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Mathematics Performance Profiles and Relation to Math Avoidance in Adolescence: The Role of Literacy Skills, General Cognitive Ability and Math Anxiety

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ABSTRACT
The main aim of the study was to differentiate adolescent profiles by math performance at the beginning and end of the final two years of lower secondary school, and relevant baseline attributes (literacy skills, general cognitive ability, math anxiety), and to investigate how these profiles differed by gender and math avoidance. A total of 193 Finnish lower secondary students participated in this study. Four profiles were identified: (1) High academic, average anxiety; (2) low academic, average anxiety; (3) average academic, high anxiety; and (4) average academic, average anxiety. They differed in baseline attributes, math performance over two school years, math avoidance, and in gender ratio. High levels of math anxiety was related to unfavourable math trajectory and future math avoidance. This high anxiety was typical of a certain group of average performers but not of the lowest performers. The educational implications of the findings are discussed.

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Math performance; adolescence; math anxiety; math avoidance

1. Introduction

Many individual and other performance-related factors influence mathematical performance during adolescence, and competence in turn shapes professional orientation. Good math-performers seem to have higher educational and occupational aspirations (Widlund et al., 2020). This effect is further concretized as school and subject choices in certain transitions, which have a significant impact on societal, educational, occupational, and financial opportunities later in life (Wang & Degol, 2017). Existing evidence suggests that many individual math pathways evolve as expected – for example, students with good math skills tend to emphasize mathematics in their studies. However, some paths seem unexpected, as for instance when a student with good math skills chooses to avoid math-intensive fields (Wang et al., 2020) or simply prefers other interests. Evidence to date also indicates that these paths are at least partly gendered, and that gender also regulates the (un)expectedness of math paths to some extent (EIGE, 2018). While math achievement predicts males' educational aspirations, females' educational aspirations are predicted by their interest in mathematics (Korhonen et al., 2016). Furthermore, Wang et al. (2013) suggested that females with high math and verbal skills simply have wider career choices, and as a result, they do not necessarily prefer math-intensive fields. The present study aimed, using person-centered approach, (1) to differentiate adolescent math profiles as defined by math performance at the beginning and end of the final two years of lower secondary school, and baseline attributes

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(literacy skills, general cognitive ability, math anxiety), and (2) to investigate how these profiles differed by gender and math avoidance.

Mathematical skills are known to be hierarchical – that is, later knowledge is built on earlier knowledge (Iuculano et al., 2018). In this way, mathematical skills acquired in earlier school years affect mathematical performance in lower secondary school (Duncan et al., 2007; Watts et al., 2015). Although genetic factors have significant effects on mathematics performance (Hart et al., 2010), this does not account for all of the variation in math performance in adolescence. Several studies have reported a downward developmental trend in mathematics performance during secondary school (Wijsman et al., 2016), possibly reflecting a loss of interest in mathematics as observed even among students with good mathematics skills (Frenzel et al., 2010; Watt, 2004). This effect seems to coincide with a decline in overall academic motivation during the same period following transition from primary to secondary education (Peetsma et al., 2005). While males generally seem to show more interest to mathematics, male and female growth trajectories are similar (Frenzel et al., 2010).

Many studies have shown that gender differences in mathematics performance are non-existent or that male or female advantage relates mainly to certain subskills (Else-Quest et al., 2010). In this regard, there are evident culture-dependent differences; for example, although males seem on average to outperform females in mathematics across all OECD countries, females score better than males in Finland (OECD, 2012, 2015). While males are overrepresented at the highest performance levels, the gender difference at mean level was found to be close to zero (Baye & Monseur, 2016). Although neurobiological findings may partly explain these gender differences in math performance (see Miller & Halpern, 2014), these should be viewed as process-level differences in brain activity rather than as an explanation for choices and future orientation in general. Traditionally, mathematical learning ability has been strongly linked to the male sex (Geary, 2010), and gender stereotypes in math favour boys (Steffens et al., 2010). Surprisingly, this narrow gendered understanding also seems prevalent among adolescents themselves (Rapoport & Thibout, 2018), and further informs explanations of why female students tend to avoid math-intensive occupations and fields of study (Wang et al., 2013).

In addition to the loss of interest, cognitive skills may contribute to the observed changes in mathematics performance during secondary school (Wijsman et al., 2016). Mathematics content and task types in secondary school are more complex than in primary school (Finnish National Board of Education, 2014) and make different cognitive demands. Several researchers have proposed that learning mathematics and solving mathematical tasks requires both domain-specific ("mathematical") knowledge and domain-general resources such as language skills (Björn et al., 2016) and general cognitive ability (for meta-analysis, see Peng et al., 2019). Previous studies have reported that mathematics performance in adolescence relates to technical reading skills (Kyttälä & Björn, 2014) and to reading comprehension (Korhonen et al., 2012). Based on Finnish data, Kyttälä and Björn (2014) found that reading comprehension became more important for mathematical word problems with more complex verbal instructions. In secondary school mathematics, problems are more complex than in primary grades and make additional demands on language skills and general cognitive ability. Fuchs and Fuchs (2002) previously suggested that complex word problems involve the application of multiple skills, and Peng et al. (2019) observed that solving complex word problems was related to general cognitive ability. It is also worth noting that many non-word problems (e.g., fractions, algebra) are embedded in a word-problem format (Fuchs et al., 2012; Jordan et al., 2013) and so make demands on language skills as well as general cognitive ability.

Math anxiety is a multidimensional academic emotion that influences the use of cognitive resources, motivation, and future career orientation (see Luttenberger et al., 2018). Math anxiety is usually defined as feelings of tension and anxiety associated with number manipulation and mathematical problem-solving (Richardson & Suinn, 1972). As well as affecting those who perform poorly, math anxiety is a problem for certain students across all achievement levels (Kyttälä & Björn, 2010). In other words, while math anxiety is often negatively related to math performance (Barroso et al., 2021; Foley et al., 2017), some high-achieving students also report high levels of anxiety (Wang et al., 2015), indicating that this is a complex phenomenon that needs to be understood in greater depth. Although mathematics performance predicts later math anxiety, math anxiety does not seem to predict later achievement in mathematics (Wang et al., 2020). However, there is also conflicting evidence that math anxiety undermines later math performance (see Carey et al., 2016). Females seem to display higher math anxiety levels than males (Kyttälä & Björn, 2010), and the effect is more stable across time in girls than in boys (Ma & Xu, 2004). However, Wang et al. (2020) suggested that math anxiety may have more negative effects on self-efficacy in mathematics among male students. Although math anxiety is considered to represent individual feelings and their cognitive and physiological consequences (Luttenberger et al., 2018), it is also shaped by socio-cultural factors such as gender stereotypes (Casad et al., 2015).

Math anxiety is related to long-term and short-term math avoidance. Individuals with high levels of math anxiety typically display a general avoidance of mathematics by taking fewer mathematics courses and choosing fields of study and occupations that are not mathematics-related (Ashcraft, 2002; Ashcraft & Moore, 2009), or by rushing through tasks (Faust et al., 1996). They also seem to prefer easier, low-reward problems over harder, high-reward math problems, showing a tendency to avoid effort in mathematics (Choe et al., 2019). Pizzie and Kraemer (2017) observed short-term attentional avoidance of mathematical information when participants with mathematics anxiety viewed mathematical stimuli without even trying to solve a problem. In the current study, we focus on math avoidance, which is reflected in future study and career orientations.

1.1. Research Context and Questions

The present study aimed (1) to identify adolescent math profiles defined by math performance at the beginning and at the end of the final two years of lower secondary school, and baseline attributes (literacy skills, general cognitive ability, math anxiety), and (2) to investigate how these profiles differ in gender and math avoidance. This lower secondary school period is often linked to downward trends in mathematics performance (Wijsman et al., 2016), and is significant because adolescents make upper secondary-level study choices at the end of lower secondary school. Math studies are increasingly relevant for Finnish adolescent students, as mathematics grades, engagement, and extent and type of math courses have recently become significant criteria for entry to higher education studies in Finland (www.opintopolku.fi). Consequently, math-related study choices made in early adolescence are now a significant determinant of entry to many study fields (including many non-mathematical fields) after upper secondary level, and math avoidance at this point may narrow one's subsequent study options. Yet, even as mathematical skills become increasingly important for Finnish adolescents, their mathematics performance has deteriorated. At the beginning of this century, Finnish adolescents were among the international top four in mathematics (OECD 2000, 2003, 2006; Programme for International Student Achievement; PISA; http://www.oecd), but PISA 2012 (OECD 2012) reported a decline in overall ratings. Although Finland continues to lag behind the top OECD countries, it has at least maintained a consistent level in recent PISA surveys (OECD 2015, 2019), and Finnish adolescents' mathematics skills are still clearly better than the OECD average.

For present purposes, students' profiles were clustered on the basis of math performance at two separate time points during lower secondary school (the beginning of eighth grade, the end of ninth grade), and relevant baseline attributes (literacy skills, general cognitive ability, math anxiety). Previous studies have confirmed that literacy skills (Korhonen et al., 2012; Kyttälä & Björn, 2014) and general cognitive ability (Peng et al., 2019) as well as math anxiety (Luttenberger et al., 2018) are linked to math performance during adolescence and may therefore be significant discriminants of performance profiles. As previous studies confirm that mathematics remains a gendered subject, and that this seems to moderate math-related choices (EIGE, 2018), gender differences in the distribution of different profiles were also examined.

The present study extends the existing research in at least two ways. First, by using person-centered approach, this study allows for a more detailed investigation of adolescent subpopulations and their underlying attributes. Rather than classifying groups in terms of different mathematical difficulties, this study looks at performers at all levels and so offers a broader account of differences in adolescents' performance profiles, and associated attributes. Previous studies of lower secondary school students have yielded somewhat conflicting results. For example, although some recent studies have suggested that math anxiety does not predict later achievement in mathematics (Wang et al., 2020), the performance and choices of some groups seem more negatively affected by math anxiety (Luttenberger et al., 2018; Wang et al., 2020). Secondly, most previous studies of the determinants of mathematical performance (other than math anxiety and math interest) have focused on primary school children.

To bridge some gaps in the existing literature, this study addressed the following research questions.

(1) What adolescent math profiles can be identified as defined by relevant baseline attributes (literacy skills, general cognitive ability, math anxiety) and math performance at the beginning and end of the final two years of lower secondary school?
(2) How do these profiles differ with regard to gender and math avoidance?

Based on previous studies, we expected to find that student math profiles would vary by performance level and baseline attributes as discussed above. Based on the existing evidence, we expected to find math anxiety at all performance levels, with higher levels of math anxiety, unfavourable math trajectory, and math avoidance in the low performance group (for an account of the reciprocal relation between math performance and math anxiety, see Carey et al., 2016).

2. Methods

2.1. Participants and Procedure

The participants in this two-school-year follow-up study were 193 lower secondary students (89 female, 104 male; aged 13–14 years) from urban economic zones in central and southern Finland. The data were drawn from the longitudinal MASA project (Mathematical learning difficulties and Sociocultural factors among Finnish Adolescents; Kyttälä & Björn, 2010, 2014), which explored the possible individual and societal factors behind mathematics performance differences among Finnish adolescents. A total of 193 students who had participated at both measurement time points were included in this study. The criterion for participation at both time points was that the student had mathematics scores in both eighth and ninth grade. The school authorities in both regions were first approached to seek permission to conduct the study; school interest in participation was the primary selection criterion. Student participation was voluntary and required informed parental consent. During the first year of the study, the participants were in the eighth grade. In Finland, ninth grade is the last year of compulsory schooling (although compulsory schooling can now be said to last for ten years, as preschool education is compulsory for all children from the year in which they turn six years of age). The sample was homogeneous in terms of race and cultural background, and all participants spoke Finnish as their native language. The study was approved by the University of Jyväskylä Research Ethics Board.

The students participated in this study in classrooms during school hours, and the data were gathered with the help of teachers. The adolescents' mathematics anxiety, literacy skills and general cognitive abilities were measured at the beginning of eighth grade. Their mathematics performance was tested at the beginning of eighth grade and again at the end of ninth grade. Math avoidance was measured at the end of ninth grade.

2.2. Measures

2.2.1. Mathematics Skills

Mathematics skills were measured using the Test for Basic Mathematical Skills for Grades 7–9 (KTLT; Räsänen & Leino, 2005), an originally Finnish-normed paper-and-pencil test used to screen for potential difficulties. The test includes calculation tasks from curriculum-relevant areas of mathematics – addition, subtraction, multiplication, and division tasks – expressed both in plain numeric form and as word problems. Tasks primarily include calculations involving whole numbers but also fractions and decimals, as well as equation tasks and geometry problems. There are four parallel versions of the test (A, B, C, D) that can be used to track the development of skills and knowledge; the present study used versions A (Time 1) and D (Time 2). Each test version contains 40 tasks, with a time limit of 40 min. The maximum total score is 40. Based on normative data ($N = 1157$), both the A and D versions achieved an internal reliability value of .88 (Räsänen & Leino, 2005). The test also correlated significantly with other measures of mathematical skills ($r = .61–.78$, $p < .001$) (Räsänen & Leino, 2005).

2.2.2. Mathematics Anxiety

Mathematics anxiety was measured using the Mathematics Anxiety Rating Scale (MARS-A; Suinn, 1988). The Finnish version of MARS-A contains 89 statements and rates anxiety on a five-point scale (0 = not at all, 4 = very much). The statements were translated from the English version with no back-translation. Nine of the 98 statements in the original version were removed because they did not fit the Finnish context. This Finnish version was originally translated with the permission of Richard Suinn and has been used and reported previously (Kyttälä & Björn, 2010, 2014). The total score is the composite of all answers, with a possible maximum of 356. For this sample, Cronbach's alpha was 0.97, and the split-half reliability using the Spearman-Brown formula was 0.94.

2.2.3. Literacy Skills

(a) *Technical reading skills* were measured as a combination of two tasks from a nationally normed dyslexia screening test for adolescents and adults (Holopainen et al., 2004). In the first sub-test ("Find the spelling errors"), the participant must find an extra letter, a missing letter, or a wrong letter in a set of words, marking each spelling error. In the second sub-test ("Separate the words"), the participant is instructed to draw lines as quickly as possible between understandable words in a word chain. The maximum score for each subtest is 100, yielding a maximum total score of 200. The time limit for each sub-test is 3 min, 30 s. For the purposes of the present analysis, the two sub-test scores were further combined to form the variable "Technical reading skills". Test-retest reliability for the spelling error task has been reported as .83, and as .84 for the separate word task (Holopainen et al., 2004).

(b) *Reading comprehension* was measured using a subtest from a dyslexia screening test for adolescents and adults (Holopainen et al., 2004). Participants read a story called "The Hounds of the Village", in which 52 words have been changed to conflict with the narrative through a change of purpose or context or other errors. The participant must find these inappropriate words and underline them, scoring a point for each correctly underlined word. The time limit for this subtest is 45 min. Cronbach's alpha is 0.91.

2.2.4. General Cognitive Ability

General cognitive ability was assessed using Raven's Progressive Matrices (hereafter, the Raven), which assesses analytic reasoning about abstract visuospatial material (e.g., Carpenter et al., 1990). The test was completed during one lesson (45 min) according to the standard instructions (Raven et al., 1992). Students were provided with a booklet containing all 60 problems and an answer sheet, on which they were instructed to choose the correct number of each Raven item working individually and in silence. The maximum score on this test is 60.

2.2.5. Math Avoidance

Future math avoidance was measured by three statements ("I will avoid math in the future if I can"; "I wouldn't succeed in studies or a job that require math skills"; and "I plan to apply for a place of study that requires as little math skills as possible"), using a five-point Likert scale (1 = I totally disagree, 5 = I totally agree). The total score was the composite score for all three, with a maximum score of 15. Cronbach's alpha for this scale was .75.

2.3. Analysis

All participants had values for math performance in eighth and ninth grade. The other key variables had a few random missing values (< 5%) that were imputed using multiple imputation (Markov Chain Monte Carlo method). The statistical analyses involved the following steps. (1) Descriptive statistics and correlations were calculated, and independent samples t-tests were performed to identify gender differences in key variables. (2) To identify adolescent math profiles, we performed a cluster analysis of standardized scores for math performance (8th and 9th grade), literacy skills, general cognitive ability, and math anxiety using the K-means method, which is considered effective for medium-sized data (Han, Kamber, & Pei, 2011) as in the present study. The number of clusters was first determined by inspecting the results of hierarchical cluster analysis (Ward's method; agglomeration schedule; see the scree plot in Figure 1 for the agglomeration coefficients) (Gore, 2000; Yim & Ramdeen, 2015). The first larger increase in agglomeration coefficient values usually indicates an optimal cluster solution (Yim & Ramdeen, 2015). However, this "larger" increase can not be unambiguously identified, and is thus based on subjective decision. In the current data, the agglomeration schedule indicated five-, four- or three-cluster solution, which were all tested using the K-means method. The five-cluster solution was rejected because it included one cluster with only one participant. The three-cluster solution was also rejected because it did not adequately

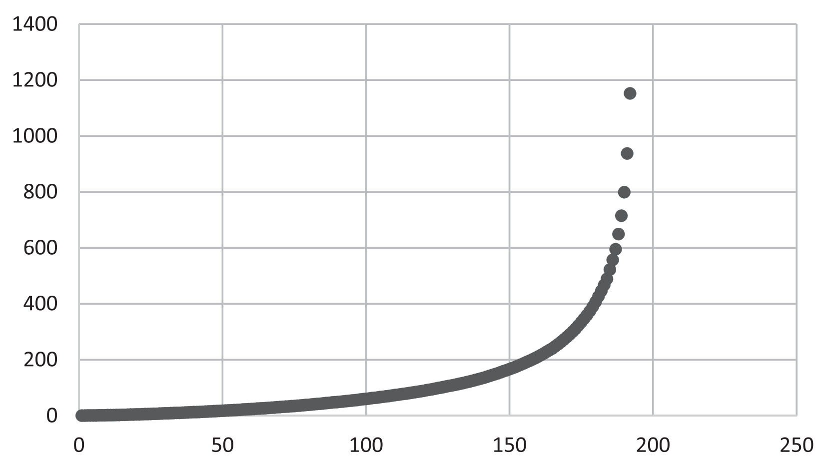

Figure 1. The scree diagram of agglomeration coefficients.

represent the diversity amongst average performing participants. Based on numerical and visual inspection, the four-cluster solution was preferred. It was theoretically justifiable and supported by hierarchical cluster analysis. (3) To further assess cluster solution fit, we performed a discriminant analysis. (4) MANOVA using math performance at two separate time points, literacy skills, general cognitive ability, and math anxiety as dependent variables was performed to inspect between-cluster differences. (5) Crosstabs and chi-square tests assessed the independence of clusters and gender. Finally, between-groups ANOVA was performed to detect differences in future math avoidance.

2.4. Results

Table 1 presents descriptive statistics (including gender differences) and correlations between key variables. Females and males performed equally well in math at both time points. There were significant gender differences in general cognitive ability, technical reading, reading comprehension, and math avoidance; in all cases, females scored higher than males. In math anxiety, the difference almost reached the level of statistical significance ($p = 0.052$), with females having higher scores than males. Math performance and all of the baseline variables were significantly correlated, with the exception of math anxiety, which did not correlate with any of the other baseline variables. Math avoidance correlated negatively with math performance at both time points as well as with general cognitive ability. It was also positively correlated with math anxiety.

Cluster profiles based on raw scores are presented in Table 2. Cluster means per factor were classified high if they were above the 75th percentile of the whole data set, average if they were between 25th and 75th percentile and low if they were below 25th percentile. Table 3 presents descriptive statistics for the four clusters. The first cluster ($n = 57$; 29.5%) refers to those with high scores in mathematics and literacy, high scores in general cognitive ability, and average scores in math anxiety – high academic, average anxiety profile. The second cluster ($n = 27$; 14.0%) refers to those with low scores in mathematics, general cognitive ability, and literacy, and average scores in math anxiety – low academic, average anxiety profile. The third cluster ($n = 38$; 19.7%) refers to those with average scores in math, general cognitive ability and literacy, and high math anxiety – average academic, high anxiety profile. Finally, the fourth cluster ($n = 71$; 36.8%) refers to students with average scores in math, general cognitive ability, literacy, and math anxiety – average academic, average anxiety.

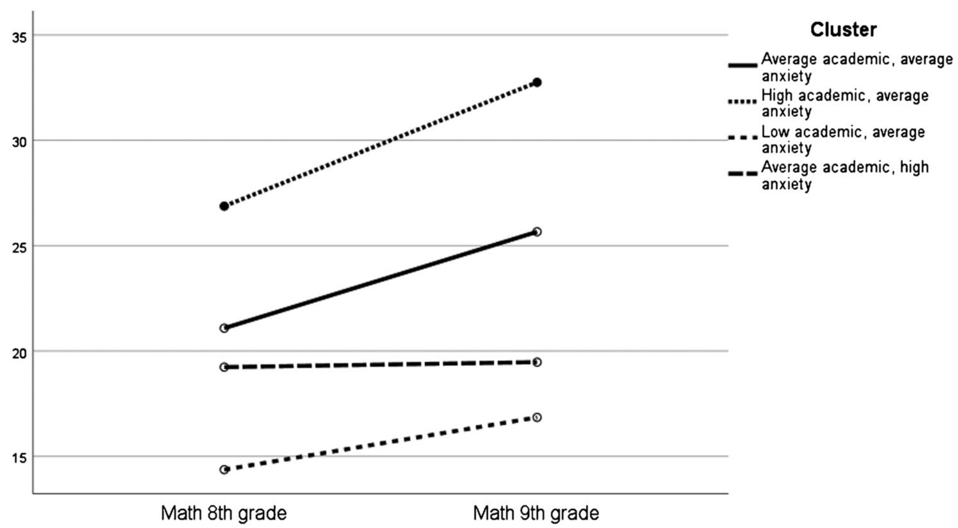

Figure 2. The math performance change from 8th grade to 9th grade.

Table 1. Descriptive statistics and correlations between variables.

	All		Females		Males									
	M	*Sd*	*M*	*Sd*	*M*	*Sd*	*t*	*d*	1	2	3	4	5	6
1.Math skills 8th grade	21.49	6.09	20.98	5.84	21.93	6.29	1.09	.16	-					
2. Math skills 9th grade	25.31	8.18	25.02	8.20	25.55	8.20	.44	.06	.66***	-				
3. General cognitive ability	45.69	6.48	46.70	5.70	44.82	7.00	−2.03*	-.29	.45***	.42***	-			
4. Technical reading	103.43	30.41	113.07	29.83	95.18	28.54	−4.25***	-.61	.45***	.37***	.32***	-		
5. Reading comprehension	30.75	8.98	33.04	7.94	28.78	9.38	−3.37***	-.49	.41***	.31***	.46***	.46***	-	
6. Math anxiety	64.05	41.49	70.31	42.42	58.70	40.11	−1.95[a]	-.28	-.02	-.13	.10	.03	-.03	-
7. Math avoidance	7.83	2.14	8.34	1.96	7.40	2.21	−3.09**	-.45	-.30***	-.32***	-.19*	-.07	-.05	.21**

Note. $N = 193$. *$p < .05$; **$p < .01$; ***$p < .001$; [a]$p = .052$.

Table 2. Student cluster profiles by math performance and baseline attributes.

	Math 8th grade	Math 9th grade	General cognitive ability	Technical reading	Reading comprehension	Math anxiety	Cluster description
Cluster 1	H	H	H	H	H	A	High academic, average anxiety (HAA)
Cluster 2	L	L	L	L	L	A	Low academic, average anxiety (LAA)
Cluster 3	A	A	A	A	A	H	Average academic, high anxiety (AHA)
Cluster 4	A	A	A	A	A	A	Average academic, average anxiety (AAA)

Note. L = low; A = average; H = high.

Table 3. Descriptive statistics of the three clusters.

	Clusters										
	HAA N=57 Females 57.9% Males 42.1%		LAA N=27 Females 25.9% Males 74.1%		AHA N=38 Females 50.0% Males 50.0%		AAA N=71 Females 42.3% Males 57.7%				
Measure	*M*	*Sd*	*M*	*Sd*	*M*	*Sd*	*M*	*Sd*	*F*	*ηp2*	Post hoc
Math skills 8th grade	26.88	4.83	14.37	5.44	19.24	4.67	20.08	3.79	52.29***	.45	1 > 3, 4 > 2
Math skills 9th grade	32.75	5.68	16.85	6.95	19.47	5.57	25.66	5.66	62.38***	.50	1 > 4 > 3, 2
General cognitive ability	50.87	3.47	37.52	7.39	46.07	4.96	44.43	4.80	47.07***	.43	1 > 3, 4 > 2
Technical reading	128.97	25.81	66.77	24.68	96.81	23.00	100.41	20.39	46.91***	.43	1 > 3, 4 > 2
Reading comprehension	37.14	6.22	18.46	7.75	28.43	7.27	31.52	6.70	47.48***	.43	1 > 3, 4 > 2
Math anxiety	63.91	29.76	45.80	32.00	121.06	34.05	40.60	23.84	68.00***	.52	3 > 1 > 2, 4

Note. ****p*<.001. HAA = High academic, average anxiety; LAA = Low academic, average anxiety; AHA = Average academic, high anxiety;
Average academic, average anxiety.

The discriminant analysis confirmed cluster solution fit (Wilks' $\lambda = 0.087$; $\chi 2 = 456.24$; df = 18; $p < .0001$). The cross-validated classification showed that, overall, 95.9% of grouped cases were correctly classified. MANOVA testing confirmed that the four clusters differed significantly on all variables (Pillai's trace = 1.39, $F(18, 558) = 26.70$, $p < .0001$, $\eta p^2 = .46$; see Table 3). More precisely, pairwise post hoc (Scheffe) comparisons revealed the following group differences. In eighth grade, all other clusters differed on math performance, with the exception of average academic, high anxiety profile and average academic, average anxiety, who performed equally. High academic, average anxiety profile had the highest scores and low academic, average anxiety profile the lowest. In ninth grade, however, the average academic, average anxiety profile performed significantly better than the average academic, high anxiety profile, whose performance did not differ from that of the low academic, average anxiety profile. The high academic, average anxiety profile still had the highest scores. Although average academic, high anxiety profile and average academic, average anxiety started from the same level, they ended up at different levels (see Figure 2). All other clusters differed significantly on general cognitive ability, with the exception of average academic, high anxiety profile and average academic, average anxiety, who scored equally. High academic, average anxiety profile returned the highest scores and low academic, average anxiety profile the lowest. In relation to technical reading and reading comprehension, all clusters again differed significantly with the exception of average academic, high anxiety profile and average academic, average anxiety, who performed equally. High academic, average anxiety profile had the highest scores and low academic, average anxiety profile the lowest. In relation to math anxiety, average academic, high anxiety profile differed from the other three clusters, showing the highest levels of anxiety while average academic, average anxiety showed the lowest. The high academic, average anxiety profile showed higher levels of math anxiety than the low academic, average anxiety and average academic, average anxiety profiles. This part of the analysis suggests that the adolescents were clustered as four distinct types based on academic performance level and math anxiety. Of the two groups that started from the same (average) math performance level, the group with the less favourable math performance trend exhibited higher math anxiety.

Based on crosstabs and a chi-squared test for independence, the gender distribution was unequal among the four clusters (χ^2 [3,193] = 8.27; $p < 0.05$; see Table 3).

Finally, one-way ANOVA showed that the clusters differed significantly in terms of future math avoidance ($F = 6.27^{***}$ (3, 193); $\eta p^2 = .09$). The highest scores for future math avoidance were returned by average academic, high anxiety profile, the group with the highest level of math anxiety ($M = 8.91$, $SD = 2.67$). Average academic, high anxiety profile differed significantly from average academic, average anxiety profile ($M = 7.90$, $SD = 1.66$; $d = 0.24$); although average academic performance was similar, the latter's lower anxiety indicates that high math anxiety is related to math avoidance. The average academic, high anxiety profile also differed significantly from the low academic, average anxiety profile ($M = 7.82$, $SD = 1.61$; $d = 0.26$), indicating that high math anxiety is a more powerful predictor of math avoidance than low performance. The average academic, high anxiety profile also differed from high academic, average anxiety profile, the highest academic performers, who showed the lowest level of math avoidance ($M = 7.00$, $SD = 2.19$; $d = 0.44$). High academic, average anxiety profile also showed significantly less math avoidance than average academic, average anxiety profile ($d = 0.20$). Average academic, average anxiety did not differ from low academic, average anxiety profile ($d = 0.02$).

3. Discussion

The study identified four profiles that capture Finnish adolescents' math performance at the beginning and end of the final two years of lower secondary school, taking account of relevant baseline attributes (literacy skills, general cognitive ability, math anxiety). As expected, our investigation of these profiles indicates that they differ by math performance level (high, average, low). Four distinct profiles were identified that differed in terms of math performance over two school years and baseline attributes (as above), as well as math avoidance and gender ratio. One of the profiles represented high math performance, two represented average math performance and one low math performance. Our results align with previous findings suggesting that adolescent math performance is related to general cognitive ability (Peng et al., 2019), and literacy skills (Korhonen et al., 2012; Kyttälä & Björn, 2014). However, the interrelationship between math performance and math anxiety was not straightforward. As we expected, high levels of math anxiety predicted unfavourable math trajectory and future math avoidance. Contrary to expectation, these data suggest that high math anxiety is typical of a *certain* group of average performers but not of the lowest performers. Although females tend to report higher levels of math anxiety than males, the proportions of female and male students in this high anxiety group were equal; for meta-analysis, see Hembree (1990) and Madjar et al. (2018). Average math anxiety was typical across all other groups at different performance levels (high, average, low), indicating that math anxiety occurs to a certain extent at all performance levels.

All four profiles showed an ascending or stable trend in math performance from the beginning of eighth grade to the end of ninth grade (the final year of compulsory schooling in the Finnish system). Although secondary school is generally linked to downward developmental trends in mathematics performance (Wijsman et al., 2016), performance improved or remained the same in all groups during the two years of our study, which is in concordance with recent Finnish results (Räsänen et al., 2021; Widlund et al., 2021). As parallel versions of the math test were used, the improvement may not be explained by a test-retest effect. However, it is noteworthy that while the two average performing groups fared equally well in mathematics at the beginning of the eighth grade, the group with high math anxiety performed significantly lower a year later. In short, the group with high math anxiety showed a less favourable math trajectory at the end of compulsory schooling when compared to the group with lower math anxiety. Although math anxiety did not correlate with math performance at the whole data level, this finding suggests that unfavourable math trajectory is associated with high anxiety levels, and that this high anxiety level is not related to low performance per se, as it is typical of some average performers (see also Kyttälä & Björn, 2010; Luttenberger et al., 2018; Wang et al., 2020). This may also explain earlier conflicting evidence about the longitudinal relation between math performance and anxiety (Hembree, 1990; Ma & Xu, 2004; Wang et al., 2020). In addition to unfavourable math trajectory, this high anxiety group also exhibited stronger future math avoidance than high performers, and average performers with lower anxiety levels, which aligns with previous studies showing an association between high math anxiety and math avoidance (Faust et al., 1996; Luttenberger et al., 2018). This high anxiety group differed significantly from the low academic group with average anxiety, indicating that high math anxiety is a more powerful predictor of math avoidance than low performance. These results suggest that emphasis should be placed on varying emotional responses to mathematics in order to support positive performance growth (see also Holm et al., 2017).

Accumulation of various learning challenges was typical of the group with low academic performance, which is in concordance with previous findings (Korpipää et al., 2019). In addition to low scores in mathematics, these students scored lowest on general cognitive ability and literacy, both of which are believed to be significant determinants of math performance during secondary school (Hakkarainen et al., 2013; Korhonen et al., 2012; Peng et al., 2019) and beyond (Holopainen & Hakkarainen, 2019). There is also evidence of the Matthew effect – that is, the trajectory of students with low skills in mathematics tends to remain the same (Aunola et al., 2004). Most of the students in this low academic performance group were males, which aligns with official statistics on special education in Finland. According to Statistics Finland (2018), most students receiving intensified support (64%) or special support (71%) are male. In the Finnish system, there are three forms of support for learning and schooling: general, intensified and special (Finnish National Board of Education, 2014).

Similarly, the high performance group typically accumulated a range of different strengths. They scored highest in mathematics, general cognitive ability, and literacy. Females were overrepresented in this high-performance group, which aligns with the latest PISA results showing that Finnish ninth-grade females outperformed ninth-grade males in both literacy and mathematics (PISA, 2018). At the whole data level, females and males performed equally well in mathematics over the final two years of compulsory schooling, which is in concordance with previous studies showing non-existent or very narrow gender differences in math (Else-Quest et al., 2010). Despite this equal math performance, females showed higher levels of math avoidance. The difference in math anxiety between males and females was near statistical significance ($p = 0.052$), with females showing higher anxiety levels. This is in line with previous studies showing that math avoidance is associated with math anxiety (Ashcraft, 2002; Ashcraft & Moore, 2009). Previously, it has been suggested that females' better literacy skills provide them with wider career choices, and for that reason they simply prefer other fields that are not math-intensive even if they have high math skills (Wang et al., 2013). However, our results suggest that female math avoidance is not just "preferring other interests". Instead, they show that females endeavour to actively avoid math in their later studies and careers compared to males. It has previously been suggested that both female math avoidance and math anxiety are, at least in part, consequences of math-related gender stereotypes that favour males (Casad et al., 2015; Wang et al., 2013).

In discussing these results, it is important to acknowledge the limitations of this study. Although it examines the development of mathematical performance and identifies different performance profiles over the final two years of compulsory schooling, the study does not take account of the course of development prior to eighth grade. Our results suggest that while high math anxiety diminishes later math performance, anxiety is not related to previous low math performance. However, it is possible that average performers experienced difficulties with mathematics when they moved from primary school to lower secondary, and that this might manifest as an increase in math anxiety at the beginning of eighth grade. For that reason, how different performance profiles develop should be investigated over a longer period, and follow-up should start earlier. More extensive data would also enable more sophisticated analysis of between-group differences in key variables and gender ratio across different profiles. It should also be noted that we used a single indicator, a total math anxiety score, which does not allow an examination of the different dimensions of math anxiety; rather, it summarizes anxiety into a single continuum including both math test anxiety and numerical anxiety (see e.g., Rounds & Hendel (1980) for different MARS dimensions). Previous studies have suggested that different math anxiety dimensions may be somewhat differently related to math performance (Lukowski et al., 2019) and avoidance behaviour in task situations (D'Ailly & Bergering, 1992). Thus, using a total MARS score may underestimate the role of math anxiety, because it combines both dimensions that are stronger and weaker related to actual math performance or math avoidance. On the other hand, MARS showed strong internal consistency in our data, and there are long traditions of using MARS as a single indicator under similar conditions (Soni & Kumari, 2017; Wang et al., 2015).

The present study extends current knowledge by providing a broader account of adolescents' differing performance profiles and associated developmental attributes and processes. As in previous studies, the present findings confirm that mathematical performance in adolescence is related to literacy skills, general cognitive ability, and math anxiety. During the final two years of compulsory schooling, when students make choices regarding future study, math anxiety is the most essential feature of unfavourable mathematical performance development and future math avoidance. Although some recent studies have suggested that math anxiety may not predict later achievement in mathematics (Wang et al., 2020), our findings align with previous evidence that the performance and choices of certain, specific groups are negatively affected by math anxiety, at least in adolescence (see also Kyttälä & Björn, 2010; Luttenberger et al., 2018; Wang et al., 2020). Our results suggest that math anxiety is a problem specifically for average performers whose skills, without math anxiety, might be sufficient to make more mathematically oriented choices. This means, in further, that pedagogical practices and career counselling should be improved to support all potential students to get engaged with making math-related study and career choices. Previous research shows that math anxiety is not solely due to characteristics of the individual but also due to characteristics of the whole learning environment including emotional atmosphere of the classroom, the quality and structuredness of instruction, emotional experiences in the case of failure and the value beliefs delivered by the teacher both directly and indirectly (Frenzel et al., 2010). A recent study also found evidence of a BFLPE (Big Fish-Little pond Effect) in the classroom (Holm et al., 2020) which suggests that the average classroom performance level may affect emotional responses to mathematics, in turn affecting the emergence of math anxiety. In conclusion, the present study confirms the need to further investigate the interrelationship between mathematics performance, math anxiety, and career choices over the whole life course.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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