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Academic achievement trajectories and risk factors during early childhood*

Laëtitia Lebihan[†], *Charles-Olivier Mao Takongmo*[‡]

Résumé/abstract

This study aims to: i) model the mathematical abilities trajectories of Canadian children from 7 to 15 years and ii) identify risk factors during early childhood for low math skills trajectories. Using a group-based trajectory approach, we identify three groups of children with distinct mathematical abilities trajectories: average abilities (47.6%), high abilities (30.1%), and low abilities (22.3%). The differences between the groups are increasing over time, especially in early adolescence. Multivariate logistic regressions indicate that the children at risk are those who have a mother with a low level of education, low cognitive score at age 4-5, and have parents with poor parenting skills.

Mots clés/keywords : achievement trajectories; mathematical abilities; group-based trajectory modeling; risk factors

* The analysis is based on Statistics Canada's National Longitudinal Survey of Children and Youth restricted-access Micro Data Files. It was conducted at the Quebec Interuniversity Centre for Social Statistics, which is part of the Canadian Research Data Centre Network (CRDCN). The views expressed in this paper are those of the authors, and not necessarily those of the CRDCN or its partners.

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Introduction

A vast volume of literature exists on the importance of skills in early childhood for academic success and future outcomes, such as employment and wages (Card, 1999; Green and Riddell, 2003; Heckman, 2006). In particular, math skills have greater long-term positive effects on future wages compared to other cognitive outcomes, such as reading or vocabulary (Rivera-Batiz, 1992; Murnane et al., 1995; Rose and Betts 2004). Similarly, despite the fact that adults are proficient in reading, it is shown that they are still more likely to be unemployed (and/or less likely to be promoted if they are employed) if they are not qualified in mathematics (Bynner and Parsons, 1997). Several studies of early intervention programs also demonstrate the importance of the child's environment in predicting future outcomes, based on family characteristics and personal characteristics of the child (behavior, adaptive capacities, etc). For these reasons, the abilities that a child possesses at the beginning of the school might result in different achievement behaviors later (Duncan et al., 2007). The present study identifies the mathematics achievement trajectories from 7 to 15 years and the risk factors associated with low math skills trajectories during early childhood.

Many studies report the existence of distinct academic achievement trajectories for children (Caro et al., 2009; Herbers et al., 2012). An implicit assumption in the identification of heterogeneity in a population is that a group of individuals who follow an atypical developmental trajectory also have specific risk factors. Thus, some child characteristics such as behaviour or cognitive abilities when entering school (Duncan et al., 2007) may have a negative effect on his math achievement and his development in general. Children living in low-income households (Jordan et al., 2006) or have a young mother at birth (Corcoran, 1998; Dahinten et al., 2007) may also have lower math scores. Similarly, living in a family environment of poor quality may also affect the child's cognitive development (Todd and Wolpin 2003, 2007).

The majority of Canadian studies on math achievement trajectories focus on a specific risk factor, such as the effect of early motherhood (Dahinten et al., 2007) or socio-economic status of parents (Caro et al., 2009). In this paper, we use a greater number of risk factors from early childhood and study both the cognitive scores and behavior of the child, the family characteristics, etc. In fact, it is shown that certain periods are more critical than others in a child's cognitive development: acting as soon as possible, particularly during early childhood, is essential in order to limit some factors that may be harmful to the child (Shore, 1997). Being able to identify different groups of individuals and the risk factors associated with each group is essential in understanding how to respond politically. We can then target public interventions to specific groups so that the children can advance in their math capabilities, ultimately reducing potential gaps amongst individuals. Indeed, several experimental studies show that high quality programs for at-risk preschool children have generated cognitive and academic gains and reduced behavioral problems (Karoly et al., 2005). These early intervention programs also have long-term benefits, such as reductions in the rates of grade retention and drop outs (Reynolds and Temple, 1998; Campbell et al., 2002).

Thus, our objective is twofold. Firstly, we identify subgroups of children with distinct math achievement trajectories using a group-based trajectory approach. Unlike previous studies which are based on arbitrary criteria to distinguish the performance of groups, our method allows for this endogenously (Côté et al., 2002). The group-based approach assumes that the population is composed of several trajectory groups, each defined by a polynomial function of age or time variance. It thus allows us to detect differences in individual trajectories and to subsequently classify them in distinct subgroups. Secondly, we model links between risk factors during early childhood and math skills trajectories using multinomial logistic regressions. In particular, we study the most atypical cases by examining the contribution of: i) child characteristics (sex, behavior, and cognitive test); ii) family characteristics (low maternal education, insufficient household income, single parents, early motherhood, presence of siblings in the household) and iii) parenting practices. Risk factors are measured when the child is between 4 and 7 years, and math achievement from 7 to 15 years. We use data from the National Longitudinal Survey of Children and Youth (NLSCY), which constitute a representative sample of the Canadian population.

Methodology

We use a semi-parametric group-based approach implemented in Proc Traj within Stata (Nagin, 2005; Jones and Nagin, 2013). This approach provides a flexible and easy way to identify distinct groups of individual trajectories within the population and to profile the characteristics of those individuals within groups. We proceed in two steps.

First, we identify the appropriate number of groups and their associated trajectories. We use a polynomial equation to capture the relationship between age and math outcomes. More precisely, math outcomes depend on a polynomial function of an individual's age at time t and membership in one of the K groups. The parameter vector β_k determines the slope of the specific trajectory group k, thus allowing each group’s trajectory to be shaped differently. Selecting of the number of trajectory groups that best fit the data is based on maximizing the Bayesian Information Criterion (BIC). We select the model with the highest BIC value. Three key elements of the model are then estimated. The first is the slope of each trajectory group. The second is the proportion of individuals belonging to each trajectory group. Finally, regarding the third element, the model provides, for each subject, the probability of belonging to each trajectory group, and then assigns trajectory group based on the highest probability. Probabilities greater than or equal to 0.7-0.8 for the group assigned to each individual is considered a good fit.

Second, conditional on this model, time-stable covariates (risk factors) are inserted into the model by assuming they influence the probability of belonging to a particular group.

Data

The National Longitudinal Survey Children and Youth (NLSCY) is a long-term survey designed to provide information about the development and well-being of Canadian children and youths. This survey has been conducted every two years. It started in 1994-95 (wave 1) and ended in 2008-09 (wave 8). Given the complex sampling design of the NLSCY, all estimates are performed using the sample weights provided by Statistics Canada (longitudinal weight of wave 8 used).

Measure of mathematical achievement

The CAT/2 mathematic test, available in NLSCY data, measures skills in mathematics of school age children. The CAT/2 test is a shorter version of the Mathematics Computation Test taken from the Canadian Achievement Tests, 2nd edition. The math test consists of 20 calculation questions and they measure the ability of the student to perform addition, subtraction, multiplication, and division of whole numbers, decimals, fractions, negatives, and exponents. Solving problems involving percentages and the order of operations are also evaluated. The test is administrated to children 7 to 15 years enrolled in grades 2 to 10. The test levels (2 to 10) vary with the school grade of the child. For example, grade 2 children (aged 7) were given the level 2 test, grade 3 children (aged 8 years) were given the test 3 level, and so on. All children who have passed the math test were awarded a raw score and a standardized score. The raw score is simply the number of correct answers to the test. The standardized score is calculated according to the standards set in 1992 by the Canadian Test Centre (CTC). We use the standardized scores because they represent the mathematical level that the child has reached, which allows us to track the mathematical progress of a child through the years.

Math scores are used only during the last five waves (waves 4-8). In fact, in 1994-95, during the first wave, a high proportion of children obtained perfect scores, making it impossible to distinguish the true top performers from the others. Subsequently, because of this ceiling effect, the difficulty level of the tests was adjusted in 1996-1997 (wave 2). Nevertheless, during waves 2 and 3, the test was administered by the students' teacher, leading to low response rate (74% in 1996-97 and 54% in 1998-99). Statistics Canada has decided that from the year 2000 (wave 4), the math test would be administered at home by the interviewer rather than at school, and almost all eligible students (about 90%) responded. Therefore, we select children between 6 and 9 years in wave 4 (2000-2001) with at least four and up to five math scores.

Table 1 shows the descriptive statistics of the standardized math scores (mean, standard deviation, number of individuals). These statistics are classified by wave and age of the child.

Risk factors

Risk factors are measured during early childhood (0-7 years) and extended over the first three waves of the NLSCY. The characteristics of early childhood are divided into three categories: i) child characteristics, ii) family characteristics, and iii) parental characteristics. All the risk factors are binary, with a score of 1 if the risk factor is present and can have a negative impact on child cognitive development and 0 otherwise. For continuous scales, unless specified, a score of 1 is assigned for the scores equal to or above the 75th percentile of the distribution and 0 if below.

Child characteristics

First, the sex of the child was coded as 0 for boys and 1 for girls. This variable is measured in wave 3. Second, the child's PPVT (Peabody Picture Vocabulary Test) score is also measured. This is a vocabulary test where the child observed pictures on an easel and identified the picture that matched the word the interviewer read out. We use the standardized PPVT-R test to reflect the age of the child, as opposed to the raw score based only on the number of correct answers. Evidence suggests the PPVT to be a good predictor of reading and writing abilities and consequently, the child's academic success (Hoddinott, Lethbridge and Phipps, 2002). It also allows us to observe whether early vocabulary skills are related to future math skills. Indeed, several studies show a significant link between the PPVT score and future cognitive outcomes (Romano et al., 2010; Baker, 2011). The PPVT score is a standardized score with a mean of 100 and a standard deviation of 15. We were coded 1 for children with low PPVT score (less than 85) and 0 otherwise. Due to the fact that the test is administrated when the child is 4-5 years old, we use the waves 2 and 3 to be able to capture it. Third, behavioral scores available in the NLSCY measure the social and emotional development of children aged 4 to 11 years based on the frequency of events related to the behavior of the child. The following scores are used: i) hyperactivity / inattention (score ranging from 0 to 16), ii) physical aggression and tendency to conduct problems (score ranging from 0 to 12), and iii) indirect aggression (score ranging from 0 to 10). Evidence shows that non-cognitive skills (social and behavioral skills) are significant in predicting future outcomes, such as employment and wages (Carneiro, Crawford and Goodman, 2007). It is natural to expect that they also affect cognitive development. Socio-emotional abilities of the child can affect individual learning and classroom dynamics. Socio-emotional or behavioral problems can generate child-teacher conflicts and social exclusion, which may reduce the child's participation in educational activities and consequently affect academic achievement (Duncan et al., 2007). We code 1 for children with high behavioral score (at or above the 75th percentile) and 0 otherwise. Variables are measured in wave 3 since it concerns only children from 4 to 11 years.

Table 1: Math scores summary statistics by wave and child age

	Math Scores				
Age in years	Wave 4 (2000-01)	Wave 5 (2002-03)	Wave 6 (2004-05)	Wave 7 (2006-07)	Wave 8 (2008-09)
7	293.51 (38.88) [709]				
8	337.81 (46.36) [438]	342.35 (38.98) [613]			
9	378.08 (49.06) [371]	393.06 (45.28) [842]			
10		418.67 (40.01) [438]	412.22 (50.96) [613]		
11		450.12 (48.18) [371]	439.24 (51.85) [857]		
12			461.42 (59.12) [438]	475.30 (62.80) [613]	
13			497.64 (63.89) [371]	510.55 (67.78) [859]	
14				549.39 (81.21) [438]	587.95 (88.89) [613]
15				579.43 (86.12) [371]	603.59 (83.35) [821]

Note: Shows the mean, standard deviation (between brackets) and the number of individuals (between hooks) of standardized math scores. These statistics are weighted.

Family characteristics

First, maternal education was treated as a dummy variable to differentiate between mothers who had a high-school diploma (0) and those who had not (1). The maternal education seems to be the most important factor for the child's cognitive development since the knowledge that she transmits depends on it. Indeed, the child's cognitive skills are promoted by the "quality" of interactions that he has with his mother, and the level of education is a good indicator of this quality (Verstraete, 2006). Many studies highlight the important role of education and social capabilities of the mother for child development (NICHD, 2002; Gagné, 2003). This variable is measured in wave 3. Second, the age of the biological mother at birth has been transformed into a binary variable with 1 if the mother was 21 years old or less at the child's birth (early motherhood) and 0 if she was more than 21 years old. Several studies show that the interaction and stimulation a child receives from his mother are most beneficial to his development if life experience of the mother is more advanced (Corcoran, 1998; Verstraete, 2006). This variable is also measured in wave 3. Third, marital status was transformed into a binary variable according to whether both parents were living with the child (0) or not (1) in wave 3. There are substantial evidence that suggests negative effects for the child's cognitive and socio-emotional outcomes under a single-parent household (McLanahan et al., 1994; Pong, 1997). Fourth, for the total number of children in the household, we code 1 if the child has at least a sibling and 0 otherwise. This predictor was measured for wave 3. The presence or absence of other children in the household is to be considered because the more children there are in the household, (whether these children are older or younger or are exactly the same age), the less time and energy the parents will have to devote to a particular child. The presence of siblings can have a negative impact on the child's cognitive development (Steelman et al., 2002). Fifth, insufficient household income was calculated as the ratio between household income and the low income threshold in 1996 (SFR96) from Statistics Canada. Children raised in low-income families are likely to have lower math skills (Dooley and Stewart, 2004). In addition, Mayer (1997) and Blau (1999) studies recommend the use of permanent income as a measure (represented by the average income for all periods). The permanent income is measured in waves 1 to 3. The individual was to be coded "permanent poor" (1) if the ratio between household income and SFR96 is strictly less than 1 for the first three waves and (0) otherwise.

Family processes characteristics

Three parenting scales were used to measure parental behavior: i) positive parenting (scores ranging between 0 and 20). The positive parenting scale includes five items reflecting the frequency at which the parent compliments, plays, laughs, or does enjoyable activities with the child. A high score indicates more positive interactions; ii) hostile/ineffective scale (scores ranging from 0 and 25). The hostile/ineffective scale includes seven items with which the parent has difficulty to control the child, disapproves of the child's behavior, or gets angry when the parent punishes the child. High scores indicate more hostile/ineffective interactions; and iii) consistent parenting scale (scores ranging between 0 and 20). The consistent parenting scale include five items showing the frequency at which the parent ensures that the child should obey or the frequency at which the child gets away with things for which he should have been punished. High scores indicate consistent parenting. Landy and Tam (1996, 1998) studied the relationship between parenting practices and cognitive, social, and behavioral outcomes and showed that a positive interaction acts as a protective factor for children at high risk. Since these variables are measured for children from 2 to 11 years old, only wave 3 is used. We code 0 for children with a high score of parenting (above the 75th percentile) and 1 otherwise (except for the hostile/ineffective parenting scale where the opposite is true).

Table 2 shows the child, family, and parenting characteristics from the sample. We have 2,318 students who were followed over time (4 or 5 waves). All estimates are weighted. About half of the children are girls. Regarding the PPVT score, 11.70% of children have a low score (less than 85) when they were between 4 and 5 years. The proportion of children with behavioral problems is 31%, 26%, and 39% for hyperactivity scores, physical aggression, and indirect aggression, respectively. Concerning family characteristics, about 10.1% of the mothers surveyed do not have a high-school diploma. Mothers who were 21 years old or less at the time of the child's birth represent 7.5% of the sample. Two-parent families represent the vast majority of the sample (about 85.8% against 14.2% for one-parent families). About 86% of children in the study had at least one sibling. Permanently poor households represent 8.3% of the sample. The proportion of children with parenting problems is respectively 22%, 36%, and 18% for positive interaction, ineffective parenting style, and consistency scores.

Table 2: Characteristics of the sample (N=2318 individuals)

Variables		n	%	Wave
Characteristics of child				
Sex of child	Female	1,152	49.68	3
	Male	1,166	50.32	
Low PPVT Score	Yes	271	11.70	2 and 3
	No	2,047	88.30	
Hyperactivity-inattention	Yes	702	31.33	3
	No	1,539	68.67	
Physical Aggression	Yes	590	26.20	3
	No	1,660	73.80	
Indirect Aggression	Yes	835	38.83	3
	No	1,315	61.17	
Characteristics of family				
Age of mother at birth	21 years or less	173	7.47	3
	Older than 21 years	2,145	92.53	
Family status	One parent	328	14.17	3
	Two parents	1,990	85.83	
Only child	No	1,983	85.55	3
	Yes	335	14.45	
Mother graduated from H-School	No	235	10.14	3
	Yes	2,083	89.86	
Permanent poor	Yes	193	8.31	1, 2 and 3
	No	2,125	91.69	
Family processes				
Positive parenting	No	515	22.22	3
	Yes	1,803	77.78	
Hostile-ineffective parenting	Yes	479	20.66	3
	No	1,839	79.34	
Consistent parenting	No	420	18.12	3
	Yes	1,898	81.88	

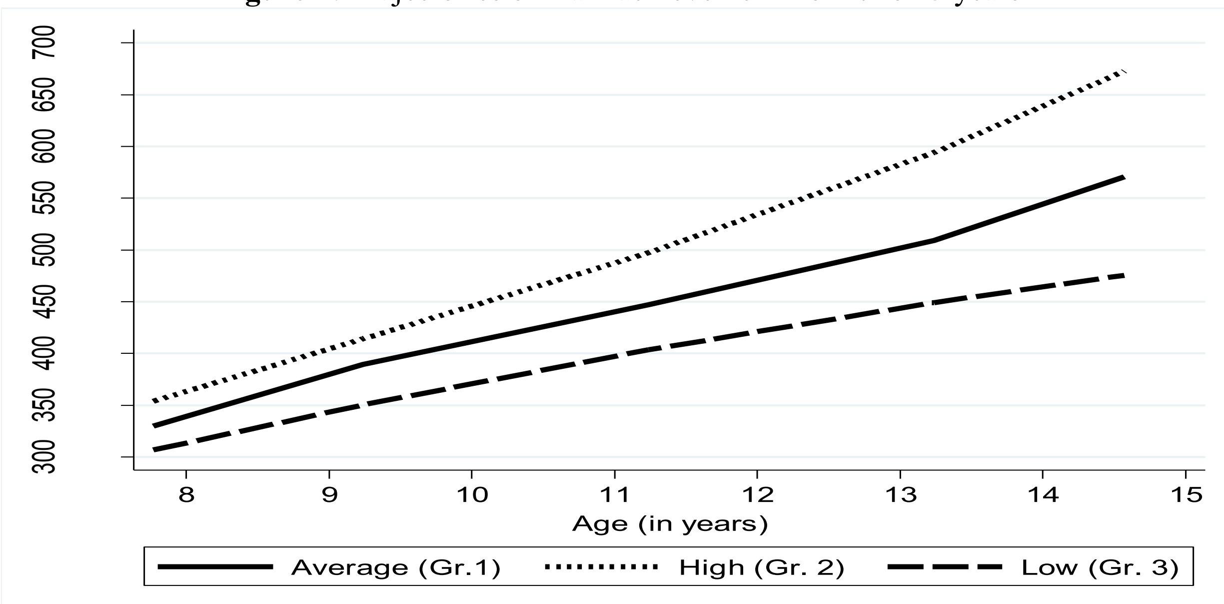
Note: Shows child, family and family processes characteristics (number of individuals, proportion and wave to which the variable is measured). All risk factors are binary. All statistics are weighted.

Results

Identification of math achievement trajectories

One of our objectives is to identify distinct mathematical abilities trajectories. In this study, the dependent variable is characterized by an individual's math scores at ages 7 to 15 years old. Trajectories are modeled using a censored normal distribution. Models with one to five groups are estimated. A three-group trajectory model for math achievement is selected based on BIC values: average abilities (group 1), high abilities (group 2), and low abilities (group 3) (see Figure 1). The polynomial term is quadratic for low abilities group and cubic for both average and high abilities groups.

Figure 1: Trajectories of math achievement from 7 to 15 years



Note: Shows the trajectories of mathematics performance for children aged 7 to 15 years: average abilities (Group 1: 47.6 % of the sample), high abilities (Group 2: 30.1% of the sample), and low abilities (Group 3: 22.3 % of the sample)

Table 3 reports the estimates of the parameters associated with the polynomial equation between age and outcomes for each group. Trajectory 1 (i.e. the average abilities group), accounting for 47.6 % of the sample, is composed of individuals who have average mathematical skills. We note that these children improve their math performances as they are older (positive linear parameter of the age) butthe relationship between age and math scores is not constant. In fact, the quadratic component of the age is significantly negative, suggesting that they improved less and less over time. We observe a positive change in the slope to the age of 13, suggesting that math skills improve (positive and significant cubic term). Trajectory 2 (i.e. the high abilities group), accounting for 30.1% of the sample, is composed of individuals with particularly high mathematical skills. Again, we observe a positive - but not constant - relationship between age and math scores as a change of the slope in early adolescence (positive and significant cubic term). Trajectory 3 (i.e. the low abilities group), accounting for 22.3 % of the sample, is composed of individuals at risk, who had lower math scores than average. Unlike the first two groups, this group is characterized by a quadratic trend.

We also note that achievement gaps between groups are increasing over time, especially in early adolescence. The average posterior probabilities assigned to the group are, respectively, 0.87, 0.90, and 0.87 for group 1, 2, and 3, while indicating a good fit of the model.

Table 3: Estimation of parameters

Variables	Coefficients	Standard Error
Group 1 (average abilities)		
Intercept	-823.84***	88.49
Age	292.21***	25.63
Age^2	-24.23***	2.40
Age^3	0.74***	0.07
Group 2 (high abilities)		
Intercept	-245.61**	118.37
Age	130.53***	34.03
Age^2	-9.41***	3.16
Age^3	0.33***	0.09
Group 3 (low abilities)		
Intercept	6.33	34.16
Age	46.11***	6.67
Age^2	-0.96***	0.31

Note: Shows estimated parameters and standard errors of equation between age and math scores for each group.

Risk factors and mathematic achievement trajectory groups

This section identifies risk factors during early childhood affecting mathematic achievement trajectory groups of Canadian children aged 7 to 15 years. Three trajectory groups were identified earlier: average abilities (group 1), high abilities (group 2), and low abilities (group 3).

Table 4 presents the prevalence of each risk factor by trajectory group. In general, the groups' math performances differ significantly in their characteristics except for the positive interaction (cf Chi-Square tests). Specifically, the groups are significantly different for sex and PPVT score of the child. We observe that there is a greater proportion of girls and individuals with low PPVT score in low abilities group than in high abilities group. Thus, 19.14% of children in low skills group had low PPVT score when they were 4-5 years old, while there are only 9.56% and 9.76% for the groups 1 and 2, respectively. Similarly, the low capacity group is one that contains more individuals with behavioral problems (hyperactivity, physical aggression, and indirect aggression). With respect to family characteristics, the prevalence of risk factors was higher in group 3 than in the other groups. Thus, factors such as early motherhood, single-parent families, low maternal education, and a poor permanent household are found more in the low abilities group. One of the most significant risk factors is the mother's level of education; we observe that only 7.64% of the children in the high abilities group have a mother with low education, compared to 18,20% in the low abilities group. Similarly, 8.02% of the children in high abilities group live with a single parent; compared to 19.11%in the low abilities group. Group 3 also contains a higher proportion of children with a young mother at birth (10.67% versus 7.77% and 4.67% respectively for groups 1 and 2). Surprisingly, the high abilities group recorded a higher proportion of siblings (89.04% against 83.67% and 84.94%, respectively, for groups 1 and 3). Furthermore, ineffective style and lack of coherence of parents seem to be determining factors of membership in the low abilities group. Finally, we report that the trajectory groups differ mainly in their PPVT score, the maternal education, living in a one-parent family, and the lack of consistency at home.

Table 5 reports the results of the multivariate logistic regression with the average abilities group (the one that contains the majority of the children) as referenced. Log-odds ratio (estimate), standard deviations, odds ratio (OR), and 95% confidence intervals (CI) are measured. We first discuss the results for high abilities group followed by the results for low abilities group.

Estimates show that being a female reduced the likelihood to be in the high abilities group, compared to average abilities group (OR: 0.44; CI: [0.30; 0.63]). The fact of having a single parent and a young mother at birth reduce the likelihood of being in the high abilities group compared to the average abilities group (OR: 0.53; CI: [0.27; 1.03] and OR: 0.49; CI: [0.23; 1.05], respectively). However, having siblings increases the likelihood to be in the high abilities group rather than in the average (OR: 1.68; CI: [0.31; 3.61]).

With respect to children in low abilities group, the two largest risks factors are: a low PPVT score (OR: 2.80; CI: [1.33; 5.90]), and a low maternal educational level (OR: 2.66; CI: [1, 42; 4.99]). The results also indicate that consistency problems at home increase the likelihood of belonging to low math skills trajectory compared to average abilities group (OR: 2.44; CI: [1.41; 4.22]). However, being a female decreases the odds of being in the low skills group.

Table 4: Sample characteristics by math abilities trajectory group

Risk factors	Average ability Gr.1 (n = 1199)	High ability Gr.2 (n = 604)	Low ability Gr.3 (n = 515)	Test chi2(df=2)	p
Child characteristics					
Girl	54.67	43.10	47.65	8.86	0.01
Low PPVT score	9.56	9.76	19.14	34.08	0.00
Hyperactivity	32.17	27.64	34.73	19.09	0.00
Physical aggression	24.77	25.45	30.62	5.60	0.05
Indirect aggression	41.21	30.21	45.97	19.48	0.00
Family characteristics					
Low maternal education	8.08	7.64	18.20	50.30	0.00
Early motherhood	7.77	4.67	10.67	18.32	0.00
One parent	15.78	8.02	19.11	29.26	0.00
At least one brother/sister	83.67	89.04	84.94	9.80	0.00
Permanent poor	8.80	5.25	11.46	21.38	0.00
Family processes					
Positive interaction	20.85	24.74	21.79	2.20	0.33
Hostile ineffective parenting	34.71	29.51	49.04	25.01	0.00
Consistent parenting	15.4	15.57	27.76	30.57	0.00

Note: Shows the characteristics of the child, the family, and parenting by math abilities trajectory group. Chi-Square tests are performed to determine if differences in characteristics are significant between groups. The number of degrees of freedom (Df) is 2 and p is the p-value.

Table 5: Predictors of low and high abilities trajectories

Variables	High abilities			Low abilities		
	Estimate (sd)	OR	95% CI	Estimate (sd)	OR	95% CI
Child characteristics						
Girl	-0.83*** (0.19)	0.44	[0.30; 0.63]	-0.46* (0.24)	0.63	[0.39; 1.01]
Low PPVT score	0.43 (0.41)	154	[0.69; 3.43]	1.03*** (0.38)	2.80	[1.33; 5.90]
Hyperactivity	-0.34 (0.23)	0.71	[0.45; 1.12]	-0.13 (0.24)	0.88	[0.55; 1.41]
Physical aggression	0.11 (0.25)	1.12	[0.68; 1.82]	0.07 (0.29)	1.07	[0.61; 1.89]
Indirect aggression	-0.35 (0.24)	0.70	[0.44; 1.13]	0.22 (0.25)	1.25	[0.76; 2.03]
Family characteristics						
Low maternal education	0.10 (0.37)	1.11	[0.54; 2.28]	0.98*** (0.32)	2.67	[1.42; 4.99]
Early motherhood	-0.72* (0.39)	0.49	[0.23; 1.05]	-0.11 (0.33)	0.90	[0.47; 1.71]
One parent	-0.64* (0.34)	0.53	[0.27; 1.03]	0.23 (0.37)	1,26	[0.61; 2.60]
Had at least one brother/sister	0.52* (0.30)	1.68	[0.93; 3.03]	0.17 (0.35)	1.19	[0.60; 2.35]
Permanent poor	0.05 (0.63)	1.05	[0.31; 3.61]	0.54 (0.48)	1.72	[0.67; 4.40]
Family processes characteristics						
Hostile ineffective parenting	-0.17 (0.22)	0.84	[0.55; 1.30]	0.43 (0.26)	1.54	[0.92; 2.56]
Lack of consistent parenting	0.25 (0.31)	1.28	[0.70; 2.36]	0.89*** (0.28)	2.44	[1.41; 4.22]
Lack of positive parenting	0.36 (0.25)	1.43	[0.88; 2.34]	-0.25 (0.28)	0.78	[0.45; 1.35]

Note: Shows the multinomial logistic regressions between risk factors and membership in the mathematics scores trajectories. Reference group: average abilities group. Estimates: log odds ratios; sd: standard deviations (in parentheses). OR: odds ratios; CI: 95% confidence intervals. All estimations are weighted.
***: significant to 1% ; **: significant to 5% ; *: significant to 10%

Discussion

The objective of this study is not only to identify the mathematical abilities trajectories of Canadian children from 7 to 15 years old and their probability of inclusion, but also to identify the predictors during early childhood that may influence the likelihood of being in one of these abilities groups. Using group-based trajectory modeling, three trajectory groups are identified: average abilities (47.6%), high abilities (30.1%), and low abilities (22.3%). Cubic slopes are estimated for the two first groups and quadratic slope for the last. The differences between the groups are increasing over time, especially in early adolescence. We then introduced the risk factors during early childhood to determine those which have an impact on group membership, in particular, on membership in the low skills trajectory group.

Our results show that maternal education is one of the most important predictors for the low math abilities trajectory. Thus, a child with low maternal education is more likely to be in the low skills group than in the average group. These results are consistent with other studies previously conducted. In fact, the PISA study (OECD, 2004, 2007) shows a positive relationship between the parental education and their child's mathematics performance. Similarly, using a wide range of cognitive assessments for young children, Korenman and Winship (1995) and Currie and Thomas (1995) show that after controlling for many observable characteristics of the family and children, education and maternal skills (measured by the test AFQT (Armed Forces Qualification Test)) are the most significant predictors in the performance of the child.

PPVT score is also a good indicator of future academic success of the student. Indeed, children with a low PPVT score have a greater probability of being in the high risk group than in the average group. Thus, the PPVT score is a good way to detect students that might struggle in early adolescence. This confirms the results of Baker (2011) on the relationship between cognitive and behavioral development of young children and their future math performance. Similarly, Duncan et al. (2007) highlight the important contribution of reading skills and cognitive tests measured at the age of 4-5 years on mathematics performance of Canadian children at the age of 8. The results obtained by Duncan et al. (2007) are also confirmed by those of Romano et al. (2010). Using NLSCY data, they show that the PPVT score is not only a strong predictor of reading skills but also math skills when the child is 8 years old. These results reinforce the idea of "cumulative advantage processes" where the advantage of a person over another accumulates over time (Merton, 1973). Thus, if a child has difficulties (low academic skills) in childhood compared to others, this is likely to persist over time and PPVT test would be a good way to detect it in an attempt to mitigate these effects.

The children at risk are also those whose parents with low parenting scores. More specifically, a lack of consistency for parents leads to a higher likelihood of being in the low skills group. Several studies report that poor parenting skills are associated with lower academic achievement (Majoribanks 1996; Spera, 2005). Additionally, poor parenting skills lead to disorders and dysfunctions within the family dynamics, which cause disturbance for the child and consequently affect his academic performance.

The sex of the child has a low impact on membership of the high-risk group. The significant effect of gender on mathematics performance is also demonstrated in other studies (Caro et al., 2009). Thus, we show that in the case of academic skills, gender has little impact and other aspects such as the parental human capital and their ability to be parents are most important.

After presenting the risk factors that may influence membership in the high-risk group, we can now turn our attention to other factors that are not significant. For example, being in a poor permanent family doesn't play a role on mathematics performance. Income effects on academic outcomes of children are generally weak and insignificant when compared to other factors (Blau, 1999; Dooley et al. 2004). Non-monetary factors, such as maternal education, play a more important role than monetary factors in the mathematical achievements of the child.

Behavior scores have no effect on membership of low abilities group. These results were also reported by Baker (2011) and Duncan et al. (2007), where a child's behavior scores measured before starting school have no effect on future cognitive performance. These results are valid for any type of behavior measured (externalized or internalized).

The number of siblings has no effect on membership in the low skills group, but it seems to have a positive effect on membership in the high skills group. This result is somewhat surprising in the sense that, in general, studies have shown that family size negatively affects a child's academic success because of the relatively smaller amount of time given to each child by the parents, as well as reduced resources allocated per child (Hanushek 1992).

Having a young mother at birth has no effect on membership in the low abilities group. This may be surprising but demonstrates the importance that other factors (such as maternal education) play.

The factor of one-parent households has no effect on membership in the low abilities group. Thus, our study shows that the risk factors such as early motherhood or being a single parent do not affect membership in the low abilities group, but does affect whether the child will be amongst the best students or more in line with the average. As discussed above, maternal education, however, is an important factor for school performance of children.

Strengths of the study

Our study has several advantages. First, by segmenting the data into multiple trajectory groups, group-based trajectory modeling provides an empirical way to summarize large amounts of data in an understandable way and introduces the risk factors that may influence membership in trajectory groups. Thus, allowing the slopes of the groups of trajectories to vary, the identification of the heterogeneity in the groups is particularly suitable (Hill et al., 2000, Nagin and Tremblay, 1999, Nagin, 1999). This method assumes that the population is composed of a mixture of distinct groups defined by their development trajectories. The probability of belonging to a group can then be used as the dependent variable to examine the predictors of these trajectories. The identification of the groups here is endogenous and not based on any arbitrary criterion (Côté et al., 2002).

Secondly, the study uses a large representative sample of the Canadian population. Many predictors during early childhood on the child and his family are measured. This will create a profile of risks that may influence the child's mathematical skills. The fact that they are measured during childhood allows for policy recommendations to be in place as soon as possible so that struggling students have the opportunity to catch up.

Limitations of the study

Despite these strengths, our study also presents some limitations. First, we cannot generalize the results obtained in mathematics to other cognitive tests such as reading or vocabulary. It would also have been interesting to study whether the mathematical results obtained at ages 4 to5 years are a more important predictor than vocabulary tests for math achievements from 7 to 15 years[1]. Secondly, other variables may also influence the membership in a particular group and were not taken into account here, such as, the unobservable factors - e.g. genetic factors, the child's motivation, or the quality of the school and the teacher.

Finally, an analysis of a more structural point of view would be interesting in order to observe the mechanisms leading to these results and to improve social policies.

[1] Such data are lacking for each wave in the NLSCY.

Implications for policy and research

This study offers several policy recommendations. Indeed, the introduction of risk factors has revealed the predictors that may influence the membership in specific math trajectory groups.

We show that maternal education is the key consideration. Thus, we should encourage mothers to invest more in their human capital. The government should provide more funding to ensure vulnerable women access to higher education (scholarship for student mothers, more childcare accessibility, etc). The PPVT score is a good way to detect children at risk. Public authorities and schools should develop a program implemented to children at risk from their early childhood, such as more intensive courses in the evenings or during the holidays, more personalized teaching, etc. This would reduce at the onset the inequalities of the cognitive performance of children before they amplify in early adolescence[2] . Efforts should be realized not only in childhood but also in adolescence, during which students begin to desire independence and to "decide" their future. Children with cognitive difficulties will remain in the background, showing disappointment with society has to offer, while the more competent children will be motivated to continue on the same trajectory that they were previously.

More generally, it is the family environment that has the greatest impact on the children's future. Since the child spends most of his time with his family, we might consider that the school compensates for some negative effects of having a mother with low education. Governments should therefore focus their efforts on improving the family environment for children at risk and increase their exposure at school. Certainly, the government cannot significantly influence on the first aspect but rather on the second; they could increase and improve the quantity and quality of time spent in

[2] Inequalities in cognitive performance increases over time is well reported by group-based trajectory modeling as the cubic terms have a positive slope for the high and middle groups later and has a concave relationship for kids with low abilities.

school through access to books, teaching materials, and educational activities (museum trips, sports courses, etc.).

Conclusion

The objective of this study is twofold. First, using a group-based trajectory modeling, we identify three distinct mathematical abilities trajectories of children: average abilities (47.6%), high abilities (30.1%), and low abilities (22.3%). We also show that these gaps increase over time, particularly in early adolescence. Secondly, using multinomial logistic regressions, we model links between risk factors during childhood and trajectories. Children at risk are those who have a mother with low education, a low PPVT score, and have parents with poor parenting skills.

This work allows us to draw several policy recommendations aimed at reducing the negative impact of some socio-demographic factors on mathematical achievements of the child. It also offers a number of future directions in order to continue the study of risk factors and their effects on academic performance of children.

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