al., 2010; Rioux et al., 2016). Findings remained the same when original or residual levels were used (Table S2; Figure S1).

Main and interaction effects

Results of regression analyses with main and interaction effects are presented in Table 2. A main effect was observed in the first step. A higher level of maternal

TABLE 2 Weighted main and interaction effects of child negative emotionality and maternal stimulation on academic readiness and performance at 6 and 7 years in the QLSCD cohort.[a]

	Preschool				First grade			
	Academic readiness (Lollipop)		Receptive vocabulary (PPVT)		Mathematics achievement (NKT)		Reading achievement (k-ABC)	
	n = 1188		*n* = 1121		*n* = 1448		*n* = 1404	
	β (95% CI)	Effect size	*β* (95% CI)	Effect size	*β* (95% CI)	Effect size	*β* (95% CI)	Effect size
Main effects (Step 1)								
Sex (male)	−5.12 (−6.77, −3.47)	−0.28	−0.13 (−1.78, 1.52)	−0.01	1.54 (0.05, 3.03)	0.11	−0.05 (−1.54, 1.44)	0.01
Socioeconomic status	4.48 (3.62, 5.34)	0.47	4.22 (3.34, 5.10)	0.56	4.57 (3.77, 5.37)	0.59	4.09 (3.35, 4.83)	0.57
Child's age at the time of test administration	6.89 (3.60, 10.18)	0.19	6.36 (3.20, 9.52)	0.24	5.29 (2.37, 8.21)	0.19	5.81 (2.95, 8.67)	0.21
Language of test administration (English)	-	-	−13.81 (−16.85, −10.77)	−0.53	-	-	−9.77 (−12.77, −6.77)	−0.34
Maternal stimulation	1.64 (0.54, 2.74)	0.14	2.18 (1.14, 3.22)	0.25	1.55 (0.55, 2.55)	0.16	2.18 (1.16, 3.20)	0.22
Child negative emotionality	0.55 (−0.33, 1.43)	0.06	0.25 (−0.55, 1.05)	0.04	0.46 (−0.30, 1.22)	0.06	0.61 (−0.13, 1.35)	0.09
R^2	.137		.153			.111	.125	
Comparative fit index	0.978		0.979			0.956	0.956	
Root mean square error of approximation	0.036		0.032			0.049	0.045	
Standardized root mean square residual	0.016		0.015			0.018	0.017	
Interaction effects (Step 2)								
Sex (male)	−5.11 (−6.76, −3.46)	−0.28	−0.13 (−1.78, 1.52)	−0.01	1.57 (0.08, 3.06)	0.11	−0.03 (−1.52, 1.46)	0.01
Socioeconomic status	4.43 (3.59, 5.27)	0.47	4.22 (3.34, 5.10)	0.56	4.52 (3.72, 5.32)	0.58	4.05 (3.31, 4.79)	0.57
Child's age at the time of test administration	6.89 (3.62, 10.16)	0.19	6.35 (3.19, 9.51)	0.24	5.28 (2.36, 8.20)	0.19	5.81 (2.95, 8.67)	0.21
Language of test administration (English)	-	-	−13.82 (−16.86, −10.78)	−0.54	-	-	−9.76 (−12.79, −6.79)	−0.34
Maternal stimulation	1.73 (0.63, 2.83)	0.14	2.20 (1.16, 3.24)	0.25	1.66 (0.66, 2.66)	0.17	2.24 (1.20, 3.28)	0.23
Child negative emotionality	0.50 (−0.38, 1.38)	0.05	0.24 (−0.58, 1.06)	0.04	0.45 (−0.29, 1.19)	0.06	0.61 (−0.13, 1.35)	0.09
Negative emotionality × mother–child interaction	1.44 (0.26, 2.62)	0.11	0.18 (−0.86, 1.22)	0.02	1.29 (0.25, 2.33)	0.13	0.69 (−0.35, 1.73)	0.07
R^2	.143		.153			.116	.127	
Comparative fit index	0.967		0.952			0.921	0.923	
Root mean square error of approximation	0.040		0.044			0.059	0.054	
Standardized root mean square residual	0.017		0.018			0.022	0.020	

Note: Outcomes raw score was converted into IQ-type scale (i.e., $M = 100$, SD = 15.0).

[a]Data were compiled from the final master file of the Quebec Longitudinal Study of Child Development Study (1998–2005), ©Gouvernement du Québec, Institut de la Statistique.

stimulation was significantly associated with higher academic readiness and achievement scores ($\beta = 1.64$ ($p < .01$), $\beta = 2.18$ ($p < .001$), $\beta = 1.55$ ($p < .01$), and $\beta = 2.18$ ($p < .001$), for academic readiness, receptive vocabulary, mathematics achievement, and reading achievement, respectively). In the second step, significant interactions between child negative emotionality and maternal stimulation were found when predicting academic readiness at 6 years ($\Delta R^2 = .01$) and mathematics achievement at 7 years ($\Delta R^2 = .01$) only. The simple slope analyses showed that the influence of maternal stimulation on academic readiness and mathematics achievement was significant for highly emotionally negative children, but not for low emotionally negative children (Figure 1). RoS on X indicated that slightly emotionally negative (−1 SD) and highly emotionally negative (+1 SD) children differed in their academic readiness and mathematics achievement at lower and higher levels of maternal stimulation, with lower and upper bounds at −1.82 and 0.24 for academic readiness and at −1.98 and 0.27 for mathematics achievement, supporting the differential susceptibility model. It indicates that the regression lines of low and highly emotionally negative children were significantly different when maternal scores were outside of these boundaries. Jonhson–Neyman plots are presented in Figure S4. The PA indexes were 0.68 for academic readiness and 0.32 for mathematics achievement. Associations were similar in the sensitivity analyses (Table S3; Figure S2). Firstly, showing that a higher level of maternal stimulation was significantly associated with better academic readiness and achievement scores (all p-values $< .01$). Secondly, showing a significant interaction term between child negative emotionality and maternal stimulation when predicting academic readiness at 6 years and mathematics achievement at 7 years. No significant interaction between child negative emotionality and maternal stimulation was found when predicting receptive vocabulary and reading achievement.

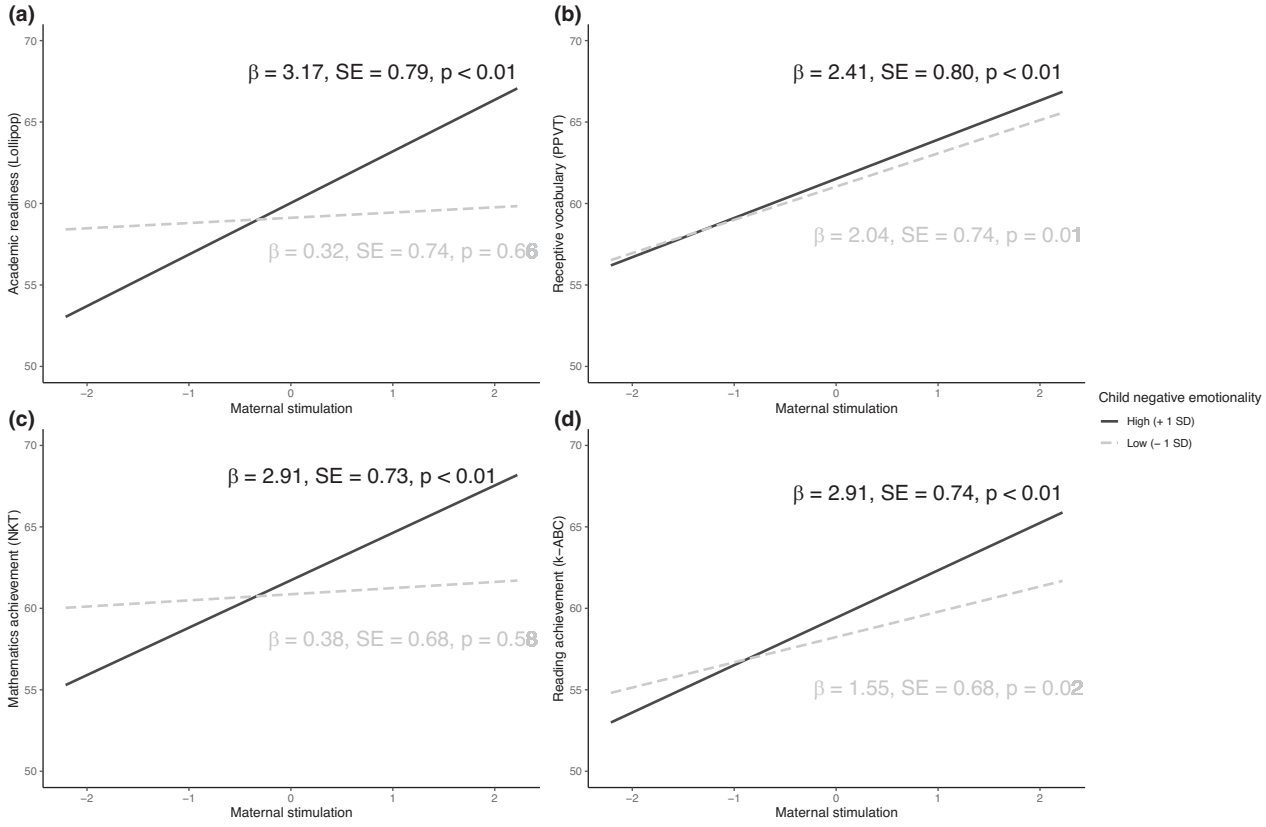

FIGURE 1 Maternal stimulation level between 5 months and 2½ years by child negative emotionality at 5 months predicting academic readiness and performance at 6 and 7 years in the QLSCD cohort[a] (weighted results). [a]Data were compiled from the final master file of the Quebec Longitudinal Study of Child Developement Study (1998–2005), ©Gouvernement du Québec, Institut de la Statistique du Québec. Sample size for academic readiness (Lollipop): low negative emotionality (below −1 SD) = 174, average negative emotionality (between −1 SD and +1 SD) = 819, and high negative emotionality (above +1 SD) = 195. Sample size for receptive vocabulary (Peabody Picture Vocabulary Test [PPVT]): low negative emotionality (below −1 SD) = 163, average negative emotionality (between −1 SD and +1 SD) = 777, and high negative emotionality (above +1 SD) = 181. Sample size for mathematics achievement (Number Knowledge Test [NKT]): low negative emotionality (below −1 SD) = 228, average negative emotionality (between −1 SD and +1 SD) = 996, and high negative emotionality (above +1 SD) = 224. Sample size for reading achievement (Kaufman Assessment Battery for children [k-ABC]): low negative emotionality (below −1 SD) = 223, average negative emotionality (between −1 SD and +1 SD) = 959, and high negative emotionality (above +1 SD) = 222.

DISCUSSION

Main findings

This population-based prospective study revealed that a higher level of maternal stimulation during infancy was associated with higher academic readiness and achievement outcomes at ages 6 and 7 years. Moreover, our findings revealed that maternal stimulation and early child negative emotionality interacted to predict academic readiness at age 6 years and mathematics achievement at age 7 years. These interactions supported the differential susceptibility model whereby highly emotionally negative children were more susceptible to the effects of both low and high levels of maternal stimulation in the development of their academic readiness and mathematics achievement. Despite weak main and interaction effects, our results remained statistically significant after adjusting for family socioeconomic status, indicating that maternal stimulation might benefit child academic abilities independently from socioeconomic level of the family. These results are consistent with previous studies showing that parenting, including maternal stimulation, interacts with infant temperament to predict academic readiness and achievement (Poehlmann et al., 2012; Stright et al., 2008).

Interpretation of the findings

As suggested by the results, low emotionally negative children may be less sensitive to environmental influence, as it relates to school success, while highly emotionally negative children may be more sensitive. Because of this higher sensitivity, high and appropriate levels of maternal stimulation might be particularly beneficial to develop cognitive abilities, resulting in higher levels of academic readiness and achievement among highly emotionally negative children. Conversely, low or inappropriate maternal stimulation, such as a lack of responsiveness or support during the child's activities, may be particularly detrimental for sensitive children. Several lines of evidence indicate that highly emotionally negative children are more likely to repeatedly experience demoralizing negative feedback from their caregivers (Gauvain, 2006). Our results as well as previous findings suggest that in the context of positive feedback (i.e., high positive maternal stimulation and responsiveness), the emotionally negative child may have the opportunity to develop particularly high levels of cognitive skills, social skills, self-control, and cooperativeness (Early et al., 2002; Kochanska, 2005; Rothbart et al., 1994; Stright et al., 2008).

Also, child negative emotionality may be associated with parenting practices (Bates et al., 2012). For instance, mothers may have difficulties responding to the needs of an irritable infant, causing worry and fatigue for the mother, thus altering the mother–child relationship. This can set into motion a series of negative interactions increasing child's negative emotionality with deleterious consequences on child's higher thinking and regulation (Blair, 2002). These results suggest that maternal stimulation during early childhood contributes to the establishment of a positive academic trajectory that might have long-term consequences on academic and personal achievements. This highlights the need to promote high and appropriate levels of maternal early stimulation aiming at fostering child's emotional capabilities for the promotion of academic readiness and achievement.

Interestingly, our results supported the differential susceptibility model regarding academic readiness (especially identification of numbers, counting, and spatial recognition) and mathematics achievement (Table S4; Figure S3). While it was not the case for receptive vocabulary and reading achievement measures, with which maternal stimulation level was positively associated independently from infant negative emotionality. These results are in line with discrepancies shown in previous results that have reported inconsistent associations between infant negative emotionality and child vocabulary and reading achievements (Gartstein et al., 2016; Liu et al., 2018; Molfese et al., 2010; Valiente et al., 2010). Similarly, these results are consistent with a study in which infant negative emotionality has been associated with mathematics achievement, although the mechanisms underlying this association are not yet completely understood (Valiente et al., 2010). As negative emotionality has been negatively associated with executive functions (Liu et al., 2018), it is possible that child negative emotionality overwhelms higher cognitive processes required for mathematics achievements (e.g., recollection, cognitive flexibility, problem-solving) (Blair, 2002; Blankenship et al., 2015). Results are also consistent with studies in which maternal stimulation has been positively associated with both letter-related (Rodriguez & Tamis-LeMonda, 2011; Vallotton et al., 2017) and mathematics-related achievements (Casey et al., 2018; Lombardi et al., 2017). Our results add to this literature by suggesting that the opportunities for dyadic interactions with the environment provided by child positive and negative emotionality can modify the acquisition of non-verbal (i.e., mathematical and spatial) skills, but not the acquisition of verbal skills (i.e., reading and vocabulary). They also add to the literature about the differential susceptibility model by reinforcing our knowledge about the role of child negative emotionality as a sensibility factor. Especially, while previous studies have suggested that child negative emotionality may be a vulnerability factor when exposed to inefficient or unresponsive parenting—in line with the diathesis-stress model (Lengua et al., 2000; Morris et al., 2002), our results suggest that

child negative emotionality may be a sensibility factor to environmental influences that could be overlooked when investigating the association between parenting and child academic achievement. Furthermore, our results expand the differential susceptibility literature by investigating domains-specific academic outcomes assessed at different time points. We also extended previous studies which focused on social skills and relationships with teachers and peers (Stright et al., 2008) and preterm infants (Poehlmann et al., 2012) by investigating domain-specific aspects of academic readiness and achievement (e.g., mathematics, reading, receptive vocabulary) in the general population.

Strength and weaknesses of the study

This study had several strengths, including a large community-based sample, a prospective longitudinal design, yearly follow-ups over the first 7 years of life, and the use of multi-reporter measures (maternal report for child negative emotionality, interviewer reports for maternal stimulation level, and test records for child academic outcomes), avoiding shared method variance. In addition, the use of FIML to estimate models accounted for missing data. Furthermore, our analysis did not use a distal marker of parenting, but rather a specific one: maternal stimulation.

The study also has some limitations. First, while stimulation is an important part of the parenting environment, other aspects of parenting, such as supporting self-regulation, warm parenting, and authoritative parenting are also important (Niklas & Schneider, 2017; Pinquart, 2016; Rodrigues et al., 2021; Topor et al., 2010). Interestingly, maternal stimulation levels were relatively high in our sample, suggesting a limited variability. Thus, our results may vary in samples presenting lower maternal stimulation levels. Second, child negative emotionality was assessed using maternal report only as neither paternal nor non-parental reports were not available at 5 months, preventing inter-rater evaluation. The emotional status of mothers may have confounded the assessment (Vaughn et al., 1981), with more depressed, anxious, or stressed mothers more likely to describe their children as highly negatively emotional, and also more likely to provide an inadequate level of stimulation to their children. However, this putative confounding effect should not impact the observed interactions as they showed that children described as highly negatively emotional by their mothers might benefit from a high level of maternal stimulation. It might have led to non-significant interactions by reducing the estimate of the effect. Furthermore, previous studies testing the interaction between child negative emotionality and parenting in predicting children's behavioral or cognitive outcomes used maternal assessment of their child (Mesman et al., 2009; Stright et al., 2008), which has been shown to be reliable and accurate (Rothbart & Bates, 1998). Third, the selective attrition among boys and socioeconomically disadvantaged families may have introduced a selection bias, which was handled using sample weighting. However, the repeated analyses without sample weighting led to similar results, suggesting that this bias might be rather low. Fourth, although we included sociodemographic and socioeconomic covariates in the analyses, other predictors of child academic readiness and achievement were not included, and residual confounding may have happened. Fifth, the study did not consider measures of children's physiological regulation (e.g., neurobiological stress reactivity) which have been found to moderate the effects of parenting on child development (Obradović et al., 2010). Finally, the results were correlational and did not allow for causal conclusions. Further experimental research would be needed to investigate whether personalized interventions based on child temperamental characteristics would benefit child academic readiness and achievement, as it has been suggested for child behavior (Nocentini et al., 2019).

In conclusion, the results of the present study showed an interaction between children's negative emotionality and maternal stimulation in infancy, when used to predict important aspects of children's academic readiness and achievement at 5 and 6 years, thus supporting the differential susceptibility model. While all children probably benefit from maternal stimulation during their cognitive development, highly emotionally negative children are particularly sensitive to such stimulation, which may have long-term impacts on school readiness and academic performance. Given the importance of early academic readiness and achievement for later personal health and economic productivity, it is crucial to understand how to provide optimal support to highly emotionally negative children. Thus, early parenting interventions aiming to support mothers in dealing with highly emotionally negative infants may improve academic readiness and achievement for these children (Webster-Stratton & Reid, 2004, 2018).

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CONFLICT OF INTEREST STATEMENT

OC was supported by a scholarship from the CHU Sainte-Justine Foundation and the Perinatal Research Network.

DATA AVAILABILITY STATEMENT

The data necessary to reproduce the analyses presented here are not publicly accessible. The analytic code necessary to reproduce the analyses presented in this paper is not publicly accessible. The materials necessary to attempt to replicate the findings presented here are not publicly accessible. The analyses presented here were not preregistered.

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REFERENCES

Akhtar, N., Dunham, F., & Dunham, P. J. (1991). Directive interactions and early vocabulary development: The role of joint attentional focus. *Journal of Child Language*, *18*(1), 41–49. https://doi.org/10.1017/s0305000900013283

Bakermans-Kranenburg, M. J., & van Ijzendoorn, M. H. (2006). Gene–environment interaction of the dopamine D4 receptor (DRD4) and observed maternal insensitivity predicting externalizing behavior in preschoolers. *Developmental Psychobiology*, *48*(5), 406–409. https://doi.org/10.1002/dev.20152

Barbarin, O. A., Early, D., Clifford, R., Bryant, D., Frome, P., Burchinal, M., Howes, C., & Pianta, R. (2008). Parental conceptions of school readiness: Relation to ethnicity, socioeconomic status, and children's skills. *Early Education and Development*, *19*(5), 671–701. https://doi.org/10.1080/10409280802375257

Bates, J. E. (1980). The concept of difficult temperament. *Merrill-Palmer Quarterly*, *26*(4), 299–319.

Bates, J. E., Freeland, C. A., & Lounsbury, M. L. (1979). Measurement of infant difficultness. *Child Development*, *50*(3), 794–803.

Bates, J. E., Schermerhorn, A. C., & Petersen, I. T. (2012). Temperament and parenting in developmental perspective. In M. Zentner & R. L. Shiner (Eds.), *Handbook of temperament* (pp. 425–441). The Guilford Press.

Belsky, J., Bakermans-Kranenburg, M. J., & Van IJzendoorn, M. H. (2007). For better and for worse: Differential susceptibility to environmental influences. *Current Directions in Psychological Science*, *16*(6), 300–304. https://doi.org/10.1111/j.1467-8721.2007.00525.x

Belsky, J., & De Haan, M. (2011). Annual research review: Parenting and children's brain development: The end of the beginning. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *52*(4), 409–428. https://doi.org/10.1111/j.1469-7610.2010.02281.x

Belsky, J., Hsieh, K. H., & Crnic, K. (1998). Mothering, fathering, and infant negativity as antecedents of boys' externalizing problems and inhibition at age 3 years: Differential susceptibility to rearing experience? *Development and Psychopathology*, *10*(2), 301–319. https://doi.org/10.1017/s095457949800162x

Belsky, J., & Pluess, M. (2009). Beyond diathesis stress: Differential susceptibility to environmental influences. *Psychological Bulletin*, *135*(6), 885–908. https://doi.org/10.1037/a0017376

Belsky, J. (2005). Differential susceptibility to rearing influence: An evolutionary hypothesis and some evidence. In *Origins of the social mind: Evolutionary psychology and child development* (pp. 139–163). Guilford Press.

Benjamini, Y. (2010). Discovering the false discovery rate: False discovery rate. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, *72*(4), 405–416. https://doi.org/10.1111/j.1467-9868.2010.00746.x

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist*, *57*(2), 111–127. https://doi.org/10.1037/0003-066X.57.2.111

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development*, *78*(2), 647–663. https://doi.org/10.1111/j.1467-8624.2007.01019.x

Blankenship, T. L., O'Neill, M., Ross, A., & Bell, M. A. (2015). Working memory and recollection contribute to academic achievement. *Learning and Individual Differences*, *43*, 164–169.

Boivin, M., & Bierman, K. L. (2013). *Promoting school readiness and early learning: Implications of developmental research for practice*. Guilford Publications.

Boyce, W. T., & Ellis, B. J. (2005). Biological sensitivity to context: I. An evolutionary-developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology*, *17*(2), 271–301. https://doi.org/10.1017/s0954579405050145

Bradley, R. H. (1993). Children's home environments, health, behavior, and intervention efforts: A review using the HOME inventory as a marker measure. *Genetic, Social, and General Psychology Monographs*, *119*(4), 437–490.

Bronfenbrenner, U., Morris, P., Damon, W., & Lerner, R. M. (1998). Theoretical models of human development. In W. Damon & R. M. Lerner (Eds.), *Handbook of child psychology* (pp. 993–1028). John Wiley & Sons, Inc.

Case, R., & Okamoto, Y. (1996). The role of central conceptual structures in the development of children's thought. *Monographs of the Society for Research in Child Development*, *61*(1–2), v–265.

Casey, B. M., Lombardi, C. M., Thomson, D., Nguyen, H. N., Paz, M., Theriault, C. A., & Dearing, E. (2018). Maternal support of children's early numerical concept learning predicts preschool and first-grade math achievement. *Child Development*, *89*(1), 156–173. https://doi.org/10.1111/cdev.12676

Chazan-Cohen, R., Raikes, H., Brooks-Gunn, J., Ayoub, C., Pan, B. A., Kisker, E. E., Roggman, L., & Fuligni, A. S. (2009). Low-income children's school readiness: Parent contributions over the first five years. *Early Education and Development*, *20*(6), 958–977. https://doi.org/10.1080/10409280903362402

Checa, P., & Abundis-Gutierrez, A. (2017). Parenting and temperament influence on school success in 9–13 year olds. *Frontiers in Psychology*, *8*, 1018–1032. https://doi.org/10.3389/fpsyg.2017.00543

Chew, A. L., & Chew, A. L. (1989). *Developmental and interpretive manual for the Lollipop test*. Humanics Limited.

DiPietro, J. A., Hodgson, D. M., Costigan, K. A., & Johnson, T. R. B. (1996). Fetal antecedents of infant temperament. *Child Development*, *67*(5), 2568–2583. https://doi.org/10.1111/j.1467-8624.1996.tb01875.x

Dipietro, J. A., Voegtline, K. M., Pater, H. A., & Costigan, K. A. (2018). Predicting child temperament and behavior from the fetus. *Development and Psychopathology*, *30*(3), 855–870. https://doi.org/10.1017/S0954579418000482

Dunn, L. M., & Dunn, L. M. (1981). *Peabody Picture Vocabulary Test-Revised (PPVT-R)*. American Guidance Services.

Dunn, L. M., Dunn, L. M., & Thériault-Whalen, C. M. (1993). *Échelle de vocabulaire en images Peabody: EVIP*. PSYCAN.

Early, D. M., Rimm-Kaufman, S. E., Cox, M. J., Saluja, G., Pianta, R. C., Bradley, R. H., & Payne, C. C. (2002). Maternal sensitivity and child wariness in the transition to kindergarten. *Parenting*, *2*(4), 355–377. https://doi.org/10.1207/S15327922PAR0204_02

Ellis, B. J., Boyce, W. T., Belsky, J., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2011). Differential susceptibility to the environment: An evolutionary—Neurodevelopmental theory. *Development and Psychopathology*, *23*(1), 7–28. https://doi.org/10.1017/S0954579410000611

Forget-Dubois, N., Dionne, G., Lemelin, J.-P., Pérusse, D., Tremblay, R. E., & Boivin, M. (2009). Early child language mediates the relation between home environment and school readiness. *Child Development*, *80*(3), 736–749. https://doi.org/10.1111/j.1467-8624.2009.01294.x

Garon-Carrier, G., Boivin, M., Lemelin, J.-P., Kovas, Y., Parent, S., Séguin, J. R., Vitaro, F., Tremblay, R. E., & Dionne, G. (2018). Early developmental trajectories of number knowledge and math achievement from 4 to 10 years: Low-persistent profile and early-life predictors. *Journal of School Psychology*, *68*, 84–98. https://doi.org/10.1016/j.jsp.2018.02.004

Gartstein, M. A., Putnam, S. P., & Kliewer, R. (2016). Do infant temperament characteristics predict core academic abilities in preschool-aged children? *Learning and Individual Differences*, *45*, 299–306. https://doi.org/10.1016/j.lindif.2015.12.022

Gauvain, M. (2006). Child temperament as a mediator of mother-toddler problem solving. *Social Development*, *4*, 257–276. https://doi.org/10.1111/j.1467-9507.1995.tb00065.x

Gauvain, M., Perez, S. M., & Beebe, H. (2013). *Authoritative parenting and parental support for children's cognitive development*. American Psychological Association.

Grusec, J. E., & Goodnow, J. J. (1994). Impact of parental discipline methods on the child's internalization of values: A reconceptualization of current points of view. *Developmental Psychology*, *30*(1), 4–19.

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

Holden, G. W., & Miller, P. C. (1999). Enduring and different: A meta-analysis of the similarity in parents' child rearing. *Psychological Bulletin*, *125*(2), 223–254. https://doi.org/10.1037/0033-2909.125.2.223

Jimenez, M. E., Reichman, N. E., Mitchell, C., Schneper, L., McLanahan, S., & Notterman, D. A. (2020). Shared reading at age 1 year and later vocabulary: A gene-environment study. *The Journal of Pediatrics*, *216*, 189–196.e3. https://doi.org/10.1016/j.jpeds.2019.07.008

Jimerson, S., Egeland, B., Sroufe, L. A., & Carlson, B. (2000). A prospective longitudinal study of high school dropouts examining multiple predictors across development. *Journal of School Psychology*, *38*, 525–549. https://doi.org/10.1016/S0022-4405(00)00051-0

Kaplan, D., Kim, J.-S., & Kim, S.-Y. (2009). Multilevel latent variable modeling: Current research and recent developments. In A. Maydeu-Olivares & R. E. Millsap (Eds.), *The sage handbook of quantitative methods in psychology* (pp. 592–612). Sage Publications Ltd. https://doi.org/10.4135/9780857020994.n24

Kaufman, A. S., & Kaufman, N. L. (1983). *Kaufman Assessment Battery for children: Interpretive manual*. American Guidance Service Inc.

Kochanska, G. (2002). Mutually responsive orientation between mothers and their young children: A context for the early development of conscience. *Current Directions in Psychological Science*, *11*(6), 191–195. https://doi.org/10.1111/1467-8721.00198

Kochanska, G. (2005). Temperament, relationships, and young children's receptive cooperation with their parents. *Developmental Psychology*, *41*(4), 648–660. https://doi.org/10.1037/0012-1649.41.4.648

Kochanska, G., Kim, S., Barry, R. A., & Philibert, R. A. (2011). Children's genotypes interact with maternal responsive care in predicting children's competence: Diathesis-stress or differential susceptibility? *Development and Psychopathology*, *23*(2), 605–616. https://doi.org/10.1017/S0954579411000071

Ladd, G. W. (1990). Having friends, keeping friends, making friends, and being liked by peers in the classroom: Predictors of children's early school adjustment? *Child Development*, *61*(4), 1081–1100. https://doi.org/10.2307/1130877

Landry, S. H., Garner, P. W., Swank, P. R., & Baldwin, C. D. (1996). Effects of maternal scaffolding during joint toy play with preterm and full-term infants. *Merrill-Palmer Quarterly*, *42*(2), 177–199.

Landry, S. H., Smith, K. E., & Swank, P. R. (2006). Responsive parenting: Establishing early foundations for social, communication, and independent problem-solving skills. *Developmental Psychology*, *42*(4), 627–642.

Lemelin, J.-P., Boivin, M., Forget-Dubois, N., Dionne, G., Séguin, J. R., Brendgen, M., Vitaro, F., Tremblay, R. E., & Pérusse, D. (2007). The genetic-environmental etiology of cognitive school readiness and later academic achievement in early childhood. *Child Development*, *78*(6), 1855–1869. https://doi.org/10.1111/j.1467-8624.2007.01103.x

Lengua, L. J., Wolchik, S. A., Sandler, I. N., & West, S. G. (2000). The additive and interactive effects of parenting and temperament in predicting adjustment problems of children of divorce. *Journal of Clinical Child Psychology*, *29*(2), 232–244. https://doi.org/10.1207/S15374424jccp2902_9

Liew, J. (2012). Effortful control, executive functions, and education: Bringing self-regulatory and social-emotional competencies to the table. *Child Development Perspectives*, *6*(2), 105–111. https://doi.org/10.1111/j.1750-8606.2011.00196.x

Li-Grining, C. P., Votruba-Drzal, E., Maldonado-Carreño, C., & Haas, K. (2010). Children's early approaches to learning and academic trajectories through fifth grade. *Developmental Psychology*, *46*(5), 1062–1077. https://doi.org/10.1037/a0020066

Liu, R., Blankenship, T. L., Broomell, A. P. R., Garcia-Meza, T., Calkins, S. D., & Bell, M. A. (2018). Executive function mediates the association between toddler negative affectivity and early academic achievement. *Early Education and Development*, *29*(5), 641–654. https://doi.org/10.1080/10409289.2018.1446880

Lombardi, C. M., Casey, B. M., Thomson, D., Nguyen, H. N., & Dearing, E. (2017). Maternal support of young children's planning and spatial concept learning as predictors of later math (and reading) achievement. *Early Childhood Research Quarterly*, *41*, 114–125. https://doi.org/10.1016/j.ecresq.2017.07.004

Mesman, J., Stoel, R., Bakermans-Kranenburg, M. J., van IJzendoorn, M. H., Juffer, F., Koot, H. M., & Alink, L. R. A. (2009). Predicting growth curves of early childhood externalizing problems: Differential susceptibility of children with difficult temperament. *Journal of Abnormal Child Psychology*, *37*(5), 625–636. https://doi.org/10.1007/s10802-009-9298-0

Molfese, V., Rudasill, K., Beswick, J., Jacobi-Vessels, J., Ferguson, M., & White, J. (2010). Infant temperament, maternal personality, and parenting stress as contributors to infant developmental outcomes. *Merrill-Palmer Quarterly*, *56*, 49–79. https://doi.org/10.1353/mpq.0.0039

Monroe, S. M., & Simons, A. D. (1991). Diathesis-stress theories in the context of life stress research: Implications for the depressive disorders. *Psychological Bulletin*, *110*(3), 406–425. https://doi.org/10.1037/0033-2909.110.3.406

Morris, A. S., Silk, J. S., Steinberg, L., Sessa, F. M., Avenevoli, S., & Essex, M. J. (2002). Temperamental vulnerability and negative parenting as interacting predictors of child adjustment. *Journal*

of Marriage and Family, *64*(2), 461–471. https://doi.org/10.1111/j.1741-3737.2002.00461.x

Neitzel, C., & Stright, A. D. (2003). Mothers' scaffolding of children's problem solving: Establishing a foundation of academic self-regulatory competence. *Journal of Family Psychology*, *17*(1), 147–159. https://doi.org/10.1037/0893-3200.17.1.147

Niklas, F., & Schneider, W. (2017). Home learning environment and development of child competencies from kindergarten until the end of elementary school. *Contemporary Educational Psychology*, *49*, 263–274. https://doi.org/10.1016/j.cedpsych.2017.03.006

Nix, R. L., Bierman, K. L., Domitrovich, C. E., & Gill, S. (2013). Promoting children's social-emotional skills in preschool can enhance academic and behavioral functioning in kindergarten: Findings from head start REDI. *Early Education and Development*, *24*(7), 1000–1019. https://doi.org/10.1080/10409289.2013.825565

Nocentini, A., Palladino, B. E., & Menesini, E. (2019). For whom is anti-bullying intervention most effective? The role of temperament. *International Journal of Environmental Research and Public Health*, *16*(3), 388. https://doi.org/10.3390/ijerph16030388

Obradović, J., Bush, N. R., Stamperdahl, J., Adler, N. E., & Boyce, W. T. (2010). Biological sensitivity to context: The interactive effects of stress reactivity and family adversity on socio-emotional behavior and school readiness. *Child Development*, *81*(1), 270–289. https://doi.org/10.1111/j.1467-8624.2009.01394.x

Olino, T. M., Durbin, C. E., Klein, D. N., Hayden, E. P., & Dyson, M. W. (2013). Gender differences in young children's temperament traits: Comparisons across observational and parent-report methods. *Journal of Personality*, *81*(2), 119–129. https://doi.org/10.1111/jopy.12000

Orri, M., Boivin, M., Chen, C., Ahun, M. N., Geoffroy, M.-C., Ouellet-Morin, I., Tremblay, R. E., & Côté, S. M. (2020). Cohort profile: Quebec longitudinal study of child development (QLSCD). *Social Psychiatry and Psychiatric Epidemiology*, *56*(5), 883–894. https://doi.org/10.1007/s00127-020-01972-z

Park, S.-Y., Belsky, J., Putnam, S., & Crnic, K. (1997). Infant emotionality, parenting, and 3-year inhibition: Exploring stability and lawful discontinuity in a male sample. *Developmental Psychology*, *33*(2), 218–227. https://doi.org/10.1037/0012-1649.33.2.218

Pinquart, M. (2016). Associations of parenting styles and dimensions with academic achievement in children and adolescents: A meta-analysis. *Educational Psychology Review*, *28*(3), 475–493. https://doi.org/10.1007/s10648-015-9338-y

Plak, R. D., Kegel, C. A. T., & Bus, A. G. (2015). Genetic differential susceptibility in literacy-delayed children: A randomized controlled trial on emergent literacy in kindergarten. *Development and Psychopathology*, *27*(1), 69–79. https://doi.org/10.1017/S0954579414001308

Poehlmann, J., Hane, A., Burnson, C., Maleck, S., Hamburger, E., & Shah, P. E. (2012). Preterm infants who are prone to distress: Differential effects of parenting on 36-month behavioral and cognitive outcomes. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *53*(10), 1018–1025. https://doi.org/10.1111/j.1469-7610.2012.02564.x

Potmesilova, P., & Potmesil, M. (2021). Temperament and school readiness—A literature review. *Frontiers in Psychology*, *12*, 599411. https://doi.org/10.3389/fpsyg.2021.599411

Power, T. G. (2004). Stress and coping in childhood: The parents' role. *Parenting*, *4*(4), 271–317. https://doi.org/10.1207/s15327922par0404_1

Räikkönen, K., Pesonen, A.-K., Järvenpää, A.-L., & Strandberg, T. E. (2004). Sweet babies: Chocolate consumption during pregnancy and infant temperament at six months. *Early Human Development*, *76*(2), 139–145. https://doi.org/10.1016/j.earlhumdev.2003.11.005

Ramchandani, P. G., IJzendoorn, M. V., & Bakermans-Kranenburg, M. J. (2010). Differential susceptibility to fathers' care and involvement: The moderating effect of infant reactivity. *Family Science*, *1*(2), 93–101. https://doi.org/10.1080/19424621003599835

Rice, J. A., Levine, L. J., & Pizarro, D. A. (2007). "Just stop thinking about it": Effects of emotional disengagement on children's memory for educational material. *Emotion*, *7*(4), 812–823. https://doi.org/10.1037/1528-3542.7.4.812

Rioux, C., Castellanos-Ryan, N., Parent, S., & Séguin, J. R. (2016). The interaction between temperament and the family environment in adolescent substance use and externalizing behaviors: Support for diathesis-stress or differential susceptibility? *Developmental Review*, *40*, 117–150. https://doi.org/10.1016/j.dr.2016.03.003

Rioux, C., Séguin, J. R., & Paris, J. (2018). Differential susceptibility to the environment and borderline personality disorder. *Harvard Review of Psychiatry*, *26*(6), 374–383. https://doi.org/10.1097/HRP.0000000000000182

Rodrigues, M., Sokolovic, N., Madigan, S., Luo, Y., Silva, V., Misra, S., & Jenkins, J. (2021). Paternal sensitivity and children's cognitive and socioemotional outcomes: A meta-analytic review. *Child Development*, *92*, 554–577. https://doi.org/10.1111/cdev.13545

Rodriguez, E. T., & Tamis-LeMonda, C. S. (2011). Trajectories of the home learning environment across the first 5 years: Associations with children's vocabulary and literacy skills at prekindergarten. *Child Development*, *82*(4), 1058–1075. https://doi.org/10.1111/j.1467-8624.2011.01614.x

Roisman, G. I., Newman, D. A., Fraley, R. C., Haltigan, J. D., Groh, A. M., & Haydon, K. C. (2012). Distinguishing differential susceptibility from diathesis-stress: Recommendations for evaluating interaction effects. *Development and Psychopathology*, *24*(2), 389–409. https://doi.org/10.1017/S0954579412000065

Rothbart, M. K., Ahadi, S. A., & Hershey, K. L. (1994). Temperament and social behavior in childhood. *Merrill-Palmer Quarterly*, *40*(1), 21–39.

Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of temperament at three to seven years: The children's behavior questionnaire. *Child Development*, *72*(5), 1394–1408. https://doi.org/10.1111/1467-8624.00355

Rothbart, M. K., & Bates, J. E. (1998). Temperament. In W. Damon & N. Eisenberg (Eds.), *Handbook of child psychology: Social, emotional, and personality development* (Vol. *3*, 5th ed., pp. 105–176). John Wiley & Sons Inc.

Rothbart, M. K., & Bates, J. E. (2006). Temperament. In N. Eisenberg, W. Damon, & R. M. Lerner (Eds.), *Handbook of child psychology: Social, emotional, and personality development* (Vol. *3*, 6th ed., pp. 99–166). John Wiley & Sons Inc.

Sheese, B. E., Voelker, P. M., Rothbart, M. K., & Posner, M. I. (2007). Parenting quality interacts with genetic variation in dopamine receptor D4 to influence temperament in early childhood. *Development and Psychopathology*, *19*(4), 1039–1046. https://doi.org/10.1017/S0954579407000521

Shiner, R. L., Buss, K. A., McClowry, S. G., Putnam, S. P., Saudino, K. J., & Zentner, M. (2012). What is temperament now? Assessing progress in temperament research on the twenty-fifth anniversary of Goldsmith et al. (†). *Child Development Perspectives*, *6*(4), 436–444. https://doi.org/10.1111/j.1750-8606.2012.00254.x

Slagt, M., Dubas, J. S., Deković, M., & van Aken, M. A. G. (2016). Differences in sensitivity to parenting depending on child temperament: A meta-analysis. *Psychological Bulletin*, *142*(10), 1068–1110. https://doi.org/10.1037/bul0000061

Spinrad, T. L., & Stifter, C. A. (2006). Toddlers' empathy-related responding to distress: Predictions from negative emotionality and maternal behavior in infancy. *Infancy*, *10*(2), 97–121. https://doi.org/10.1207/s15327078in1002_1

Stright, A. D., Gallagher, K. C., & Kelley, K. (2008). Infant temperament moderates relations between maternal parenting in early childhood and children's adjustment in first grade. *Child Development*, *79*(1), 186–200. https://doi.org/10.1111/j.1467-8624.2007.01119.x

Tabachnick, B. G., & Fidell, L. S. (2012). *Using multivariate statistics* (6th ed.). Pearson.

Takegata, M., Matsunaga, A., Ohashi, Y., Toizumi, M., Yoshida, L. M., & Kitamura, T. (2021). Prenatal and intrapartum factors associated with infant temperament: A systematic review. *Frontiers in Psychiatry*, *12*, 609020. https://doi.org/10.3389/fpsyt.2021.609020

Thomas, A., & Chess, S. (1977). *Temperament and development*. Brunner/Mazel.

Topor, D. R., Keane, S. P., Shelton, T. L., & Calkins, S. D. (2010). Parent involvement and student academic performance: A multiple mediational analysis. *Journal of Prevention & Intervention in the Community*, *38*(3), 183–197. https://doi.org/10.1080/10852352.2010.486297

Valiente, C., Lemery-Chalfant, K., & Swanson, J. (2010). Prediction of kindergartners' academic achievement from their effortful control and emotionality: Evidence for direct and moderated relations. *Journal of Educational Psychology*, *102*(3), 550–560. https://doi.org/10.1037/a0018992

Vallotton, C., Mastergeorge, A., Foster, T., Decker, K. B., & Ayoub, C. (2017). Parenting supports for early vocabulary development: Specific effects of sensitivity and stimulation through infancy. *Infancy: The Official Journal of the International Society on Infant Studies*, *22*(1), 78–107. https://doi.org/10.1111/infa.12147

Vaughn, B. E., Taraldson, B. J., Crichton, L., & Egeland, B. (1981). The assessment of infant temperament: A critique of the Carey Infant Temperament Questionnaire. *Infant Behavior & Development*, *4*(1), 1–17. https://doi.org/10.1016/S0163-6383(81)80003-3

Venet, M., Normandeau, S., Letarte, M.-J., & Bigras, M. (2003). Les propriétés psychométriques du Lollipop. *Revue de Psychoéducation*, *32*, 165–176.

Vitaro, F., Barker, E. D., Boivin, M., Brendgen, M., & Tremblay, R. E. (2006). Do early difficult temperament and harsh parenting differentially predict reactive and proactive aggression? *Journal of Abnormal Child Psychology*, *34*(5), 685–695. https://doi.org/10.1007/s10802-006-9055-6

Webster-Stratton, C., & Reid, M. J. (2004). Strengthening social and emotional competence in young children—The Foundation for Early School Readiness and Success: Incredible years classroom social skills and problem-solving curriculum. *Infants & Young Children*, *17*(2), 96–113.

Webster-Stratton, C., & Reid, M. J. (2018). The incredible years parents, teachers, and children training series: A multifaceted treatment approach for young children with conduct problems. In J. R. Weisz & A. E. Kazdin (Eds.), *Evidence-based psychotherapies for children and adolescents* (3rd ed., pp. 122–141). The Guilford Press.

Zuckerman, M. (1999). *Vulnerability to psychopathology: A biosocial model*. American Psychological Association. https://doi.org/10.1037/10316-000

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