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Age group differences in SFON tendency and arithmetical skills of four to seven year olds in four countries with different school starting ages

Minna Hannula-Sormunen [a,*], Sophie Batchelor [b], Joke Torbeyns [c], Victoria Simms [d], Cristina Nanu [a], Eero Laakkonen [a], Bert De Smedt [e]

[a] Department of Teacher Education, University of Turku, Finland
[b] Mathematics Education Centre, Loughborough University, UK
[c] Center for Instructional Psychology and Technology, KU Leuven, Belgium
[d] Psychology Research Institute, Ulster University, Belfast, UK
[e] Faculty of Psychology and Educational Sciences, KU Leuven, Belgium

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ABSTRACT

This study investigated age group differences in Spontaneous Focusing on Numerosity (SFON) tendency and arithmetical skills across age groups with differing starting ages of formal mathematics instruction. Children (N = 685) aged 4–7 years participated from four countries, i.e., Northern Ireland, England, Belgium and Finland, where children start formal school at 4, 5, 6, and 7 years respectively. Children completed measures of SFON tendency, Arabic number naming, verbal arithmetic and written arithmetic. Results revealed strong age group effects for all measures and some developmental differences between SFON tendency and arithmetical skills. Whether children were, or were not, in school had a strong effect on SFON tendency but not on arithmetical skills. In the 5 and 6 years old age group, children already in school had significantly lower SFON tendency compared to those not yet in school. Within each country, when comparing consecutive age groups situated near school starting age, SFON tendency scores were similar in three out of the four countries. Results suggest both informal and formal mathematical skills need to be considered when assessing young children's mathematical competence.

Mathematical skills are essential to meet life's daily demands. Several reports have shown that poor numeracy is associated with a range of negative outcomes, from low income and unemployment to higher rates of physical illness, depression, and criminality (e.g., Bynner & Parsons, 2006; Reyna et al., 2009). As such, research into the cognitive foundations of mathematical skills has increased substantially over the last two decades (e.g., Rittle-Johnson & Jordan, 2016). Much of this research shows that individual differences in mathematics emerge early and that numerical knowledge in preschool is a remarkably strong predictor of later mathematics achievement (Aunola et al., 2004; Duncan et al., 2007; Jordan et al., 2009; Nguyen et al., 2016; Reeve et al., 2012). The effects of these early individual differences even extend into adulthood, for example, mathematical skills measured at 7 years were a stronger predictor of adult socioeconomic status (SES) than childhood SES, even after controlling for IQ and reading skills (Ritchie & Bates, 2013).

Abbreviations: SFON, Spontaneous Focusing On Numerosity.

* Corresponding author at: Department of Teacher Education, University of Turku, Assistentinkatu 5, 20014, Finland.
E-mail address: Minna.Hannula-Sormunen@utu.fi (M. Hannula-Sormunen).

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The current cross-sectional study aims at advancing our limited understanding about how different formal and informal mathematical skills develop in four European countries with different early educational systems and school starting ages.

There are large variations in the nature and timing of early mathematics instruction across the world. The compulsory age for children starting school ranges from 4 to 7 years and the amount and type of formal mathematics instruction that children receive varies significantly (OECD, 2014; Sharp, 2002). Data from large international assessments such as the 'Programme for International Student Assessment' (PISA) and the 'Trends in International Mathematics and Science Study' (TIMSS) have featured heavily in discussions over whether there should be more formal mathematical content or more play-based learning in the preschool curriculum (e.g., van Oers, 2010; Whitebread, Basilio, Kuvalja & Verma, 2012).

While formal schooling is directed towards achievement and offers systematic training of mathematical skills, early education is not homogeneous in instructional practices. Research on effectiveness of early education (as assessed by outcomes, such as math achievement tests) shows that explicit math teaching sessions bring relevant additional value to unguided and more free-play curriculum. This is particularly true for children with weaker early number skills (Lewis Presser, Clements, Ginsburg and Ertle, 2015). However, if the assessment of math skills only includes more formal skills, this potentially misses skills that are developed in play-based pedagogy typically used in early education settings or informal contexts outside school. Children at this age (i.e., 4–7 –year-olds) do not easily transfer the skills they learned into a new context (Fullo, 2005). Children also learn more informal mathematical skills, adapted to play and real-life situations. It is therefore important to include measures that capture more informal mathematical skills in research with children in this age group. For instance, in traditional mathematics achievement tests, the mathematical tasks are already very clearly formulated by specific questions for the children. Thus, the task is only to solve the mathematical problem that is explicitly defined, while in real life situations, noticing mathematical aspects and formulating the problem are the starting points of mathematical activities, which the child often needs to do on its own (Hannula & Lehtinen, 2005; Hannula, Mattinen, & Lehtinen, 2005). If we want to have a good understanding of children's mathematical skills, we should not limit our assessments to formal mathematical skills but also include more informal ones.

With the growing interest in the development of mathematical skills, researchers have examined the types of early numeracy experiences that may be important for later mathematics, both in the home (e.g., Gunderson & Levine, 2011; Skwarchuk et al., 2014; see Daucourt et al., 2021 for a meta-analysis) and in preschool settings (e.g., Ginsburg et al., 2008; Klibanoff et al., 2006). One strand of research has highlighted the role of children's spontaneous focusing on numerosity (SFON); that is, the extent to which a child recognizes and uses numbers of items spontaneously in his/her everyday environment (Hannula & Lehtinen, 2005; Rathé, Hannula-Sormunen, De Smedt, & Verschaffel, 2016; McMullen et al., 2019, for a review). Such numerical activities are known to foster formal mathematical skills. Since its first description, SFON has been shown to correlate with concurrent numerical skills (Batchelor, Inglis, & Gilmore, 2015; Bojorque, Torbeyns, Hannula-Sormunen, Van Nijlen, & Verschaffel, 2017; Edens & Potter, 2012; Gray & Reeve, 2016; Hannula, Räsänen, & Lehtinen, 2007; McMullen, Chan, Mazzocco, & Hannula-Sormunen, 2019; Rathé, Torbeyns, De Smedt, & Verschaffel, 2021), and to be a domain-specific predictor of later mathematical performance (Hannula et al., 2007; Hannula, Lepola, & Lehtinen, 2010; Batchelor et al., 2015; McMullen et al., 2019; Bojorque et at., 2018; Gloor et al., 2021; Hannula-Sormunen, Batchelor, Torbeyns, Simms, Nanu, Laakkonen, & De Smedt, 2021). SFON tendency, measured by several SFON tasks across different task contexts, indicates the child́s amount of self-initiated practice in exact number recognition in everyday surroundings (Hannula & Lehtinen, 2005). Some evidence suggests that there is a reciprocal relation between SFON tendency and number skills before school age (Hannula & Lehtinen, 2005). Studies conducted in one country documented age effects between children and adults (Mazzocco, 2017) while Poltz et al. (2022) recently demonstrated in 5-year-old children a significant increase in SFON tendency during a nine-month follow-up. Intervention studies have shown that SFON tendency can be enhanced through guided activities in daycare centers and preschools (Bojorque, Torbeyns, Van Hoof, Van Nijlen, & Verschaffel, 2018; Hannula & Lehtinen, 2005; Mattinen, 2006; Hannula-Sormunen, Nanu, Luomaniemi, Heinonen, Sorariutta, Södervik, & Mattinen, 2020) as well as through parent - child interaction in informal settings (Braham et al., 2018). A recent review summarized specific task and intervention effects in SFON (McMullen, Chen, Mazzocco, Hannula-Sormunen, 2019 for a review).

Arithmetical skills start to develop before children are enrolled in formal education, but written arithmetic is typically taught in school. Addition and subtraction with concrete objects and solving word problems that include number words are early manifestations of arithmetical skills (for reviews, Fuson, 1988; Ginsburg, 1977; Clements and Sarama, 2014). While expanding their numerical competencies and learning number symbols, children start integrating the verbal representations of operations with numbers into written arithmetic. Arabic number knowledge is a stepping-stone in the development of formal arithmetical skills (Habermann et al., 2020). Thus, measures of both verbal and written arithmetic as well as Arabic number knowledge are relevant to capture mathematical skills during transition from early education to primary school (Aunola et al., 2004; Hannula et al., 2010).

In the current study, we examined age group differences in SFON and arithmetical skills before formal school and in early primary school education. We directly compared outcomes across and within four countries where the compulsory age for starting school varies from 4–7 years. We investigated age differences in SFON tendency and arithmetical skills across four age groups (4, 5, 6 and 7 years, respectively) from four different countries (Northern Ireland, England, Belgium and Finland), all of whom started school, and started to receive formal mathematics instruction, at different ages (4, 5, 6 and 7 years, respectively). We used selected age groups based on the start of the schooling in each country. For brevity, and also because children in these countries started to receive formal mathematics instruction at different ages, we will use the term "country" that will encapsulate differing school starting ages and other country-related educational differences.

We had the following research questions:

1. How do children in different age groups differ in their SFON tendency and arithmetical skills?

2. How do children of same age group who are in school compared to those not yet in school differ in their SFON tendency and arithmetical skills?
3. What are the age group differences in SFON and arithmetical skills across and within each of the four investigated countries?

In answering these questions, we also considered country-related differences in children's SES and their home numeracy activities.

1. Method

1.1. Participants

Participants were 685 children aged 4–7 years, recruited from preschools and schools in Northern Ireland, England, Belgium (Flanders) and Finland. This study is part of a larger research project called International Comparison of Children's Attention and Learning, ICCAL.[1] Preschools and schools were selected from middle SES neighborhoods in each country, and data were collected in the 2016 spring/summer term. Demographic information was gathered from teachers at participating schools, and descriptions of the educational context in each country can be found in the Supplementary Material, Appendix A. Questionnaires were circulated to parents to ascertain family characteristics and the frequency of numerical activities taking place in the home (Appendix B).

1.2. Procedure

All procedures followed the guidelines of the ethical advisory board at each institution. All parents gave written informed consent and children gave verbal assent. Children participated in two 20–30-minute testing sessions separated by a short break. During Session 1 children completed four SFON tasks in the following order: Imitation with Bird, Picture task, Imitation with Postbox, and Memory Card Game. During Session 2, they completed three arithmetical tasks: Arabic number naming, verbal arithmetic and written arithmetic. Testing took place on a one-to-one basis with a researcher (all trained using group sessions and video-recordings), and the tasks were presented in the same order for every child. Between each task children completed a short physical activity to refocus their attention and maintain their engagement level.

During the tasks, children received general praise, but no specific feedback. The researcher ensured that the testing area was free from any numerical displays that might have prompted the children to focus on number (during Session 1) or helped them to solve a numerical problem (during Session 2). To keep the numerical aspect of the study concealed, children, parents and teachers were told that the study was an international comparison of children's attention and learning.

1.3. Measures

To capture SFON tendency, rather than children's performance on specific SFON tasks we used a set of SFON measures (imitation tasks, a memory card game and a picture description task; Gray & Reeve, 2016; Hannula & Lehtinen, 2005; Hannula et al., 2005). To capture arithmetical skills, Arabic number naming, verbal and written arithmetical tasks were used. Average of proportion correct scores were created separately for SFON tendency and arithmetical skills.

1.3.1. SFON tendency

Imitation Task with Bird (Hannula & Lehtinen, 2005). In this action-based SFON task, children sat next to the researcher in front of a bird puppet (Elsi) and two tubs of coloured beads (berries). The researcher fed a given number of berries into the bird's mouth, with an over-exaggerated hand movement, and asked the child to do the same. The numerosities were two red and one blue (Trial 1), three green and two white (Trial 2), and two yellow and three light blue (Trial 3). For each trial children scored 0 or 1, depending on whether they focused on numerosity. They were scored as focusing on numerosity if they fed the same total number of berries as the researcher, and/or if they showed any signs of counting (e.g., finger counting), number word utterances or comments revealing the numerical goal of the task. Children received a total score out of three (Cronbach's alpha =.75).

Picture Task (Batchelor et al., 2015). In this verbal-based SFON task, the researcher showed the child a cartoon, picture and asked: "What can you see in this picture?" There was no time limit to respond. When the child appeared to have finished the researcher asked: "Is that everything?" before proceeding to the next trial. Responses were audio-recorded and transcribed. Each picture contained several small arrays (of objects, people or animals) that could be enumerated. For each of three trials, children scored 0 or 1, depending on whether they focused on numerosity. They were scored as focusing on numerosity if their description included any number word utterance (e.g., "three chickens, "two children", "four flowers") regardless of whether they had enumerated the array correctly. Because in Dutch the word for "a" is the same as the word for "one", we excluded the number word "one" from responses from the entire sample to avoid language effects. Children received a total score out of three (Cronbach's alpha =.71).

Imitation Task with Postbox (Hannula & Lehtinen, 2005). The procedure and scoring of this action-based SFON task were the same as the Bird version, except the materials were a toy postbox and piles of coloured envelopes. The numerosities were one orange and two

[1] Nanu, Laakkonen and Hannula-Sormunen (2020) published a person-centered analysis of the same dataset, investigating the question as to whether the effects of schooling are different dependent on children mathematical skill profile. The current study was conceptualized, designed, analyzed and drafted before Nanu et al.

green (Trial 1), two brown and three yellow (Trial 2), and three blue and two pink (Trial 3). For each trial children scored 0 or 1, giving a total score out of three (Cronbach's alpha =.71).

Memory Card Game (developed from Hannula, Grabner, & Lehtinen, 2009). In this verbal-based SFON task, children were asked to look at a card, memorize it and, immediately after turning it over, describe the card so that the researcher could find a matching card from their cards. Detailed test instructions can be found from https://osf.io/tk8wb There were four sets of cards. The child had one card from each set and the researcher had four cards from each set. On each trial the researcher asked the child to turn over their top card and look at it for 5 s. The researcher then asked the child to turn the card face-down and describe what was on the card so that they could find the matching card from their pile, which was briefly flashed to the child to show that the cards were "very similar" and thus careful description was needed. There was no time limit to respond. When the child stopped, the researcher asked: "What else do you remember about this card?" The trial then finished with the researcher playfully trying to find the matching card from their pile. There was one practice trial followed by three test trials. Responses were audio recorded and transcribed. For each trial children scored 0 or 1, depending on whether they focused on numerosity. They were scored as focusing on numerosity if their description included any number words and/or if the researcher observed any signs of counting (e.g., finger counting), or comments about the numerical goal of the task. As with the Picture Task we excluded the number word "one" to avoid language effects. Children received a total score out of three (Cronbach's alpha =.74).

As we were interested in general SFON tendency (see, Hannula & Lehtinen, 2005; Hannula, Mattinen, & Lehtinen, 2005) and how it manifests across different contexts and activities, children's scores on the four SFON tasks were summed to create a SFON tendency score out of 12 (Cronbach's alpha =.85). An overall proportion score (ranging 0–1) was then calculated and used in all analyses.

1.3.2. Arithmetical skills

Arabic Number Naming Task. Children were asked to read aloud a series of Arabic numerals. There were 10 blocks with 3 trials per block (ranging one- to five- multi-digit numbers). The test was discontinued when a child made a mistake on all three items within a block. Children scored one point for each correct identification giving a total score out of 30 (Cronbach's alpha =.96).

Verbal Arithmetic Task (developed from Hannula & Lehtinen, 2005). Children were asked to solve a series of verbal arithmetic problems (12 additions and 12 subtractions). The addition and subtraction subtests both started with 3 concrete problems (where the researcher demonstrated the problem with 'sweeties') followed by 9 problems without demonstration. The problems increased in difficulty, ranging one- to two-digit addends and subtrahends. Each subtest was discontinued when a child made two consecutive mistakes, and the next subtest was started. Children scored one point for each correct solution, giving a total score out of 24 (Cronbach's alpha =.94).

Written Arithmetic Task (developed from Aunola et al., 2004). Children were asked to solve a series of written arithmetic problems. The addition and subtraction subtests both comprised 4 blocks, with 6 problems per block. The problems increased in difficulty, ranging one- to three-digit addends and subtrahends. Each subtest was discontinued when a child made two or more mistakes within a block. Children scored one point for each correct solution, giving a total score out of 48 (Cronbach's alpha was.93).

A proportion correct score was calculated for each of the arithmetical tasks: Arabic number naming, verbal arithmetic and written arithmetic. These proportion correct scores were then averaged to create a composite measure of arithmetical skills with scores ranging 0–1. Cronbach's alpha across all these 103 items in the three measures was.98.

1.3.3. SES and numerical activities at home

SES and home numeracy data were collected via a questionnaire from mothers of participants. SES was operationalized by asking mother's occupation, education and income. It was further modeled as a formative measure using principal component analysis (e.g. Caro & Cortés, 2012). The home numeracy environment was measured by the frequency of numerical activities at home. Mothers indicated on a 7-point Likert scale how often their child performed number-related activities at home. The average of five items was used. The score with higher values indicate more frequently occurring activities (see Supplementary Material, Appendix B).

2. Results

Descriptive statistics for children's age, gender, SES and the frequency of numerical activities in the home environment, SFON tendency and arithmetical skills are presented in Table 1.

There was 30 % missing data for the questionnaire based self-report measures of SES and the frequency of numerical activities at home. Data was not randomly missing, children whose parents returned questionnaires had slightly higher mathematical skills than those who did not ($M = 0.56$, $SD = .29$, $M = 0.44$, $SD = .31$, t(683) = 4.72, $p < .001$, $d = .29$ for SFON tendency and $M = 0.45$, $SD = .25$, $M = 0.36$, $SD = .25$, $t(682) = 4.19$, $p < .001$, $d = .25$ for arithmetical skills). In addition, we have one missing value for arithmetical skills measures, 7 missing values in the picture description task and 12 missing values in memory card game. No missing data replacement system was used. Table 2 presents the descriptive statistics for all variables by country.

A one-way ANOVA revealed a significant difference in age across countries (see Table 2), $F(3, 681) = 8.99$, $p < .001$, $\eta_p^2 = .04$. Post-hoc comparisons with Bonferroni correction showed that children in Northern Ireland, $M = 68.98$ months, $SD = 14.66$, and England, $M = 66.99$ months, $SD = 13.57$ were significantly younger than those in Belgium, $M = 73.22$ months, $SD = 13.50$, and Finland, $M = 73.46$ months, $SD = 13.44$ (Northern Ireland vs. Belgium, $t(357) = -2.84$, $p = .023$, $d = -0.30$; Northern Ireland vs. Finland, $t(341) = -2.93$, $p = .017$, $d = -0.32$; England vs. Belgium, $t(340) = -4.25$, $p < .001$, $d = -0.46$; England vs. Finland, $t(324) = -4.32$, $p < .001$, $d = -0.48$). These age differences are due to the cut-off date for entry to school is January in Belgium and Finland, July for

Table 1
Age, gender, SES, frequency of numerical activities at home, SFON tendency and arithmetical skills in entire sample and across age groups.

	Full sample $N = 685$		4-year-olds $n = 176$		5-year-olds $n = 166$		6-year-olds $n = 169$		7-year-olds $n = 174$	
	M (SD)	[Min, Max]	*M (SD)*	[Min, Max]	*M (SD)*	[Min, Max]	*M (SD)*	[Min, Max]	*M (SD)*	[Min, Max]
Age (in months)	70.6 (14.07)	[40,97]	53.02 (4.86)	[40,62]	64.56 (4.43)	[55,73]	76.88 (5.02)	[65,92]	88.06 (4.56)	[79,97]
Gender (female)	362		96		75		90		101	
SES*	0.00 (1.00)	[− 3.02, 2.43]	.14 (.91)	[− 2.34, 2.12]	.21 (.93)	[− 2.06, 2.43]	-.11 (1.07)	[− 2.74, 2.12]	-.13 (1.04)	[− 3.03, 1.95]
Frequency of numerical activities at home*	3.68 (0.91)	[0.2, 6.0]	3.48 (0.95)	[0.2, 6.0]	3.73 (0.9)	[1.2, 5.6]	3.71 (0.92)	[1.4, 5.8]	3.80 (0.88)	[0.6, 5.6]
SFON tendency	0.52 (0.30)	[0,1]	0.27 (0.23)	[0, 0.92]	0.47 (.26)	[0,1]	0.60 (0.26)	[0,1]	0.76 (0.21)	[0,1]
Arithmetical skills	0.42 (0.25)	[1,1]	0.15 (0.08)	[0.01, 0.42]	0.29 (0.11)	[0.06, 0.64]	0.53 (0.14)	[0.17, 0.84]	0.73 (0.14)	[0.38, 1]

Note. * $N = 482$, 30.6 % missing data.

Table 2
Age, gender, SES, frequency of numerical activities at home, SFON tendency and arithmetical skills across countries.

	Northern Ireland ($n = 185$)		England ($n = 168$)		Belgium ($n = 174$)		Finland ($n = 158$)	
	n	*M (SD)*	*n*	*M (SD)*	*n*	*M (SD)*	*n*	*M (SD)*
Age	185	68.98 (14.66)	168	66.99 (13.57)	174	73.22 (13.50)	158	73.46 (13.44)
Gender								
Female	82		75		91		75	
Male	103		93		83		83	
SES	110	-0.18 (1.07)	110	-0.06 (1.01)	126	0.30 (0.95)	136	-0.09 (0.92)
Numerical activities at home	127	4.07 (0.93)	116	3.94 (0.81)	144	3.40 (0.90)	141	3.40 (0.90)
SFON tendency	185	0.44 (0.29)	168	0.46 (0.31)	174	0.63 (0.27)	158	0.57 (0.29)
Arithmetical skills	184	0.40 (0.25)	168	0.43 (0.25)	174	0.45 (0.27)	158	0.41 (0.24)

Northern Ireland and September in England.

There was also a significant difference in SES across countries, $F(3, 478) = 5.71$, $p = .001$, $\eta_p^2 = .04$, such that SES was significantly higher in Belgium than it was in Northern Ireland, $t(234) = 3.67$, $p = .001$, $d = 0.47$, England, $t(234) = 2.84$, $p = .029$, $d = 0.37$, and Finland, $t(260) = 3.37$, $p = .009$, $d = 0.42$. There were no other SES-differences between countries.

There was a significant difference in the frequency of numerical activities at home across countries, $F(3, 524) = 21.73$, $p < .001$, $\eta_p^2 = .11$. Parents of children in Northern Ireland and England reported a greater frequency of numerical activities in the home than parents of children in Belgium and Finland (countries with a later school starting age): Northern Ireland vs. Belgium, $t(269) = 6.00$, $p < .001$, $d = 0.73$; Northern Ireland vs. Finland, $t(266) = 6.26$, $p < .001$, $d = 0.76$; England vs. Belgium, $t(258) = 4.98$, $p < .001$, $d = 0.63$; England vs. Finland, $t(255) = 5.24$, $p < .001$, $d = 0.66$).

Given these significant differences, we included age, SES and the frequency of numerical activities in the home environment as covariates in our analyses. In the following sections, we always describe group comparisons first without controlling for these covariates and next with taking these covariates (age, SES and home environment) additionally into account.

2.1. How do children in different age groups differ in their SFON tendency and arithmetical skills?

Two one-way ANOVAs were run with age group (4, 5, 6, 7) as independent variable and SFON tendency or arithmetical skills as the dependent variable (Table 1). Results showed a significant effect of age group on both SFON, $F(3, 681) = 130.74$, $p < .001$, $\eta_p^2 = .36$ and arithmetical skills, $F(3, 680) = 780.67$, $p < .001$, $\eta_p^2 = .78$. Contrasts showed significant increase in performance across consecutive age groups for SFON tendency (between 4 and 5 years old age groups, $M_{diff} = 0.21$, $p < 0.001$, 95 % CI [0.14, 0.27], between 5 and 6 years old age groups, $M_{diff} = 0.13$, $p < 0.001$, 95 % CI [0.06, 0.20] and between 6 and 7 years old age groups, $M_{diff} = 0.16$, $p < 0.001$, 95 % CI [0.09, 0.22]), and arithmetical skills (between 4 and 5 years old age groups, $M_{diff} = 0.14$, $p < 0.001$, 95 % CI [0.10, 0.17] between 5 and 6 years old age group, $M_{diff} = 0.24$, 95 % CI [0.20, 0.27], and between 6 and 7 years old age groups, $M_{diff} = 0.20$, $p < 0.001$, 95 % CI [0.17, 0.24]).

One-way ANCOVAs with SES and numerical activities at home as covariates showed similar effects of age group on SFON tendency, $F(3, 476) = 83.63$, $p < .001$, $\eta_p^2 = .35$ but smaller effect size on arithmetical skills, $F(3, 475) = 504.67$, $p < .001$, $\eta_p^2 = .36$. The differences between the age groups remained significant for both SFON tendency (between 4 and 5 years old age groups, $M_{diff} = 0.19$, $p < 0.001$, 95 % CI [0.10, 0.27] between 5 and 6 years old age groups, $M_{diff} = 0.14$, 95 % CI [0.06, 0.22] and between 6 and 7 years old age groups, $M_{diff} = 0.15$, $p < 0.001$), 95 % CI [0.06, 0.22], and arithmetical skills (between 4 and 5 years old age groups, $M_{diff} = 0.14$, $p < 0.001$, 95 % CI [0.09, 0.18] between 5 and 6 years old age group, $M_{diff} = 0.25$, $p < 0.001$, 95 % CI [0.20, 0.29]and between 6 and 7 years old age groups, $M_{diff} = 0.19$, $p < 0.001$, 95 % CI [0.15, 0.23]).

2.2. How do children of same age group who are in school compared to those not yet in school differ in their SFON tendency and arithmetical skills?

Two separate series of 4 × 2 ANOVAs were run with age group (4, 5, 6, 7) and not in school/in school as independent variables and SFON tendency or arithmetical skills as the dependent variable (Fig. 1a and b). For SFON tendency, results revealed significant main effect of age group, $F(3, 672) = 122.33$, $p < .001$, $\eta_p^2 = .35$, a significant main effect of not in school/in school $F(1, 678) = 35.63$, $p < .001$, $\eta_p^2 = .05$ and a significant interaction effect, $F(2, 677) = 3.64$, $p = .02$, $\eta_p^2 = .01$. For arithmetical skills, the main effect of age group was significant, $F(3, 677) = 537.56$, $p < .001$, $\eta_p^2 = .70$, the main effect of not in school/in school was not significant, $F(2, 677) = 3.68$, $p = .055$, $\eta_p^2 = .01$, and the interaction effect was not significant, $F(2, 677) = 0.85$, $p = .427$, $\eta_p^2 = .00$.

When age, SES and numerical activities at home were included as covariates in the 4 × 2 ANCOVA with SFON as dependent variable, the main effect of age group was no longer significant, $F(3, 472) = 0.54$, $p = .653$, $\eta_p^2 = .00$, the main effect of not in school/in school remained significant, $F(1, 472) = 4.93$, $p < .05$, $\eta_p^2 = .01$, whilst the interaction effect was also no longer significant, $F(2, 472) = 1.71$, $p = .183$, $\eta_p^2 = .01$. For arithmetical skills, while controlling for age, SES and numerical activities at home, the main age group effect was significant, $F(3, 471) = 14.70$, $p < .001$, $\eta_p^2 = .09$, the main effect of not in school/in school was not significant, $F(1, 471) = 0.21$, $p = .651$, $\eta_p^2 = .00$, and the interaction effect was not significant, $F(2, 471) = 0.88$, $p = .414$, $\eta_p^2 = .00$.

Pairwise comparisons with Bonferroni correction showed that children not in school had significantly higher SFON tendency scores compared to children in school in the 5-year-old age group, $M_{diff} = 0.19$, $p < .001$, 95 % CI [0.10, 0.27] and in the 6-year-old age group, $M_{diff} = 0.16$, $p < .001$, 95 % CI [0.07, 0.24] whilst the difference was not significant in the 4-year-old age group, $M_{diff} = 0.05$, $p = .172$, 95 % CI [−0.02, 0.13]. Results were similar when controlling for covariates (4-year-old age group, $M_{diff} = - 0.01$, $p = .854$, 95 % CI [−0.12, 0.10]; 5-year-old age group, $M_{diff} = 0.09$, $p = .037$, 95 % CI [0.01, 0.18]; 6-year-old age group, $M_{diff} = 0.12$, p = .011, 95 % CI [0.03, 0.21]).

For arithmetical skills, no significant differences were found between children not in school compared to those in school in any of the age groups (4-year-old age group, $M_{diff} = - 0.04$, $p = .050$, 95 % CI [−0.08, 1.19], 5-year-old age group, $M_{diff} = - 0.03$, $p = .153$, 95 % CI [−0.01, 0.06] and 6-year-old age group, $M_{diff} = 0.00$, $p = .958$), 95 % CI [− 0.04, 0.04]. Again, the results remained similar after controlling for covariates (4-year-old age group, $M_{diff} = - 0.02$, $p = .544$, 95 % CI [−0.04, 0.07]; 5-year-old age group, $M_{diff} = - 0.01$, $p = .732$, 95 % CI [−0.05, 0.04]; 6-year-old age group, $M_{diff} = - 0.03$, $p = .193$, 95 % CI [−0.07, 0.02]).

2.3. What are the age group differences in SFON and arithmetical skills across, and within, each of the four investigated countries?

Two separate series of 4 × 4 ANOVAs were run with age group (4, 5, 6, 7) and country (Northern Ireland, England, Belgium, Finland) as independent variables and SFON tendency or arithmetical skills as the dependent variable (Fig. 2a and b).

For SFON tendency, the results showed a significant main effect of country, $F(3, 669) = 31.62$, $p < .001$, $\eta_p^2 = .12$, a significant main effect of age group, $F(3, 669) = 152.75$, $p < .001$, $\eta_p^2 = .41$, and a significant country by age group interaction $F(9, 669) = 2.90$, $p = .002$, $\eta_p^2 = .04$. The significant interaction suggests that the effect of country is different for different age groups.

When we controlled for age, SES and numerical activities at home, we found a significant main effect of country, $F(3, 463) = 9.45$, $p < .001$, $\eta_p^2 = .06$, but no significant main effect of age group, $F(3, 463) = 2.43$, $p = .065$, $\eta_p^2 = .02$. However, the significant interaction

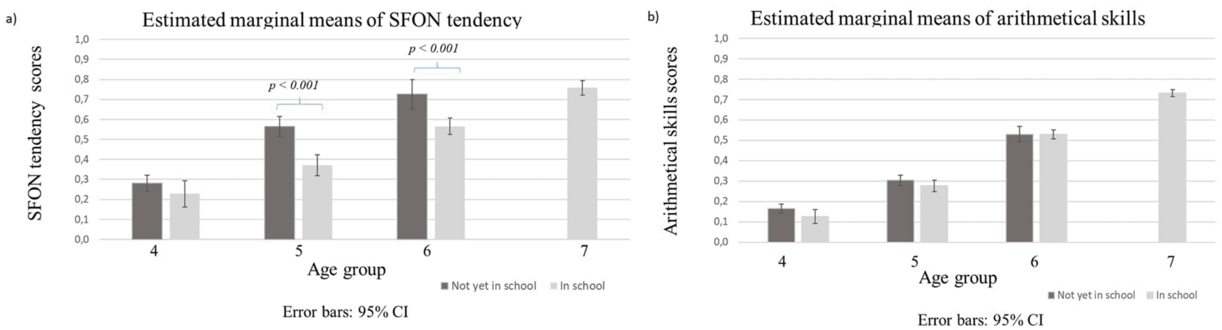

Fig. 1. Estimated marginal means and standard errors of SFON tendency (a) and arithmetical skills (b) by cross-sectional data of age group and not in school / in school groups.

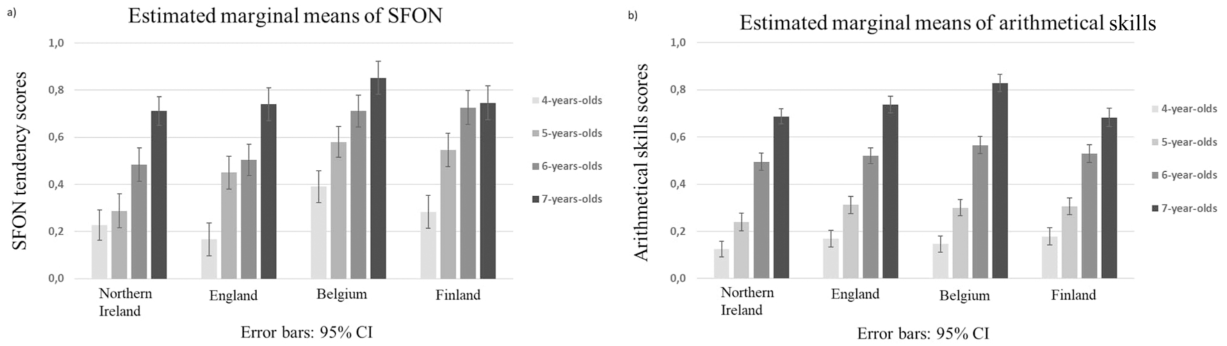

Fig. 2. Estimated marginal means and standard errors of SFON tendency score (a) and arithmetical skills score (b) by age group and country.

between country and age group, $F(9, 463) = 2.80$, $p = .003$, $\eta_p^2 = .05$ remained.

For arithmetical skills, there was a significant main effect of country, $F(3, 668) = 12.36$, $p < .001$, $\eta_p^2 = .05$, a significant main effect of age group, $F(3, 668) = 839.87$, $p < .001$, $\eta_p^2 = .79$, and a significant country by age group interaction, $F(9, 668) = 3.52$, $p < .001$, $\eta_p^2 = .05$.

Again, these results held when we controlled for age, SES, and the frequency of numerical activities at home. A 4 × 4 ANCOVA including all three covariates showed a significant main effect of country, $F(3, 462) = 7.29$, $p < .001$, $\eta_p^2 = .05$, a significant main effect of age group, $F(3, 462) = 12.58$, $\eta_p^2 < .001$, $\eta_p^2 = .08$, and a significant country by age group interaction, $F(3, 462) = 3.82$, $p < .001$, $\eta_p^2 = .07$.

To investigate country differences within each age group, we ran planned comparisons with Bonferroni correction (Table 3).

In the 4-year-old age group, children from Belgium outperformed children from Northern Ireland and England. In the 5-year-old age group, children from Northern Ireland, who started school at the age of four, had significantly lower SFON tendency score compared to children from England, Belgium and Finland, these results remained significant after controlling for covariates. In the 6-year-old age group, England, (where formal school starts at five) aligned with Northern Ireland in significantly lower SFON tendency scores compared to Belgium and Finland, and this difference remained significant after controlling for covariates. In the 7-year-old groups, only Belgian children scored significantly higher than children in Northern Ireland, but this difference did not remain significant after controlling for covariates.

Table 3
SFON tendency and arithmetical skills planned comparisons of age groups between each country.

Age group	Country		ANOVA		ANCOVA with age, SES and numerical activities at home[a]		ANOVA		ANCOVA with age, SES and numerical activities at home[a]	
			SFON tendency				*Arithmetical skills*			
4	Northern Ireland	England	0.06	1.000	0.09	1.000	-0.04	.420	-0.06	.550
		Belgium	-0.16 *	.003	-0.09	.983	-0.02	1.000	0.02	1.000
		Finland	-0.06	1.000	-0.01	1.000	-0.06	.154	-0.02	1.000
	England	Belgium	-0.22 *	< .001	-0.18 *	.042	0.02	1.000	0.09	.086
		Finland	-0.12	.111	-0.10	.864	-0.01	1.000	0.04	1.000
	Belgium	Finland	0.11	.162	0.07	.693	-0.03	1.000	-0.04	.727
5	Northern Ireland	England	-0.16 *	.008	-0.19 *	.009	-0.07*	.039	-0.11*	.002
		Belgium	-0.29 *	< .001	-0.23 *	<.001	-0.06	.101	-0.02	1.000
		Finland	-0.26 *	< .001	-0.22 *	<.001	-0.07	.070	-0.07	.190
	England	Belgium	-0.13 *	.043	-0.04	1.000	0.01	1.000	0.10*	.014
		Finland	-0.09	.334	-0.03	1.000	0.01	1.000	0.05	.707
	Belgium	Finland	0.03	1.000	0.01	1.000	-0.01	1.000	-0.05	.575
6	Northern Ireland	England	-0.02	1.000	-0.01	1.000	-0.03	1.000	-0.05	.480
		Belgium	-0.23 *	< .001	-0.21 *	.002	-0.07*	.030	-0.03	1.000
		Finland	-0.24 *	< .001	-0.23 *	<.001	-0.03	1.000	0.01	1.000
	England	Belgium	-0.21 *	< .001	-0.20 *	.004	-0.05	.408	0.03	1.000
		Finland	-0.22 *	< .001	-0.22 *	.002	-0.01	1.000	0.06	.238
	Belgium	Finland	-0.02	1.000	-0.02	1.000	0.04	.883	0.04	1.000
7	Northern Ireland	England	-0.03	1.000	0.02	1.000	-0.05	.215	-0.05	.439
		Belgium	-0.14 *	.015	-0.14	.084	-0.14 *	<.001	-0.11*	.002
		Finland	-0.03	1.000	0.02	1.000	0.00	1.000	0.04	.958
	England	Belgium	-0.11	.149	-0.16	.050	-0.09 *	.003	-0.06	.419
		Finland	-0.01	1.000	-0.00	1.000	0.06	.223	0.09*	.014
	Belgium	Finland	0.11	.216	0.16 *	.035	0.15 *	<.001	0.14*	<.001

Note. *Significant with Bonferroni correction. [a] $N = 482$, 30.6 % missing data for SES and numerical activities at home.

Table 4
SFON tendency and arithmetical skills planned comparisons of consecutive age groups in each country. Bolded the non-significant differences.

Country	Age groups					
	5 vs. 4		6 vs. 5		7 vs. 6	
	M_{diff}	*p*	M_{diff}	*p*	M_{diff}	*p*
SFON tendency						
Northern Ireland	**0.06**	**.197**	0.20	<.001	0.23	<.001
England	0.28	<.001	**0.05**	**.294**	0.24	<.001
Belgium	0.19	<.001	0.13	.004	0.14	.003
Finland	0.26	<.001	0.18	.001	**0.02**	**.713**
Arithmetical skills						
Northern Ireland	0.16	<.001	0.26	<.001	0.19	<.001
England	0.14	<.001	0.21	<.001	0.22	<.001
Belgium	0.16	<.001	0.27	<.001	0.26	<.001
Finland	0.13	<.001	0.22	<.001	0.15	<.001

Note. Significant at the Bonferroni-corrected alpha level of.0042

In arithmetical skills, planned contrasts did not show any pattern in differences between the countries except for Belgian children scoring significantly higher. When controlling for age, SES, and the frequency of numerical activities at home, children from Belgium significantly outperformed children from England in the 5-year-old age and children from Northern Ireland in the 7-year-old age group. Children from England outperformed children from Northern Ireland in the 5-year-old age group. In the 7-year-olds, Finnish children scored higher than English children.

To investigate differences in SFON tendency and arithmetical skills within each country, a series of planned comparisons were run between consecutive age groups for each country. Results showed significant differences between all consecutive groups except for the groups situated around school starting point (Table 4). As illustrated in the table, in Northern Ireland and England, we found no differences in SFON between age groups from first and second grade of primary education, while in Finland we found no significant difference between the age group of children from preschool and the first grade of primary school. For arithmetical skills, significant differences were found between all consecutive age groups.

2.4. Discussion

The aim of the present study was to investigate age group differences in SFON tendency and arithmetical skills by comparing groups of children from four European countries where school starts at 4, 5, 6, and 7 years of age. The naturally occurring age groups within each educational system were used as grouping criteria. First, age group differences in SFON tendency and arithmetical skills across the whole sample were investigated. Second, children already in school were compared with those of same age but not yet in school. Third, age group differences across and within each country were investigated.

Results revealed strong age group effects, indicating substantial development of SFON tendency and arithmetical skills from the age of 4–7 years. Differences between the age groups in school and the same age groups not in school were found for SFON tendency but not for arithmetical skills, suggesting that while arithmetical skills develop similarly, irrespective of the nature of educational settings, SFON tendency is more variable. In 5- and 6-year-old age groups, children not in school outperformed those already in school in SFON tendency. These differences remain significant even after controlling for chronological age, SES and numerical activities at home.

Further investigation of the differences across countries showed a significant main effect of country and a significant interaction between country and age group, after controlling for chronological age, SES and numerical activities at home, suggesting that there are significant differences in SFON tendency and arithmetical skills in same age groups between different countries. Planned contrasts with Bonferroni correction showed that after controlling for chronological age, SES and numerical activities at home, in the 5-year-old age group, children from Northern Ireland, where school starts at 4 had significantly lower SFON tendency scores compared to children from Belgium and Finland when school starts later. In the 6-year-old age group, children from both Northern Ireland and England had significantly lower scores compared to children from Finland who were still in preschool suggesting that differences in SFON tendency scores manifest later, after one year of formal schooling. Differences in arithmetical skills did not show any such patterns, only Belgian children outperformed the other countries in different age groups, a difference that remained significant after controlling for SES.

Within each country, when comparing consecutive age groups, no significant differences were found in SFON around school starting age in three out of the four countries. In arithmetical skills, all consecutive age groups significantly differed. Given the cross-sectional nature of the data, there seem to be interesting tentative differences in the developmental pattern between arithmetical skills and SFON tendency. While arithmetical skills increase steadily across all age groups, the increase of SFON tendency shows temporary flattening during first year of formal schooling in all but one country. This is an interesting preliminary finding that is worthy of further investigation. More studies on this phenomenon focused at differences of mathematics learning before and after start of formal schooling should be conducted. It is important to investigate features of educational environments that foster the development of mathematical competencies needed in real life situations. This is particularly important given that previous research has identified that the preschool education has special emphasis on mathematical skill development, it improves not only numerical skills but also SFON (Bojorque et al., 2018).

2.5. Implications

The results do not necessarily indicate that educational context, i.e. school, is irrelevant for mathematical learning outcomes. In principle, the countries differ in the onset of "formal mathematics instruction", but the content of the activities children engage with at different ages could resemble each other to some extent, even though there are substantial differences in the curricula of different countries. For example, in the two English-speaking countries, written arithmetic starts at an earlier age than in both Belgium and Finland, particularly in comparison to Finland. Further examination of the types of numerical activities taking place in the different educational settings will help to shed light on how much the day-to-day mathematical curriculum and activities differ.

These findings also raise interesting questions about the developmental nature of SFON tendency. The strong age effects suggest that SFON tendency develops from four to seven years old, a result in line with previous research (Mazzoco et al., 2017; Poltz et al., 2022). The result that in 5- and 6-year-old, SFON tendency is higher among children not yet in school along with the lack of difference in SFON tendency when comparing consecutive age groups around school start age suggests that less formal teaching of math content might create a more favorable context for SFON tendency. The flattening of SFON tendency around school entry may reflect a changed focus in mathematics learning from seeing math all around you to seeing mathematics as a more limited to a school subject. Because school teachers could view mathematics as more instruction- and textbook –based than early educators at day care and preschool, their practices may shift focus away from mathematical aspects needed for everyday activities to focusing attention on more narrow mathematical aspects as part of more formal mathematics tasks. These speculations open interesting new research avenues for future studies.

One factor that might affect both SFON tendency and arithmetical development is the home numeracy environment. Recent meta-analytic work suggests that, although significant, the association between the home environment and mathematical ability is small ($r = .13$) (Daucourt et al., 2021). Nevertheless, we accounted for the home environment in our analyses by controlling for parent-reported frequency of numerical activities at home. There is some preliminary evidence to suggest that home numeracy practices vary across cultures (Hornburg et al., 2021; LeFevre et al., 2010). For example, in Singapore, parents have higher expectations for their children's mathematical abilities than in Western societies, and there is a large emphasis on integrating mathematics instruction into real life activities (Bull & Lee, 2017). In our data, parents from Northern Ireland and England reported significantly more home numeracy activities compared to parents from Belgium and Northern Ireland. This suggests that it may be useful to look cross-culturally at parents' expectations and the numerical activities taking place at home, as well as in preschools and schools. Recent evidence even suggests that (cross-cultural) differences in the characteristics of the preschool system, i.e. the length of time per day children can attend and offers structured numerical activities, might explain differences between countries with regard to the home math environment and mathematical skill association (De Keyser et al., 2020). In all, combining information from the home and (pre) school environment would provide a richer understanding of the differences in early numeracy practices across countries. Parents may change their involvement in mathematics with their child when they start school. For example, Sonnenschein et al. (2012) showed that parental home numeracy activities differed between kindergarten and school children. This could mean that our measure of numerical activities at home contains activities that are more typical to children when they are in formal instruction. Selecting age-appropriate home numeracy practice measures may enable researchers to more accurately measure parent–child mathematics engagement at home as Thompson et al. (2017) and Huntsinger et al. (2016) suggest.

2.6. Limitations

There are a few limitations to the current study that need to be considered. First, our study is cross-sectional, thus no certain developmental or causal conclusions can be drawn based on our data. In addition, even though our total sample is rather large, sub-samples in each country and age group are relatively small. Generalizations at within-country and across-country levels should be treated with caution. Planned contrasts were done with rather small ($n = 40$) sub-groups, which limits the power of detecting differences in statistical analyses. In addition, due to differences in the cut-off date for entry to school, our samples in the same age groups have substantial age differences between the English speaking countries and Belgium/Finland. Also, SES was significantly higher in Belgium and numerical activities at home differed between the countries. For this reason, controlling for age, SES and numerical activity at home was a necessary step in our analyses. Unfortunately, not all parents' responded to the questionnaire, and the consequent drop out of participants in the analyses was not at random. The children, whose parent returned the questionnaire, had slightly higher mathematical skills than the ones whose parents did not return the questionnaire. This needs to be considered when interpreting the results. However, importantly, the analyses with and without controlling for SES and numerical activities showed substantially similar results.

3. Conclusions

In sum, this study compared children's SFON tendency and arithmetical skills in four countries where the compulsory age for starting school varies from 4–7 years. The results revealed very similar age group patterns across countries in arithmetical skills but not in SFON tendency, suggesting that the age at which children start formal mathematics instruction does not have a significant effect on arithmetical skills. However, a lagged effect could still be possible as suggested by the SFON tendency scores around school starting age. For SFON tendency, results raise a question whether early education settings are more stimulating for SFON tendency than formal school settings. Further investigation of this finding is needed. Overall, our results do not imply that educational context does not impact on mathematics learning. The countries involved in this study differ in what they describe as "formal schooling", but the activities children engage with at different ages may have been similar independent of context. Finally, the indications of developmental differences between SFON tendency and arithmetical skills in the current study suggest that it would be important to include both formal and informal measures in the future studies of young children's mathematical development.

Conflict of Interest

We have no known conflict of interest to disclose.

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Appendix A & B. Supporting information

Supporting information associated with this article can be found in the online version at doi:10.1016/j.cogdev.2023.101296.

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