Learning and Individual Differences 79 (2020) 101855

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

Early maternal autonomy support and mathematical achievement trajectories during elementary school

Catherine Cimon-Paquet[a], Annie Bernier[a,*], Célia Matte-Gagné[b], Geneviève A. Mageau[a]

[a] University of Montreal, P.O. Box 6128, Downtown Station, Montreal, Québec H3C 3J7, Canada
[b] Laval University, 2325, rue de l'Université, Québec, Québec G1V 0A6, Canada

ARTICLE INFO

Keywords:
Autonomy support
Mathematical achievement
Longitudinal design
Growth curve modeling

ABSTRACT

Increasing evidence suggests that maternal autonomy support fosters mathematical achievement in children. However, the role of autonomy support in mathematical achievement trajectories has never been investigated, despite findings showing that mathematical achievement evolves markedly during elementary school years. In addition, few studies have considered the role of child general cognitive abilities in the links between maternal autonomy support and mathematical achievement. With a sample of 113 mother–child dyads, the current study investigated whether patterns of growth in mathematical achievement during the first three years of elementary school were predicted by the interaction between maternal autonomy support and child general cognitive abilities, both assessed in infancy. Results suggest that early maternal autonomy support is related to later mathematical achievement trajectories in children, although this relation unfolds differently based on children's baseline cognitive abilities. These findings suggest that maternal autonomy support in infancy may confer long-lasting benefits for children's acquisition of mathematical knowledge.

1. Introduction

Mathematical achievement in the first years of formal schooling is related to long-term academic success (Duncan et al., 2007; Watts, Duncan, Siegler, & Davis-Kean, 2014), which in turn is associated with college enrollment (Entwisle, Alexander, & Olson, 2005). Poor academic achievement also forecasts school dropout (Doll, Eslami, & Walters, 2013; Henry, Knight, & Thornberry, 2012). In addition, many adults do not have the numeracy skills essential for everyday life tasks, such as health-related decisions (Reyna & Brainerd, 2007), highlighting the need to study mathematical learning. Consequently, scholars have underscored the importance of examining early individual differences in mathematical achievement (e.g., Byrnes & Wasik, 2009).

Although caution is required when interpreting the longitudinal studies assessing the stability of mathematical achievement over time (Bailey, Duncan, Watts, Clements, & Sarama, 2018), studies show that trajectories of mathematical learning between the first and third grade of elementary school present interindividual variability (Geary et al., 2009; Jordan, Kaplan, Ramineni, & Locuniak, 2009; Pianta, Belsky, Vandergrift, Houts, & Morrison, 2008), indicating that children differ in their learning rates across this time span. In turn, these trajectories of mathematical learning forecast later outcomes, with faster rates of learning in the first years of school showing prospective relations to higher mathematical achievement in adolescence, regardless of children's level of mathematical skills at school entry (Watts et al., 2014). Furthermore, Tomasik, Napolitano, and Moser (2018) observed that a steeper increase in academic achievement from childhood to adolescence, but not baseline achievement at age 7, was associated with personal adjustment in young adulthood. Given the empirical evidence showing that growth patterns in mathematical skills vary significantly across children during elementary school and that this variability forecasts future outcomes, identifying early correlates of how mathematical skills increase over time is an important scientific endeavor.

Parenting practices and child cognitive abilities are known correlates of children's mathematical achievement (Geary, 2011; Gutman, Sameroff, & Cole, 2003; Morgan, Farkas, Hillemeier, & Maczuga, 2016). However, very few studies have investigated such factors as antecedents of mathematical achievement as early as infancy, despite the fact that both parental and child behavior are emerging and most malleable early in development. The current study focuses on early maternal autonomy support and infant general cognitive abilities as antecedents of mathematical achievement growth during early elementary school.

* Corresponding author at: Department of Psychology, University of Montreal, P.O. Box 6128, Downtown Station, Montreal, QC H3C 3J7, Canada.
E-mail addresses: catherine.cimon-paquet@umontreal.ca (C. Cimon-Paquet), annie.bernier@umontreal.ca (A. Bernier), celia.matte-gagne@psy.ulaval.ca (C. Matte-Gagné), g.mageau@umontreal.ca (G.A. Mageau).

https://doi.org/10.1016/j.lindif.2020.101855
Received 11 September 2019; Received in revised form 30 January 2020; Accepted 5 March 2020
1041-6080/ © 2020 Elsevier Inc. All rights reserved.

1.1. Maternal autonomy support and mathematical achievement

Mother–child relationships constitute key factors to consider when examining the environmental factors related to mathematical development, as these relationships play a significant role in children's academic development (Gutman et al., 2003; Morgan et al., 2016) and can be effectively improved (Steele & Steele, 2018). Moreover, the predictive capacity of the quality of early mother–child relationships in relation to later child academic achievement is enduring, persisting from school entry to adulthood (Morrison, Rimm-Kauffman, & Pianta, 2003; Raby, Roisman, Fraley, & Simpson, 2015). Among the different facets of mother–child relationships, several studies have found that maternal support of child autonomy is associated with academic achievement (Mattanah, Pratt, Cowan, & Cowan, 2005; see Vasquez, Patall, Fong, Corrigan, & Pine, 2016, for a meta-analysis).

The notion of autonomy support is embedded in Self-Determination Theory (SDT), which proposes the existence of three universal psychological needs: autonomy, competence, and relatedness (Deci & Ryan, 2000; Ryan & Deci, 2000). Satisfaction of these three basic needs has been related to well-being in several cultures and across the life span (Chen et al., 2015; Ferrand, Martinent, & Durmaz, 2014; Véronneau, Koestner, & Abela, 2005). Maternal autonomy support refers to the ways in which mothers actively support children's volition and sense of ownership of their behaviors (Mageau et al., 2015; Ryan, Deci, Grolnick, & La Guardia, 2006), notably by showing consideration for children's distinct internal frame of reference and encouraging their active participation in decision-making and problem-solving (Grolnick & Ryan, 1989; Koestner, Ryan, Bernieri & Holt, 1984). Although there has been some controversy concerning the role that autonomy support may play in child-rearing across cultures when it refers to the promotion of independence (e.g., Chirkov, Ryan, Kim, & Kaplan, 2003; Liu et al., 2005; Soenens et al., 2007), increasing evidence suggests that autonomy support, defined in line with SDT as the promotion of volition, is beneficial across cultures (Chirkov, 2009; Knee & Uysal, 2011).

Maternal autonomy support (defined as the promotion of volition) could promote better school performance in children by fostering the development of an array of competencies. For example, maternal autonomy support in infancy relates to executive functioning in preschoolers (Bernier, Carlson, & Whipple, 2010; Distefano, Galinsky, McClelland, Zelazo, & Carlson, 2018), which itself is associated with subsequent academic success (Bindman, Pomerantz, & Roisman, 2015), presumably by helping children resolve complex multistep problems (Bull & Lee, 2014). Also, a recent meta-analysis showed that parental autonomy support is related to autonomous motivation and engagement, which have been related to academic success as well (see Vasquez et al., 2016). Furthermore, parental autonomy support in the early years could promote self-regulated learning, which is increasingly important as children become more independent from their parents and have new opportunities to learn outside the home (e.g., at school; see Pino-Pasternak & Whitebread, 2010, for a review).

A great deal of research has focused on autonomy support and academic achievement, including mathematical achievement, both cross-sectionally and longitudinally. Meta-analytic data revealed a modest, yet robust positive association between parental autonomy support and academic achievement during elementary school (Vasquez et al., 2016). Most longitudinal studies have used school-age assessments of maternal autonomy support (Joussemet, Koestner, Lekes, & Landry, 2005; Mattanah et al., 2005; NICHD, 2008), and only a handful of studies have considered autonomy support in early childhood. Yet, mathematical knowledge develops prior to school entry (Skwarchuk, Sowinski, & LeFevre, 2014), and thus, maternal autonomy support during infancy may be important for mathematical development. In line with this, two studies from the same research group found that certain types of autonomy-supportive behaviors (i.e., the extent to which mothers allowed children to set goals, be independent, and avoided controlling child behavior) as observed during a mother–infant play interaction was associated with pre-mathematical skills at preschool age and mathematics grades in ninth grade, nearly 15 years after the initial assessment (Sorariutta, Hannula-Sormunen, & Silvén, 2017; Sorariutta & Silvén, 2017). Bindman et al. (2015) also found that autonomy support observed during mother–child interactions at 36 months (i.e., the extent to which mothers followed children's pace and interests, allowed children to take the lead when appropriate, and mothers' flexibility) was related to children's subsequent school performance through high school.

Taken together, these studies suggest that early maternal autonomy support may be associated with mathematical achievement several years later, during elementary school. Despite this, previous studies have not examined the relation between early autonomy support and the unfolding of mathematical achievement growth during this period. This may constitute an important oversight, given that as mentioned above, development rates of achievement may be more strongly related to later outcomes than single-time assessments (Tomasik et al., 2018; Watts et al., 2014). In addition, it is well-known that children are active agents in parent–child relationships and can influence specific parental behaviors related to their academic outcomes as well as how their parents' behaviors affect them (Pomerantz & Grolnick, 2017). Yet, very few studies have considered the reasonable possibility that the putative benefits of maternal autonomy support on mathematical achievement may vary across children. The current study aimed to fill these gaps.

1.2. Child general cognitive abilities as a moderator

One way to assess child effects is by using child characteristics as moderators of parenting effects, and thus study child by environment interactions (Davidov, Knafo-Noam, Serbin, & Moss, 2015). While well-documented with respect to several aspects of child development, interactive processes involving the home environment and child characteristics are rarely addressed in relation to mathematical development, although they most likely exist (Elliott & Bachman, 2018; see for instance Ng, Kenney-Benson, & Pomerantz, 2004).

More specifically, it has been proposed that children's basic capacity for learning could interact with environmental factors in affecting mathematical development (Bull, Espy, & Wiebe, 2008). The opportunity-propensity framework (Byrnes & Miller, 2007) posits that achievement in a specific domain, such as mathematics, is influenced by both the presence of environmental opportunities to acquire knowledge or skills and child propensity to seize these opportunities. Thus, according to this framework, achievement in mathematics not only depends on environmental support of children's knowledge and skills acquisition (e.g., in a classroom or at home), it is also determined by children's ability to learn from these opportunities.

In line with this, general cognitive abilities are robust predictors of mathematical achievement and growth over time (Geary, 2011; Primi, Ferrão, & Almeida, 2010; see Peng, Wang, Wang, & Lin, 2019, for a meta-analysis). These general abilities are believed to allow children to resolve complex cognitive operations (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007) and accordingly, may be especially important for mathematics, which require reasoning and applying rules and principles to abstract concepts (see Peng et al., 2019, for a meta-analysis). Consistent with these ideas, general cognitive abilities, assessed in infancy, have been found to be associated with elementary and high school mathematical achievement (Bindman et al., 2015; Johnson, Wolke, Hennessy, & Marlow, 2011). These findings suggest that general cognitive abilities should be considered in models attempting to predict subsequent mathematical achievement.

Yet, in light of the large body of literature documenting that some children with high potential nonetheless experience underachievement, it is likely that the actualization of children's full cognitive potential at school may not be possible without support from their social environment (Reis & McCoach, 2000). One may therefore propose that children's baseline cognitive abilities lay the groundwork for later mathematical achievement, but that it is also crucial to consider the role that parental autonomy support may play in children's mathematical development, notably in interaction with children's cognitive abilities.

1.3. The current study

The current study set out to examine the hypothesis that infant baseline cognitive abilities moderate the association between early maternal autonomy support and the development of child mathematical achievement at school age. Children who are exposed to more maternal autonomy support and who demonstrate greater cognitive abilities in infancy benefit from two cumulative promotive factors (Sameroff, 2010) known to relate to mathematical performance. Hence, these children were expected to show higher initial mathematics performance and steeper improvements over the first three years of schooling.

Given that family socioeconomic status and prenatal risk are often found to relate to subsequent mathematical achievement and cognitive development (e.g., Glass et al., 2017; Jordan et al., 2009; Kristjansson et al., 2018; Starnberg, Norman, Westrup, Domellöf, & Berglund, 2018), and that some evidence suggests that child sex may be related to mathematical achievement (Fryer & Levitt, 2010; Lindberg, Hyde, Petersen, & Linn, 2010), these factors were considered as potential covariates.

Maternal sensitivity, also assessed during infancy, was included as a covariate as well. Maternal sensitivity represents mothers' capacity to interpret and respond to their infant's emotional needs promptly and appropriately (Ainsworth, Bell, & Stayton, 1974). Early maternal sensitivity has been associated with both school readiness and achievement (Fraley, Roisman, & Haltigan, 2013; Raby et al., 2015) as well as with maternal autonomy support (Bernier, Matte-Gagné, Bélanger, & Whipple, 2014). Therefore, examining the hypothesis while controlling for maternal sensitivity constituted a very conservative test of the predicted associations, allowing us to ensure that any results would be specific to autonomy support, and not to a halo effect of a generally more competent mother during infancy.

2. Method

2.1. Participants

The sample consisted of 113 mother–child dyads (62 girls, 51 boys). Participants were recruited when children were 7 months old from random birth lists of a large metropolitan area provided by the Ministry of Health and Social Services. Sociodemographic data were collected at recruitment and informed consent was obtained for all participants. The study protocol was approved by the university's institutional review board. Families were included only if the infant was born full term or late preterm (≥36 gestational weeks) and without any known physical or mental disability. Family income (in Canadian dollars) was based on categorical scores distributed as follows (two families did not report): 1 (n = 3; *< $20,000*); 2 ($n$ = 9; *$20,000–39,999*); 3 ($n$ = 13; *$40,000–59,999*); 4 ($n$ = 27; *$60,000–79,999*); 5 ($n$ = 20; *$80,000–99,999*); 6 ($n$ = 39; *≥$100,000*). The mean family income for the sample was 4.5 (SD = 1.4). Mothers were between 20 and 45 years old (M = 32.01; SD = 4.53) and had on average 15.7 years of education (SD = 2.2). Of the 113 mothers, 107 were White, one was African Canadian and five did not report; with respect to ethnicity, three were Latinas. Fathers were between 22 and 52 years old (M = 34.38; SD = 5.81) and had on average 15.2 years of education (SD = 2.3). Of the 113 fathers, 105 were White, two were African Canadian and six did not report; with respect to ethnicity, four were Latinos.

This study is part of a larger longitudinal project. Participants included in the current study had valid scores on both infant general cognitive abilities at 12 months (M = 12.57, SD = 1.13) and maternal autonomy support at 15 months (M = 15.52 months, SD = 0.78). They had also taken part in at least one of the three mathematical achievement assessments. Of the 113 children, 103 participated in the mathematical achievement assessment in first grade (G1; M = 7.11 years, SD = 0.25), 109 in second grade (G2; M = 7.79 years, SD = 0.28) and 103 in third grade (G3; M = 8.71 years, SD = 0.28). Attrition analyses suggested that families with missing data (n = 22) did not differ from those who participated in all time points on sociodemographic data (child sex, parents' age, parents' education, number of siblings, family income, all $ps > .05$). Although families with missing data on mathematical achievement did not differ on infant cognitive abilities scores, they did differ on maternal autonomy support, $t(111) = 3.62$, $p < .001$, $\eta^2 = 0.11$. Families who had missing data had significantly lower scores on maternal autonomy support compared to families who did not. Missing data are considered missing at random when other observed variables are associated with the probability of missingness (Enders, 2010). As a predictor of missingness was identified (i.e., maternal autonomy support) and included in the final model, data were considered missing at random and were handled using the robust full-information maximum likelihood estimator, as per current best practices, which allows the estimation of model parameters using all available data (Enders, 2010).

2.2. Procedure and measures

2.2.1. General cognitive abilities

When children were aged 12 months, their general cognitive abilities were measured during a home visit by a trained research assistant using the Mental Development Index of the Bayley Scales of Infant Development 2nd edition (MDI; Bayley, 1993). The MDI is a standardized measure that assesses cognition (i.e., sensory-perception, knowledge, memory, problem solving and early language; Lowe, Erickson, Schrader, & Duncan, 2012) in children aged 1–42 months. The MDI is considered a gold-standard assessment tool to assess cognition and shows adequate predictive validity (Dos Santos, de Kieviet, Van Elburg, & Oosterlaan, 2013; Fernald, Kariger, Engle, & Raikes, 2009; Fernandes et al., 2014; Frongillo, Tofail, Hamadani, Warren, & Mehrin, 2014). The MDI also shows concurrent validity with another widely-used developmental test, the Griffiths Mental Development Scale (Cirelli, Graz, & Tolsa, 2015; Huntley, 1996).

2.2.2. Maternal autonomy support

When children were aged 15 months, mothers were asked to complete three tasks (two puzzles and a tower of blocks) with their child during a home visit. The tasks were chosen to be slightly too difficult for the children, such that they would require some support from their mothers. These sequences were videotaped and later coded by trained graduate students for autonomy-supportive behaviors. Maternal behaviors were rated on four Likert scales (1–5) following Whipple, Bernier, and Mageau's (2011) coding system. The subscales assessed the extent to which the mother (1) encourages her child in the pursuit of the task, offers suggestions, and uses a positive tone of voice (verbally supportive behaviors); (2) takes her child's perspective and demonstrates flexibility in her attempts to keep the child on task; (3) follows her child's pace, provides the child with the opportunity to make choices, and ensures that the child plays an active role in task completion; (4) intervenes and adapts the task according to the infant's needs and minimizes the use of controlling techniques. A total autonomy support score was computed for each task by averaging the four subscales (α = 0.85–0.91), as they were highly correlated (range r = 0.49–0.87). This global score was correlated across the three tasks (range r = 0.46–0.85); consequently, these three scores were averaged into a global autonomy support score (α = 0.82). A recent study using the same autonomy support coding system confirmed that the four subscales are representative of a single latent factor of autonomy support (Hughes, Lindberg, & Devine, 2018).

Two research assistants independently rated a randomly selected 23% of the interactions. Interrater reliability was excellent ($ICC = 0.96$). This autonomy support measure has previously been found to relate to its expected correlates, notably maternal sensitivity as well as child attachment security, self-regulation and executive functioning (Bernier et al., 2010; Meuwissen & Carlson, 2015, 2019; Whipple et al., 2011).

2.2.3. Mathematical achievement

When children were in first, second, and third grades of elementary school, mathematical achievement was assessed during home visits using the mathematics reasoning subscale (e.g., number identification, problem solving) of the Weschler Individual Achievement Test – Second edition – French Canadian version (WIAT-II CDN-F; Weschler, 2005). Scores on this subscale vary from 0 to 67. The WIAT-II CDN-F has adequate temporal stability and reliability coefficients vary between 0.86 and 0.92 in children aged 6–11 years (Weschler, 2008). The mathematics reasoning subscale presents excellent convergent validity with the global IQ score from the WISC-IV ($r = 0.73$). Given our goal to estimate developmental trajectories in mathematical achievement, which age-standardized scores would flatten (thus removing the intra-individual growth over time that is of interest here), the raw scores were used.

2.2.4. Covariates

In addition to child sex, the following three covariates were measured.

2.2.4.1. Maternal sensitivity. When children were aged 12 months, maternal sensitivity was assessed using the Maternal Behavior Q-Sort (MBQS; Pederson & Moran, 1995). As per standard procedures, a trained research assistant noted maternal behaviors throughout a home visit and rated the MBQS immediately upon returning to the laboratory, based on observations conducted throughout the visit. The 90 MBQS items, which all describe potential maternal behaviors, were sorted from “very unlike” to “very similar” to the observed mother's behaviors. The observer's sort was then correlated with a criterion sort representing the prototypically sensitive mother. This correlation constitutes the sensitivity score. In the current study, approximately 20% of home visits were randomly chosen to be conducted by two research assistants, who completed the MBQS independently. Agreement between the two raters' sorts was very good, $ICC = 0.86$.

2.2.4.2. Prenatal risk factors. Based on obstetric information reported by mothers upon recruitment, five prenatal risk factors were derived: preterm pregnancy (< 37 weeks), alcohol consumption, tobacco consumption, type of birth, and pregnancy complications (e.g., cardiac problems, diabetes, anemia or rubella). Each factor was coded 0 (*no*) or 1 (*yes*), except for type of birth 0 (*vaginal*) and 1 (*caesarean*) and pregnancy complications, which were coded as 0 (*none*), 1 (*one complication*), and 2 (*more than one complication*). The five prenatal risk factors were then summed to create a cumulative prenatal risk score (*range* = 0–6, with higher scores suggesting greater risk).

2.2.4.3. Family socio-economic status (SES). Family SES was obtained by averaging standardized scores (Z-scores) of maternal and paternal years of education and family income (rs between 0.44 and 0.58).

2.3. Analytic strategy

Multilevel growth curves analyses were conducted using Mplus (Muthén & Muthén, 2012). Maximum likelihood estimation with robust standard errors (MLR) was used, as it is robust to nonnormality and eliminates the need to discard individuals with missing data, thereby increasing statistical power (Hox & Van de Schoot, 2013). A multilevel modeling framework (MLM) was preferred to structural equation modeling because it is particularly well suited to the conditions encountered in this study as it can easily handle partially missing data, unequally spaced time points, and data collected across a range of ages within any one occasion (Burchinal, Nelson, & Poe, 2006; Hox & Van de Schoot, 2013; Singer & Willett, 2003). With multilevel modeling, repeated and dependent observations are considered nested within individuals, which allows for the investigation of intraindividual change over time (level-1; within-subject) as well as inter-individual differences in baselines and growth rates (level-2; between-subjects; Heck & Thomas, 2015). Moreover, level-2 differences can be predicted by variables of interest. Another advantage of using multilevel modeling is that these analyses require as few as 30–50 level-2 units (Burchinal et al., 2006; see Maas & Hox, 2005, for a simulation study). In this study, each child constitutes a level-2 unit such that adequate statistical power was achieved.

2.3.1. Modeling change in mathematical achievement over time

Intraindividual growth curves in mathematical achievement over time were first modeled (level-1) and differences between children were then examined (level-2). To ascertain the best-fitting models of growth in mathematical achievement, three unconditional models were specified. Model A (fixed linear model) included the fixed effect of child exact age in years, coded such that the intercept represented average mathematical achievement at the first assessment (i.e., first grade) and the slope represented the average yearly decrease or increase in mathematical achievement. Model B (random linear model) included the random effect of time (i.e., between-subjects variability in individual intercepts and slopes). Model C (fixed quadratic model) was specified to test for change in growth rates. In this model, a fixed quadratic term was added to identify any significant acceleration or deceleration in the slope across time (i.e., indicating a decreasing or increasing curvilinear trajectory). The quadratic term was retained if the pertinent p value for the estimate was < 0.05.

Goodness of fit was assessed using the log-likelihood (an indicator of deviance) and the Akaike information criterion, with lower values indicating better representation of the data by the model (Grimm, Ram, & Estabrook, 2017). The random effects were therefore retained if the model's log likelihood (LL) differed significantly with the addition of the random terms, based on an adjusted chi-square difference test (i.e., adapted to the MLR estimator), or if the model's Akaike information criterion was lowered with the addition of the random terms.

2.3.2. Predicting change in mathematical achievement over time

After the best-fitting model for the trajectory of mathematical achievement growth over time was identified, a preliminary conditional model was tested including the effects of the potential covariates (i.e., child sex, family SES, prenatal risk, and maternal sensitivity) on mathematical achievement trajectory parameters (i.e., intercept and slope). Then, to increase parsimony, maximize statistical power, and prevent any spurious effects that may be caused by the high number of covariates included in the preliminary model (Little, 2013), a final predictive model was estimated using only the main predictors and the covariates found to be significantly associated with the slope or the intercept of the growth curve in the preliminary model. This final model thus included the effects of the retained covariates, maternal autonomy support, general cognitive abilities, and their interaction on the intercept (i.e., mathematical achievement in first grade) and slope (i.e., mathematical development between first and third grade). Finally, to ease interpretation of the results, continuous predictors were centered at the grandmean. By centering the predictors at their grandmean, the intercept represents the estimated initial status (baseline level) for individuals with an average value on all predictors. In line with our hypothesis, we planned to interpret the coefficient of the interaction, and if significant, to interpret the simple effects as well.

As multilevel models include multiple variance components (e.g., within-subject and between-subjects variances), standardized coefficients and thus effects sizes are not readily available. In order to obtain

Table 1
Descriptive statistics.

	n	*M* (*SD*)	Range	Skewness	Kurtosis
General cognitive abilities	113	97.11 (10.41)	66.00–120.00	−.32	.02
Autonomy support	113	3.37 (1.03)	1.44–5.00	−.20	−1.15
Mathematical achievement G1	103	23.69 (4.60)	14.00–42.00	.72	1.61
Mathematical achievement G2	109	28.80 (5.46)	17.00–51.00	.69	1.73
Mathematical achievement G3	103	34.80 (5.60)	22.00–52.00	.49	.69
Family SES	113	−.02 (.84)	−2.32–1.09	−.72	−.47
Prenatal risk	108	1.02 (.86)	.00–4.00	1.03	1.63
Maternal sensitivity	110	.65 (.28)	−.79–.89	−2.73	9.48

Notes. G1 = grade 1; G2 = grade 2; G3 = grade 3.
SES = socioeconomic status.

an estimate of the proportion of the variance in mathematical achievement explained by the predictors, we computed pseudo-R^2 estimates, following Hoffman's (2015) procedure.

3. Results

3.1. Preliminary analyses

Table 1 displays the descriptive statistics for all continuous variables. All variables were normally distributed (skewness < 3.0; kurtosis < 7.0; Curran, West, & Finch, 1996; Kline, 2011), except for maternal sensitivity that showed high kurtosis. Zero-order correlations among the covariates (i.e., family SES, child sex, prenatal risk and maternal sensitivity) and the core study variables are shown in Table 2. Better general cognitive abilities at 12 months were associated with more maternal autonomy support at 15 months. As expected, mathematical achievement was highly correlated across grades 1, 2 and 3. However, neither maternal autonomy support nor general cognitive abilities was associated with time-specific mathematical achievement at the bivariate level. Family SES and maternal sensitivity, but not child sex nor prenatal risk, were related to all primary study variables.

3.2. Main analyses

3.2.1. Mathematical achievement growth curves

A random linear model (see Model B in Table 3) was the best-fitting unconditional model. An adjusted chi-square difference test using the models' log likelihood (LL) revealed that Model B was significantly better than Model A, $\chi^2(2) = 12.55$, $p = .002$. Model C was not retained as the quadratic term was not significant (see Table 3). The pseudo-R^2 revealed that child age explained 82% of the within-level variance in mathematical achievement scores. Model parameters revealed that mathematical achievement increased consistently over time. On average, children's mathematical achievement increased by 6.72 points per year (γ_{10}), starting with an average score of 18.92 (γ_{00}) in first grade. The covariance between the slope and intercept was not significant, which indicates that children who had better mathematical achievement in first grade did not show a faster or slower increase between first and third grades than those who had lower mathematical achievement at baseline. There was significant between-subjects variability around the intercept (σ_0^2), and marginally significant variability around the slope (σ_1^2).

Table 2
Correlations among main variables and covariates.

	1.	2.	3.	4.	5.	6.	7.	8.
1. General cognitive abilities	–							
2. Autonomy support	.24**	–						
3. Mathematical achievement G1	.11	.10	–					
4. Mathematical achievement G2	.14	.12	.75***	–				
5. Mathematical achievement G3	.15	.15	.63***	.68***	–			
6. Family SES	.30**	.23*	.31**	.32**	.34***	–		
7. Child sex[a]	−.02	−.09	−.12	−.11	−.15	−.04	–	
8. Prenatal risk	−.07	−.00	.04	.09	.15	.02	.06	–
9. Maternal sensitivity	.29**	.27**	.22*	.20*	−.04	.28**	.09	−.10

Notes. Results are based on the raw data set.
G1 = grade 1; G2 = grade 2; G3 = grade 3.
SES = socioeconomic status.
[a] Boys = 1, girls = 2.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

3.2.2. Autonomy support and general cognitive abilities as predictors of mathematical achievement

A preliminary conditional model assessed the effects of the potential covariates (i.e., child sex, family SES, prenatal risk, and maternal sensitivity) on mathematical achievement trajectory parameters (i.e., between-subjects variability in the intercept and the slope). This model revealed that maternal sensitivity was related to the intercept, $\gamma_{04} = 4.26$, $p = .01$, whereas family SES was related to the slope, $\gamma_{12} = 0.76$, $p = .02$. The other covariates were not related to the trajectory parameters. Therefore, only maternal sensitivity and family SES were retained as covariates, in the prediction of the mathematical achievement intercept and slope respectively, in the final model presented in Table 4. The pseudo-R^2 revealed that maternal sensitivity accounted for 5.7% of the between-subjects variance in mathematical achievement initial status and that family SES accounted for 11.3% of the between-subjects variance in rate of change.

The final model assessed the relations of the covariates (i.e., maternal sensitivity and family SES), maternal autonomy support, general cognitive abilities, and their interaction to mathematical achievement trajectory parameters (i.e., intercept and slope). In this model (see Table 4), the interaction term (autonomy support by general cognitive abilities) significantly predicted both the initial status (first grade mathematical achievement), $\gamma_{04} = -0.13$, $p < .01$, while accounting for maternal sensitivity, and the rate of change (i.e., mathematical development between first and third grade), $\gamma_{14} = 0.07$, $p < .01$, above and beyond family SES. As general cognitive abilities increased, the simple effect of autonomy support on mathematical achievement in first grade decreased, whereas its effect on the slope of mathematical achievement increased. The main variables (i.e., maternal autonomy support, general cognitive abilities and the interaction term) accounted for 8.8% of between-subjects variance in initial status and 25.2% of the between-subjects variance in the rate of change.

In order to break down these interactions, the moderator (general cognitive abilities) was recoded, such that the simple effect of maternal autonomy support represents its effect at one standard deviation above or below the mean of cognitive abilities (Hoffman, 2015). Among

Table 3
Growth models of mathematical achievement.

	Mathematical achievement (ICC = 0.19)			
	Par	Model A	Model B	Model C
Intercept-initial status (G1)	γ_{00}	18.94 (.53)***	18.92 (.54)***	18.28 (.79)***
Linear slope (yearly growth)	γ_{10}	6.69 (.28)***	6.72 (.28)***	7.72 (1.15)***
Change in slope (quadratic term)	γ_{20}			−.32 (.36)
Within-person variance (residual)	σ^2_E	8.63 (.91)***	6.96 (.92)***	6.86 (.91)***
Variance in initial status	σ^2_0	19.72 (3.65)***	16.84 (4.68)***	17.78 (5.13)**
Variance in rate of change	σ^2_1		2.47 (1.37)^{t}	2.52 (1.38)^{t}
Slope intercept covariance	σ_{01}		−.70 (1.99)	−1.02 (2.08)
Goodness-of-fit	LL	−895.91	−890.91	−890.53
	AIC	1799.82	1793.82	1795.06

Notes. Standard errors are within parentheses. G1 = grade 1; ICC = intraclass correlation; Par = parameters; LL = log likelihood; AIC = Akaike information criterion. Model A: fixed linear model; Model B: random linear model; Model C: fixed quadratic model.
^{t} $p < 0.10$.
** $p < .01$.
*** $p < .001$.

Table 4
Final model of predictors of growth in mathematical achievement.

	Par	Mathematical development
		B (SE)
Initial status, π_{0i}		
Intercept (G1)	γ_{00}	17.99*** (1.30)
Maternal sensitivity	γ_{01}	1.77 (1.78)
Autonomy support[a]	γ_{02}	.06 (0.3)
At low level of general cognitive abilities (−1 SD)	γ_{02}	1.37*(.56)
At high level of general cognitive abilities (+1 SD)	γ_{02}	−1.25 (.81)
General cognitive abilities	γ_{03}	−.05 (.05)
Autonomy support × general cognitive abilities	γ_{04}	−0.13** (.04)
Rate of change, π_{1i}		
Child age in months	γ_{10}	6.64*** (.27)
Family SES	γ_{11}	.91*** (.24)
Autonomy support[a]	γ_{12}	.34 (.27)
At low level of general cognitive abilities (−1 SD)	γ_{12}	−.42 (.29)
At high level of general cognitive abilities (+1 SD)	γ_{12}	1.10* (.45)
General cognitive abilities	γ_{13}	.00 (.03)
Autonomy support × general cognitive abilities	γ_{14}	.07** (.03)
Within-person variance (residual)	σ^2_E	7.00*** (.94)
Variance in initial status	σ^2_0	14.40 (4.55)**
Variance in rate of change	σ^2_1	1.57 (1.30)
Slope intercept covariance	σ_{01}	−.31 (1.89)
Goodness-of-fit	LL	−892.49
	AIC	1816.98

Notes. [a]Estimated at mean level of general cognitive abilities. G1 = grade 1; SE = Standard errors; SD = Standard deviation; Par = parameters; LL = log likelihood; AIC = Akaike information criterion; SES = socioeconomic status. All predictors are centered at their grandmean. Only covariates which were significantly related to the intercept or the slope of the mathematical achievement trajectory were retained in the final model.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

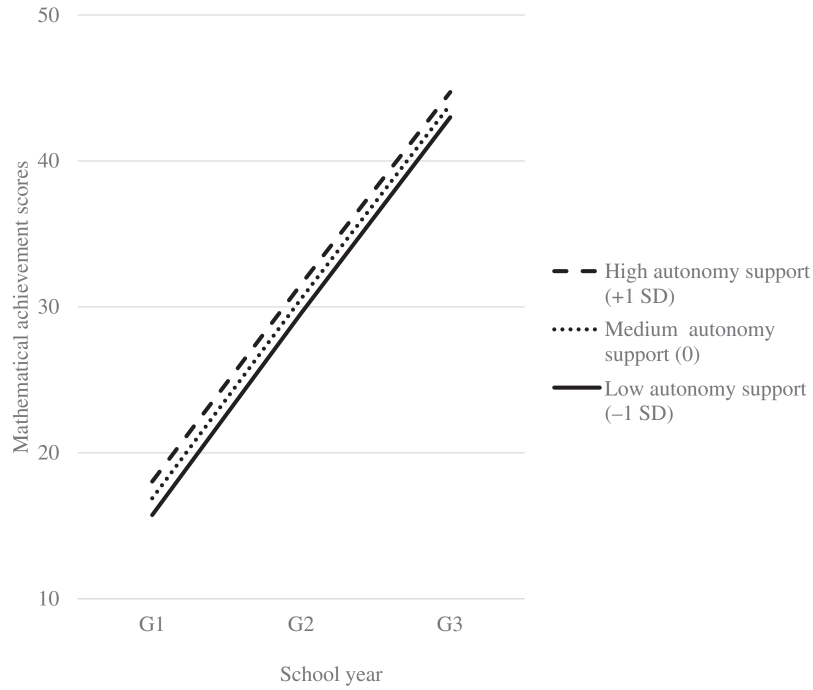
children with lower general cognitive abilities, maternal autonomy support was not related to the mathematical achievement rate of change, $p = .14$, but it predicted the initial status (i.e., mathematical achievement in first grade), $\gamma_{02} = 1.37$, $p = .015$, controlling for maternal sensitivity. These findings indicate that infants with relatively lower baseline cognitive abilities, but who had more autonomy supportive mothers, later showed better mathematics performance in first grade. On average, for each 1-unit increase in maternal autonomy support, children's mathematics scores in first grade increased by 1.37 points. However, they did not subsequently show faster, nor slower, growth across the first three years of school (see Fig. 1a). Hence, children with lower general cognitive abilities at 12 months had consistently (but not increasingly) higher mathematical achievement over time when they had more autonomy-supportive mothers.

In contrast, among children with higher initial cognitive abilities, maternal autonomy support was not associated with variability in the initial status (i.e., mathematical achievement in first grade), $p = .12$, but predicted a faster rate of change in mathematical achievement, $\gamma_{12} = 1.10$, $p = .01$, after accounting for family SES. For each 1-unit increase in maternal autonomy support, children's yearly mathematics growth was 1.10 points faster on average. These results suggest that among children with higher general cognitive abilities during infancy, those who also had more autonomy-supportive mothers did not demonstrate better mathematical achievement in first grade, but subsequently showed faster growth in mathematical achievement between the first and third grades (see Fig. 1b).

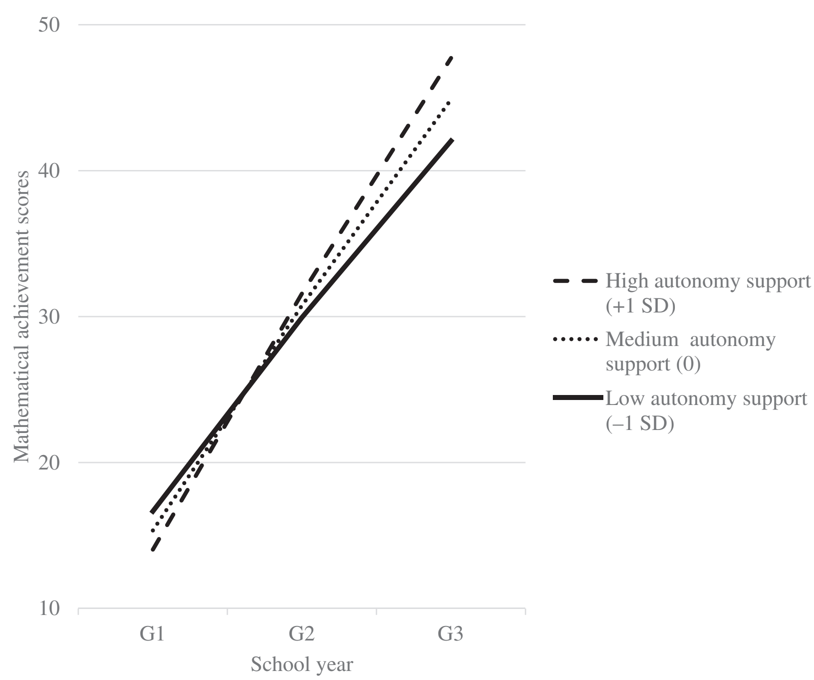
a) Associations between early maternal autonomy support and yearly growth in mathematical achievement among children with lower general cognitive abilities
b) Associations between early maternal autonomy support and yearly growth in mathematical achievement among children with higher general cognitive abilities

4. Discussion

Growth in mathematical achievement during the first years of formal schooling is a well-documented antecedent of long-term academic success (Watts et al., 2014). Hence, in order to promote school achievement and related positive outcomes, research should strive to identify the early antecedents of mathematical development. The main purpose of this study was to examine whether infant general cognitive abilities moderated the links between maternal autonomy support and patterns of growth in mathematical achievement during the first years of elementary school. Results showed that the effect of autonomy support on mathematical achievement manifests itself differently according to children's initial general cognitive abilities. Children with lower general cognitive abilities in infancy had better mathematical achievement in first grade when they had more autonomy-supportive mothers. However, these children's subsequent mathematics learning rate did not differ (i.e., was neither faster nor slower) from those who had less autonomy-supportive mothers. In contrast, children who had higher general cognitive abilities in infancy did not have better



a) Associations between early maternal autonomy support and yearly growth in mathematical achievement among children with lower general cognitive abilities



b) Associations between early maternal autonomy support and yearly growth in mathematical achievement among children with higher general cognitive abilities

Fig. 1. Yearly growth in mathematical achievement according to level of maternal autonomy support and general cognitive abilities in infancy.

mathematical achievement in first grade when they benefitted from more maternal autonomy support, but they displayed faster learning between the first and third years of elementary school.

This study builds on a growing body of work suggesting that parental autonomy support plays a role in children's school performance. Consistent with a recent meta-analysis conducted by Vasquez et al. (2016) which found that autonomy support is associated with better school outcomes, the current findings suggest that maternal autonomy support as early as infancy may have long-lasting effects on children's mathematical achievement, which are not due to the characteristics that maternal autonomy support shares with maternal sensitivity. Yet, those putative effects may unfold differently according to child basic cognitive abilities.

Among children with relatively lower general cognitive abilities, autonomy support was associated with mathematical achievement in first grade, although it was not related to learning curves between the first and third grades of formal schooling. These results are meaningful given that academic achievement, including mathematical achievement, is known to be fairly stable across time (Duncan et al., 2007; Morgan, Farkas, & Wu, 2009): children who have higher mathematical skills at school entry tend to perform better in mathematics several years later. In other words, early achievement is likely to set children on a relatively persistent trajectory. The current findings suggest that early autonomy support, before school entry, may promote the acquisition of pre-mathematical knowledge in children with lower cognitive abilities and in turn, better mathematical performance at school entry as observed here.

There are different ways in which maternal autonomy support may promote the acquisition of pre-mathematical knowledge in children. A first hypothesis is that autonomy-supportive parents may provide more hands-on numeracy experiences to their preschool children. In line with this hypothesis, collaborative parent-child interactions, which include parent-child discussions and entail involving the child while performing a task, are associated with higher frequency of home numeracy activities (Lukie, Skwarchuk, LeFevre, & Sowinski, 2013). Likewise, autonomy support includes collaboration by ensuring that the child plays an active role in the task and using verbally-supportive behaviors, and thus may also be associated with higher frequency of parent-child numeracy activities. Moreover, given that a key aspect of autonomy support is adaptation to the child's unique perspective, autonomy-supportive parents may be better equipped to note that their child with lower cognitive abilities needs assistance with numeracy, and hence be more inclined to provide not only a higher quantity of joint numeracy activities, but also more support during those activities. Overall, more autonomy-supportive mothers might provide more *and* higher-quality numeracy experiences. In turn, exposure to numeracy experiences during preschool years constitutes an opportunity factor, as these experiences are known to foster mathematical skills in children (Elliott & Bachman, 2018; Huntsinger, Jose, & Luo, 2016; LeFevre et al., 2009). Further studies are needed to investigate the hypothesis that more autonomy-supportive parents provide more and better guided numeracy activities to their preschool children, especially when children are more challenged with numeracy, thereby promoting their pre-mathematical knowledge and hence their mathematical achievement once they enter school.

Furthermore, the home learning environment during the preschool years provides a special opportunity for children to learn with adults in one-on-one contexts. The quality of adult behavior in such individualized learning contexts may be especially important for children with lower cognitive abilities. Indeed, in individualized (vs. group-based) learning contexts, the adult has ample opportunities to adapt his or her teaching style and methods to the individual child's level and needs, and such adaptation may be especially important for children who have a lesser natural ability to learn quickly. As autonomy support implies the ability to adapt flexibly to child individual competence and needs, it may unfold especially well in the individualized home learning environment during the preschool years. Thus, early maternal autonomy support may be particularly beneficial for pre-academic and early mathematical knowledge (i.e., Grade-1 achievement) among children who need more individualized teaching due to their lower baseline capacity to learn.

In contrast, the current findings suggest that among children who had relatively higher baseline cognitive abilities, autonomy support was not associated with initial mathematical achievement (Grade 1), yet it was associated with a steeper mathematical achievement trajectory (i.e., faster learning rate) between the first and third grades of elementary school. In children with higher cognitive abilities, autonomy-supportive mothers may promote growth in mathematical achievement indirectly, through provision of tools that children will carry forward and use once they reach school. By encouraging their preschool-aged children to participate and solve problems on their own, mothers may promote propensity factors that are related to children's willingness to learn (e.g., motivation, sense of competence). Relatedly, autonomy support is known to be associated with intrinsic motivation in children, which leads to more exploration and self-regulated learning (see Pino-Pasternak & Whitebread, 2010, for a review). Autonomy support is also related to perseverance and effort, which in turn, are associated with academic achievement and could develop as early as the preschool period (Vasquez et al., 2016). In sum, autonomy support may foster propensity factors in children with relatively higher cognitive abilities in infancy, who are prone to also have higher capacities for learning at school age. The combination of propensity factors such as motivation, perseverance and effort with higher baseline capacity to learn is likely conducive to school engagement and learning. Hence, the emotional and behavioral dispositions for learning that are facilitated by autonomy support might allow children to actualize their cognitive potential and gain more knowledge from the various opportunities to learn mathematics at school, thereby leading to steeper mathematical achievement trajectories during the first years of formal schooling.

In addition, parental autonomy support promotes internalization of rules and self-regulation in children (Joussemet, Landry, & Koestner, 2008; Meuwissen & Carlson, 2019), which can be considered as propensity factors as well (Byrnes & Miller, 2007). As school settings require children to sit calmly for extended periods, resist distraction, and follow specific rules, developing self-regulation and rule internalization during the preschool period could be especially beneficial for children when they reach school. These skills likely allow children with higher cognitive abilities to develop their learning potential and fully benefit from learning opportunities at school age, and thus show faster learning rates.

Although the lack of association between early maternal autonomy support and first-grade mathematical achievement among children with higher cognitive abilities was unexpected, these children may be more easily influenced by other factors in the acquisition of pre-academic knowledge (and thus academic achievement at school entry). For example, they may more easily benefit from other opportunities to learn outside of home (e.g., at daycare) than children with relatively lower cognitive abilities, regardless of their mothers' autonomy support, explaining the absence of relation between maternal autonomy support and first-grade mathematical achievement. Individualized contexts of learning may be less important for pre-mathematical knowledge acquisition in children with higher general cognitive abilities than their peers with lower abilities, because the former may need less guidance to learn and have greater natural learning capacities. In line with our findings, Ng et al. (2004) found that maternal autonomy support, albeit assessed at school age, was associated with school grades, yet only in low-achieving and average-achieving children. They did not find an association between maternal autonomy support and time-specific school grades among high-achieving children (growth in grades was not examined). Overall, further studies should investigate the mechanisms through which parental autonomy support may lay the groundwork for higher academic achievement in children with different capacities for learning.

It is noteworthy that early autonomy support and general cognitive abilities were not directly associated with later mathematical achievement in bivariate or multivariate analyses. Of course, the lack of significant main effects is partly due to the presence of interaction effects, which qualify main effects by definition. However, the non-significant main effects may also result from low statistical power. Children's learning rates had fairly low variability around the slope, increasing the difficulty to detect putative effects on individual differences in rates of change. The normative sample used in the present study may also play a role in the lack of main effects of maternal autonomy support and general cognitive abilities. The sample was comprised of middle-class, mostly White participants, and did not include children who displayed major school difficulties or developmental disorders, thus limiting the variability in mathematics achievement. Some previous studies found longitudinal links between both autonomy support and cognitive abilities and later mathematical achievement, but had large samples (e.g., Bindman et al., 2015; $N = 1306$), or focused on clinical samples (e.g., Johnson et al., 2011). Overall, the lack of significant main effects found in the current study may be due to both conceptual and methodological reasons. In fact, in the recent meta-analysis by Vasquez et al. (2016), the link between parental autonomy support and academic achievement weakened when only considering mathematical outcomes (although there were only four studies that focused on mathematics). One interesting possibility is that the modest meta-analytic relation between autonomy support and mathematical achievement may partly be due to the presence of undetected interaction effects, such as those found in the current study.

While standardized coefficients are not available in the statistical framework used here, the effects reported in the present study appear to be modest, but practically relevant. Indeed, a difference of only one point in the raw scores of the mathematics reasoning subtest of the WIAT-II can represent a clinically significant difference. For a child aged 6.5 years, the difference between a score of 19 points (i.e., the average Grade-1 score in mathematical achievement observed in the current study) and 20 points represents a 11% increase in terms of percentiles (Weschler, 2008). Considering the evidence suggesting that mathematical achievement during elementary school relates to a range of subsequent outcomes (e.g., Duncan et al., 2007; Watts et al., 2014), this increase is likely to be meaningful. Also, this study unfolded over nearly 6 years and the magnitude of the links between early maternal autonomy support and later mathematical achievement can be expected to fade as children mature. Nonetheless, developmental theory asserts that early factors with decreasing links to outcomes can have enduring effects on child development through indirect longitudinal mechanisms (i.e., developmental cascades; Masten & Cicchetti, 2010). Hence, even modest associations between parenting and child development in early childhood may snowball into substantial long-term consequences through transactional processes.

The modest effect sizes found in the present study may occur because maternal autonomy support is only part of a constellation of factors that influence mathematical achievement during elementary school. Conceivably, several factors can affect children's mathematical development and accumulate over time. Of paramount importance, the daycare and classroom environments, the teacher–student relationships, the concurrent level of maternal autonomy support, which may change between infancy and school years, and other aspects of mother–child relationships can influence the evolution of children's mathematical knowledge. Furthermore, as father autonomy support plays a role in children's school readiness and academic achievement (Meuwissen & Carlson, 2018; Vasquez et al., 2016), fathers most likely have unique contributions to their children's mathematical development, which we did not assess.

4.1. Strengths and limitations

The current study has several strengths, notably the prospective longitudinal design, the observational measure of autonomy support assessed in infancy and the repeated and standardized measures of mathematical achievement. This study is also among the first to examine early antecedents of the evolution of mathematical achievement over time. Furthermore, controlling for maternal sensitivity allowed us to examine the unique contribution of autonomy support, beyond the features that it shares with sensitivity, and thus increase the theoretical specificity of the results. However, this study is not without limits. The sample was comprised of White middle-class families, which precludes generalization, and the design was longitudinal yet non-experimental, thus causal inference cannot be drawn from the results. Moreover, adding other control variables could have contributed to increasing the robustness of the results. Arguably, the greatest limitation may be that we did not assess father autonomy support. Scholars have recently emphasized the need to consider father autonomy support in future studies (Hughes et al., 2018; Meuwissen & Carlson, 2015). Moreover, autonomy support was not measured at school age. Concurrent autonomy support most likely plays a role in mathematical performance during the early school years and thus may underlie the relation between early autonomy support and mathematical development. Untangling the effects of early and concurrent parental behavior is a difficult task, and this could not be achieved using the current study design. Finally, although we chose to use a standardized mathematical assessment to reduce the effects of idiosyncrasies between instructors and schools, it would have been interesting and perhaps more ecological to use end-of-year report cards.

4.2. Conclusion

In conclusion, the present study is the first to investigate the interactive processes between maternal autonomy support and child general cognitive abilities in relation to mathematical development in childhood. As maternal autonomy support can be effectively improved (Meuwissen & Carlson, 2019), early interventions focusing on parental autonomy support may have the potential to promote optimal mathematical achievement in children. Moreover, the potential benefits of autonomy support interventions reach beyond mathematical development and include need satisfaction, motivation, perseverance, well-being and other desirable outcomes (Joussemet et al., 2008; Vansteenkiste & Ryan, 2013; Vasquez et al., 2016). Quite interestingly, the putative effects of early caregiving experiences on academic achievement may diminish over time, but not disappear (Fraley et al., 2013). Accordingly, the early positive effects of maternal autonomy support may be carried forward by developmental cascades that unfold over the years (Masten et al., 2005).

Acknowledgments

We gratefully acknowledge Chantal Mongeau, Émilie Rochette, Natasha Ballen, Isabelle Demers, Natasha Whipple, Jessica Laranjo, Stéphanie Bordeleau, Véronique Jarry-Boileau, Marie Deschênes, Marie-Ève Bélanger, Andrée-Anne Bouvette-Turcot, Christine Gagné, Célia Matte-Gagné, Gabrielle Lalonde, Marie-Soleil Sirois, Rachel Perrier, Sarah Hertz, Élizabel Leblanc, Élodie Larose-Grégoire, Émilie Lemelin, Laurianne Bastien, Valexie Lafontaine, Camille Brideau-Marquis, Juliette Milner and Nadine Marzougui for help with data collection. Special thanks go to the participating families of the *Grandir Ensemble* project who generously opened their homes to us.

Funding

This work was supported by the Canadian Institutes of Health Research [MOP-119390], the Social Sciences and Humanities Research Council of Canada [410-2010-1366 & 435-2016-1396], and le Fonds de Recherche du Québec - Société et Culture [2012-RP-144923].

References

Ainsworth, M. D. S., Bell, S. M., & Stayton, D. J (1974). Infant–mother attachment and social development: "Socialization" as a product of reciprocal responsiveness to signals. In M. P. M. Richards (Ed.). *The integration of the child into a social world* (pp. 99–135). London, England: Cambridge University Press.

Bailey, D. H., Duncan, G. J., Watts, T., Clements, D. H., & Sarama, J. (2018). Risky business: Correlation and causation in longitudinal studies of skill development. *American Psychologist, 73*, 81–94. https://doi.org/10.1037/amp0000146.

Bayley, N. (1993). *Bayley scales of infant development* (2nd ed.). New York, NY: Psychological Corporation.

Bernier, A., Carlson, S. M., & Whipple, N. (2010). From external regulation to self-regulation: Early parenting precursors of young children's executive functioning. *Child*

Development, 81, 326–339. https://doi.org/10.1111/j.1467-8624.2009.01397.x.
Bernier, A., Matte-Gagné, C., Bélanger, M.-È., & Whipple, N. (2014). Taking stock of two decades of attachment transmission gap: Broadening the assessment of maternal behavior. *Child Development, 85*, 1852–1865. https://doi.org/10.1111/cdev.12236.
Bindman, S. W., Pomerantz, E. M., & Roisman, G. I. (2015). Do children's executive functions account for associations between early autonomy-supportive parenting and achievement through high school? *Journal of Educational Psychology, 107*, 756–770. https://doi.org/10.1037/edu0000017.supp.
Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33*, 205–228. https://doi.org/10.1080/87565640801982312.
Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives, 8*, 36–41. https://doi.org/10.1111/cdep.12059.
Burchinal, M. R., Nelson, L., & Poe, M. (2006). IV. Growth curve analysis: An introduction to various methods for analyzing longitudinal data. *Monographs of the Society for Research in Child Development, 71*, 65–87. https://doi.org/10.1111/j.1540-5834.2006.00405.x.
Byrnes, J. P., & Miller, D. C. (2007). The relative importance of predictors of math and science achievement: An opportunity–propensity analysis. *Contemporary Educational Psychology, 32*, 599–629. https://doi.org/10.1016/j.cedpsych.2006.09.002.
Byrnes, J. P., & Wasik, B. A. (2009). Factors predictive of mathematics achievement in kindergarten, first and third grades: An opportunity–propensity analysis. *Contemporary Educational Psychology, 34*, 167–183. https://doi.org/10.1016/j.cedpsych.2009.01.002.
Chen, B., Vansteenkiste, M., Beyers, W., Boone, L., Deci, E. L., Van der Kaap-Deeder, J., ... Verstuyf, J. (2015). Basic psychological need satisfaction, need frustration, and need strength across four cultures. *Motivation and Emotion, 39*, 216–236. https://doi.org/10.1007/s11031-014-9450-1.
Chirkov, V., Ryan, R. M., Kim, Y., & Kaplan, U. (2003). Differentiating autonomy from individualism and independence: A self-determination theory perspective on internalization of cultural orientations and well-being. *Journal of Personality and Social Psychology, 84*, 97–110. https://doi.org/10.1037/0022-3514.84.1.97.
Chirkov, V. I. (2009). A cross-cultural analysis of autonomy in education. *Theory and Research in Education, 7*, 253–262. https://doi.org/10.1177/1477878509104330.
Cirelli, I., Graz, M. B., & Tolsa, J. F. (2015). Comparison of Griffiths-II and Bayley-II tests for the developmental assessment of high-risk infants. *Infant Behavior and Development, 41*, 17–25. https://doi.org/10.1016/j.infbeh.2015.06.004.
Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to non-normality and specification error in confirmatory factor analysis. *Psychological Methods, 1*, 16–29. https://doi.org/10.1037/1082-989X.1.1.16.
Davidov, M., Knafo-Noam, A., Serbin, L. A., & Moss, E. (2015). The influential child: How children affect their environment and influence their own risk and resilience. *Development and Psychopathology, 27*, 947–951. https://doi.org/10.1017/S0954579415000619.
Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 37–41. https://doi.org/10.1207/S15327965PLI1104.
Distefano, R., Galinsky, E., McClelland, M. M., Zelazo, P. D., & Carlson, S. M. (2018). Autonomy-supportive parenting and associations with child and parent executive function. *Journal of Applied Developmental Psychology, 58*, 77–85. https://doi.org/10.1016/j.appdev.2018.04.007.
Doll, J. J., Eslami, Z., & Walters, L. (2013). Understanding why students drop out of high school, according to their own reports: Are they pushed or pulled, or do they fall out? A comparative analysis of seven nationally representative studies. *SAGE Open, 3*, 1–15. https://doi.org/10.1177/2158244013503834.
Dos Santos, E. S. L., de Kieviet, J. F., Van Elburg, R. M., & Oosterlaan, J. (2013). Predictive value of the Bayley scales of infant development on development of very preterm/very low birth weight children: A meta-analysis. *Early Human Development, 89*, 487–496. https://doi.org/10.1016/j.earlhumdev.2013.03.008.
Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., ... Duckworth, K. (2007). School readiness and later achievement. *Developmental Psychology, 43*, 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428.
Elliott, L., & Bachman, H. J. (2018). How do parents foster young children's math skills? *Child Development Perspectives, 12*, 16–21. https://doi.org/10.1111/cdep.12249.
Enders, C. K. (2010). *Applied missing data analysis.* New York, NY: Guilford Press.
Entwisle, D. R., Alexander, K. L., & Olson, L. S. (2005). First grade and educational attainment by age 22: A new story. *American Journal of Sociology, 110*, 1458–1502. https://doi.org/10.1086/428444.
Fernald, L. C., Kariger, P., Engle, P., & Raikes, A. (2009). *Examining early child development in low-income countries: A toolkit for the assessment of children in the first five years of life.* Washington: DC: The World Bank. Retrieved at http://siteresources.worldbank.org/INTCY/Resources/395766-1187899515414/Examining_ECD_Toolkit_FULL.pdf.
Fernandes, M., Stein, A., Newton, C. R., Cheikh-Ismail, L., Kihara, M., Wulff, K., ... Ibanez, D. (2014). The INTERGROWTH-21st project neurodevelopment package: A novel method for the multi-dimensional assessment of neurodevelopment in pre-school age children. *PLoS One, 9*, e113360. https://doi.org/10.1371/journal.pone.0113360.
Ferrand, C., Martinent, G., & Durmaz, N. (2014). Psychological need satisfaction and well-being in adults aged 80 years and older living in residential homes: Using a self-determination theory perspective. *Journal of Aging Studies, 30*, 104–111. https://doi.org/10.1016/j.jaging.2014.04.004.
Fraley, R. C., Roisman, G. I., & Haltigan, J. D. (2013). The legacy of early experiences in development: Formalizing alternative models of how early experiences are carried forward over time. *Developmental Psychology, 49*, 109–126. https://doi.org/10.1037/a0027852.
Frongillo, E. A., Tofail, F., Hamadani, J. D., Warren, A. M., & Mehrin, S. F. (2014). Measures and indicators for assessing impact of interventions integrating nutrition, health, and early childhood development. *Annals of the New York Academy of Sciences, 1308*, 68–88. https://doi.org/10.1111/nyas.12319.
Fryer, R., & Levitt, S. (2010). An empirical analysis of the gender gap in mathematics. *American Economic Journal: Applied Economics, 2*, 210–240. https://doi.org/10.1257/app.2.2.210.
Geary, D. C. (2011). Cognitive predictors of achievement growth in mathematics: A 5-year longitudinal study. *Developmental Psychology, 47*, 1539–1552. https://doi.org/10.1037/a0025510.
Geary, D. C., Bailey, D. H., Littlefield, A., Wood, P., Hoard, M. K., & Nugent, L. (2009). First-grade predictors of mathematical learning disability: A latent class trajectory analysis. *Cognitive Development, 24*, 411–429. https://doi.org/10.1016/j.cogdev.2009.10.001.
Geary, D. C., Hoard, M. K., Byrd-Craven, J., Nugent, L., & Numtee, C. (2007). Cognitive mechanisms underlying achievement deficits in children with mathematical learning disability. *Child Development, 78*, 1343–1359. https://doi.org/10.1111/j.1467-8624.2007.01069.x.
Glass, L., Moore, E. M., Akshoomoff, N., Jones, K. L., Riley, E. P., & Mattson, S. N. (2017). Academic difficulties in children with prenatal alcohol exposure: Presence, profile, and neural correlates. *Alcoholism: Clinical and Experimental Research, 41*, 1024–1034. https://doi.org/10.1111/acer.13366.
Grimm, K. J., Ram, N., & Estabrook, R. (2017). *Growth modeling: Structural equation and multilevel modeling approaches.* New York, NY: Guilford Press.
Grolnick, W. S., & Ryan, R. M. (1989). Parent styles associated with children's self-regulation and competence in school. *Journal of Educational Psychology, 81*, 143–154. https://doi.org/10.1037/0022-0663.81.2.143.
Gutman, L. M., Sameroff, A. J., & Cole, R. (2003). Academic growth curve trajectories from 1st grade to 12th grade: Effects of multiple social risk factors and preschool child factors. *Developmental Psychology, 39*, 777–790. https://doi.org/10.1037/0012-1649.39.4.777.
Heck, R. H., & Thomas, S. L. (2015). *An introduction to multilevel modeling techniques: MLM and SEM approaches using Mplus.* New York, NY: Routledge.
Henry, K. L., Knight, K. E., & Thornberry, T. P. (2012). School disengagement as a predictor of dropout, delinquency, and problem substance use during adolescence and early adulthood. *Journal of Youth and Adolescence, 41*, 156–166. https://doi.org/10.1007/s10964-011-9665-3.
Hoffman, L. (2015). *Longitudinal analysis: Modeling within-person fluctuation and change.* New York, NY: Routledge.
Hox, J., & Van de Schoot, R. (2013). Robust methods for multilevel analysis. In M. A. Scott, J. S. Simonoff, & B. D. Marx (Eds.). *The SAGE handbook of multilevel modeling* (pp. 387–402). London, UK: SAGE Publications.
Hughes, C., Lindberg, A., & Devine, R. T. (2018). Autonomy support in toddlerhood: Similarities and contrasts between mothers and fathers. *Journal of Family Psychology, 32*, 915–925. https://doi.org/10.1037/fam0000450.
Huntley, M. (1996). *The Griffiths mental developmental scales manual from birth to two years.* Oxford, UK: The Test Agency.
Huntsinger, C. S., Jose, P. E., & Luo, Z. (2016). Parental facilitation of early mathematics and reading skills and knowledge through encouragement of home-based activities. *Early Childhood Research Quarterly, 37*, 1–15. https://doi.org/10.1016/j.ecresq.2016.02.005.
Johnson, S., Wolke, D., Hennessy, E., & Marlow, N. (2011). Educational outcomes in extremely preterm children: Neuropsychological correlates and predictors of attainment. *Developmental Neuropsychology, 36*, 74–95. https://doi.org/10.1080/87565641.2011.540541.
Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology, 45*, 850–867. https://doi.org/10.1037/a0014939.
Joussemet, M., Koestner, R., Lekes, N., & Landry, R. (2005). A longitudinal study of the relationship of maternal autonomy support to children's adjustment and achievement in school. *Journal of Personality, 73*, 1215–1236. https://doi.org/10.1111/j.1467-6494.2005.00347.x.
Joussemet, M., Landry, R., & Koestner, R. (2008). A self-determination theory perspective on parenting. *Canadian Psychology/Psychologie Canadienne, 49*, 194–200. https://doi.org/10.1037/a0012754.
Kline, R. B. (2011). *Principles and practice of structural equation modeling* (3rd ed.). New York, NY: The Guilford Press.
Knee, C. R., & Uysal, A. (2011). The role of autonomy in promoting healthy dyadic, familial, and parenting relationships across cultures. In V. I. Chirkov, R. M. Ryan, & K. M. Sheldon (Eds.). *Cross-cultural advancements in positive psychology: Vol. 1. Human autonomy in cross-cultural context: Perspectives on the psychology of agency, freedom, and well-being* (pp. 95–110). Dordrecht, Netherlands: Springer. https://doi.org/10.1007/978-90-481-9667-8_5.
Koestner, R., Ryan, R. M., Bernieri, F., & Holt, K. (1984). Setting limits on children's behavior: The differential effects of controlling vs. informational styles on intrinsic motivation and creativity. *Journal of Personality, 52*(3), 233–248. https://doi.org/10.1111/j.1467-6494.1984.tb00879.x.
Kristjansson, A. L., Thomas, S., Lilly, C. L., Thorisdottir, I. E., Allegrante, J. P., & Sigfusdottir, I. D. (2018). Maternal smoking during pregnancy and academic achievement of offspring over time: A registry data-based cohort study. *Preventive Medicine, 113*, 74–79. https://doi.org/10.1016/j.ypmed.2018.05.017.
LeFevre, J. A., Skwarchuk, S. L., Fast, L., Smith-Chant, B., Kamawar, D., & Bisanz, J. (2009). Home numeracy experiences and children's math performance in the early school years. *Canadian Journal of Behaviorial Science, 41*, 55–66. https://doi.org/10.1037/a0014532.
Lindberg, S. M., Hyde, J. S., Petersen, J. L., & Linn, M. C. (2010). New trends in gender and mathematics performance: A meta-analysis. *Psychological Bulletin, 136*,

1123–1135. https://doi.org/10.1037/a0021276.

Little, T. (2013). *Longitudinal structural equation modeling.* New York, NY: The Guilford Press.

Liu, M., Chen, X., Rubin, K., Zheng, S., Cui, L., Li, D., ... Wang, L. (2005). Autonomy- vs. connectedness-oriented parenting behaviours in Chinese and Canadian mothers. *International Journal of Behavioral Development, 29*, 489–495. https://doi.org/10.1080/01650250500147063.

Lowe, J. R., Erickson, S. J., Schrader, R., & Duncan, A. F. (2012). Comparison of the Bayley II Mental Developmental Index and the Bayley III cognitive scale: Are we measuring the same thing?: Comparison of the Bayley Scales. *Acta Paediatrica, 101*, e55–e58. https://doi.org/10.1111/j.1651-2227.2011.02517.x.

Lukie, I. K., Skwarchuk, S.-L., LeFevre, J.-A., & Sowinski, C. (2013). The role of child interests and collaborative parent–child interactions in fostering numeracy and literacy development in Canadian homes. *Early Childhood Education Journal, 42*, 251–259. https://doi.org/10.1007/s10643-013-0604-7.

Maas, C. J. M., & Hox, J. J. (2005). Sufficient sample sizes for multilevel modeling. *Methodology European Journal of Research Methods for the Behavioral and Social Sciences, 1*, 86–92. https://doi.org/10.1027/1614-2241.1.3.86.

Mageau, G. A., Ranger, F., Joussemet, M., Koestner, R., Moreau, E., & Forest, J. (2015). Validation of the perceived parental autonomy support scale (P-PASS). *Canadian Journal of Behavioural Science, 47*, 251–262. https://doi.org/10.1037/a0039325.

Masten, A. S., & Cicchetti, D. (2010). Developmental cascades. *Development and Psychopathology, 22*, 491–495. https://doi.org/10.1017/S0954579410000222.

Masten, A. S., Roisman, G. I., Long, J. D., Burt, K. B., Obradović, J., Riley, J. R., ... Tellegen, A. (2005). Developmental cascades: Linking academic achievement and externalizing and internalizing symptoms over 20 years. *Developmental Psychology, 41*, 733–746. https://doi.org/10.1037/0012-1649.41.5.733.

Mattanah, J. F., Pratt, M. W., Cowan, P. A., & Cowan, C. P. (2005). Authoritative parenting, parental scaffolding of long-division mathematics, and children's academic competence in fourth grade. *Journal of Applied Developmental Psychology, 26*, 85–106. https://doi.org/10.1016/j.appdev.2004.10.007.

Meuwissen, A. S., & Carlson, S. M. (2015). Fathers matter: The role of father parenting in preschoolers' executive function development. *Journal of Experimental Child Psychology, 140*, 1–15. https://doi.org/10.1016/j.jecp.2015.06.010.

Meuwissen, A. S., & Carlson, S. M. (2018). The role of father parenting in children's school readiness: A longitudinal follow-up. *Journal of Family Psychology, 32*, 588–598. https://doi.org/10.1037/fam0000418.

Meuwissen, A. S., & Carlson, S. M. (2019). An experimental study of the effects of autonomy support on preschoolers' self-regulation. *Journal of Applied Developmental Psychology, 60*, 11–23. https://doi.org/10.1016/j.appdev.2018.10.001.

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. *Educational Researcher, 45*, 18–35. https://doi.org/10.3102/0013189X16633182.

Morgan, P. L., Farkas, G., & Wu, Q. (2009). Five-year growth trajectories of kindergarten children with learning difficulties in mathematics. *Journal of Learning Disabilities, 42*, 306–321. https://doi.org/10.1177/0022219408331037.

Morrison, E. F., Rimm-Kauffman, S., & Pianta, R. C. (2003). A longitudinal study of mother-child interactions at school entry and social and academic outcomes in middle school. *Journal of School Psychology, 41*, 185–200. https://doi.org/10.1016/S0022-4405(03)00044-X.

Muthén, L. K., & Muthén, B. O. (2012). *Mplus user's guide* (7th ed.). Los Angeles, CA: Authors.

National Institute of Child Health and Human Development Early Child Care Research Network (2008). Mothers' and fathers' support for child autonomy and early school achievement. *Developmental Psychology, 44*, 895–907. https://doi.org/10.1037/0012-1649.44.4.895.

Ng, F. F.-Y., Kenney-Benson, G. A., & Pomerantz, E. M. (2004). Children's achievement moderates the effects of mothers' use of control and autonomy support. *Child Development, 75*, 764–780. https://doi.org/10.1111/j.1467-8624.2004.00705.x.

Pederson, D. R., & Moran, G. (1995). A categorical description of infant–mother relationships in the home and its relation to Q-sort measures of infant–mother interaction. *Monographs of the Society for Research in Child Development, 60*, 111–132. https://doi.org/10.1111/j.1540-5834.1995.tb00207.x.

Peng, P., Wang, T., Wang, C., & Lin, X. (2019). A meta-analysis on the relation between fluid intelligence and reading/mathematics: Effects of tasks, age, and social economics status. *Psychological Bulletin, 145*, 189–236. https://doi.org/10.1037/bul0000182.

Pianta, R. C., Belsky, J., Vandergrift, N., Houts, R., & Morrison, F. J. (2008). Classroom effects on children's achievement trajectories in elementary school. *American Educational Research Journal, 45*, 365–397. https://doi.org/10.3102/0002831207308230.

Pino-Pasternak, D., & Whitebread, D. (2010). The role of parenting in children's self-regulated learning. *Educational Research Review, 5*, 220–242. https://doi.org/10.1016/j.edurev.2010.07.001.

Pomerantz, E. M., & Grolnick, W. S. (2017). The role of parenting in children's motivation and competence: What underlies facilitative parenting? In A. J. Elliot, C. S. Dweck, & D. S. Yeager (Eds.). *Handbook of competence and motivation: Theory and application* (pp. 566–585). New York, NY: Guilford Press.

Primi, R., Ferrão, M. E., & Almeida, L. S. (2010). Fluid intelligence as a predictor of learning: A longitudinal multilevel approach applied to math. *Learning and Individual Differences, 20*, 446–451. https://doi.org/10.1016/j.lindif.2010.05.001.

Raby, K. L., Roisman, G. I., Fraley, R. C., & Simpson, J. A. (2015). The enduring predictive significance of early maternal sensitivity: Social and academic competence through age 32 years. *Child Development, 86*, 695–708. https://doi.org/10.1111/cdev.12325.

Reis, S. M., & McCoach, D. B. (2000). The underachievement of gifted students: What do we know and where do we go? *The Gifted Child Quarterly, 44*, 152–170. https://doi.org/10.1177/001698620004400302.

Reyna, V. F., & Brainerd, C. J. (2007). The importance of mathematics in health and human judgment: Numeracy, risk communication, and medical decision making. *Learning and Individual Differences, 17*(2), 147–159. https://doi.org/10.1016/j.lindif.2007.03.010.

Ryan, R., & Deci, E. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *The American Psychologist, 55*, 68–78. https://doi.org/10.1037/0003-066X.55.1.68.

Ryan, R. M., Deci, E. L., Grolnick, W. S., & La Guardia, J. G. (2006). The significance of autonomy and autonomy support in psychological development and psychopathology. In D. Cicchetti, & D. J. Cohen (Vol. Eds.), *Developmental psychopathology: Theory and method. Vol 1. Developmental psychopathology: Theory and method* (pp. 795–849). Hoboken, NJ: John Wiley & Sons, Inc.

Singer, J. D., & Willett, J. B. (2003). *Applied longitudinal data analysis: Modeling change and event occurrence.* New York, NY: Oxford University Press.

Skwarchuk, S.-L., Sowinski, C., & LeFevre, J.-A. (2014). Formal and informal home learning activities in relation to children's early numeracy and literacy skills: The development of a home numeracy model. *Journal of Experimental Child Psychology, 121*, 63–84. https://doi.org/10.1016/j.jecp.2013.11.006.

Soenens, B., Vansteenkiste, M., Lens, W., Luyckx, K., Goossens, L., Beyers, W., & Ryan, R. M. (2007). Conceptualizing parental autonomy support: Adolescent perceptions of promotion of independence versus promotion of volitional functioning. *Developmental Psychology, 43*, 633–646. https://doi.org/10.1037/0012-1649.43.3.633.

Sorariutta, A., Hannula-Sormunen, M. M., & Silvén, M. (2017). Maternal sensitivity in responding during play and children's pre-mathematical skills: A longitudinal study from infancy to preschool age. *European Journal of Developmental Psychology, 14*, 1–15. https://doi.org/10.1080/17405629.2016.1140641.

Sorariutta, A., & Silvén, M. (2017). Maternal cognitive guidance and early education and care as precursors of mathematical development at preschool age and in ninth grade. *Infant and Child Development, 27*, e2069. https://doi.org/10.1002/icd.2069.

Starnberg, J., Norman, M., Westrup, B., Domellöf, M., & Berglund, S. K. (2018). Lower cognitive test scores at age 7 in children born with marginally low birth weight. *Pediatric Research, 83*, 1129–1135. https://doi.org/10.1038/pr.2018.35.

Sameroff, A. (2010). A unified theory of development: A dialectic integration of nature and nurture. *Child Development, 81*(1), 6–22. https://doi.org/10.1111/j.1467-8624.2009.01378.x.

Steele, H., & Steele, M. (2018). *Handbook of attachment-based interventions.* New York, NY: Guilford Press.

Tomasik, M. J., Napolitano, C. M., & Moser, U. (2018). Trajectories of academic performance across compulsory schooling and thriving in young adulthood. *Child Development.* https://doi.org/10.1111/cdev.13150 Advanced online publication.

Vansteenkiste, M., & Ryan, R. M. (2013). On psychological growth and vulnerability: Basic psychological need satisfaction and need frustration as a unifying principle. *Journal of Psychotherapy Integration, 23*, 263–280. https://doi.org/10.1037/a0032359.

Vasquez, A. C., Patall, E. A., Fong, C. J., Corrigan, A. S., & Pine, L. (2016). Parent autonomy support, academic achievement, and psychosocial functioning: A meta-analysis of research. *Educational Psychology Review, 28*, 605–644. https://doi.org/10.1007/s10648-015-9329-z.

Véronneau, M., Koestner, R. F., & Abela, J. R. Z. (2005). Intrinsic need satisfaction and well–being in children and adolescents: An application of the self–determination theory. *Journal of Social and Clinical Psychology, 24*, 280–292. https://doi.org/10.1521/jscp.24.2.280.62277.

Watts, T. W., Duncan, G. J., Siegler, R. S., & Davis-Kean, P. E. (2014). What's past is prologue: Relations between early mathematics knowledge and high school achievement. *Educational Researcher, 43*, 352–360. https://doi.org/10.3102/0013189X14553660.

Weschler, D. (2005). *Test de rendement individuel de Wechsler, 2e édition pour francophones du Canada.* Toronto, CA: Pearson Canada Assessment Inc.

Weschler, D. (2008). *WIAT-II test de rendement individuel de Wechsler: Manuel de normes québécoises* (2e éd). Toronto, CA: Pearson Canada Assessment Inc.

Whipple, N., Bernier, A., & Mageau, G. A. (2011). A dimensional approach to maternal attachment state of mind: Relations to maternal sensitivity and maternal autonomy support. *Developmental Psychology, 47*, 396–403. https://doi.org/10.1037/a0021310.