Learning and Individual Differences 20 (2010) 427–435

Contents lists available at ScienceDirect

Learning and Individual Differences

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

Predicting children's mathematical performance in grade one by early numeracy

Pirjo Aunio [a,*], Markku Niemivirta [b]

[a] University of Jyväskylä, Finland
[b] University of Helsinki, Finland

ARTICLE INFO

Article history:
Received 22 September 2009
Received in revised form 16 June 2010
Accepted 29 June 2010

Keywords:
Early numeracy
Basic arithmetical skills
Children
Longitudinal study

ABSTRACT

This longitudinal study examined how children's early numeracy assessed in kindergarten predicts their mathematical performance in the first grade, after controlling for the effects of age, gender, and parents' education. The participants were 212 Finnish children (107 girls and 105 boys). At the time of the first assessment (kindergarten), the mean age was six years, and the second assessment was conducted one year later. The results demonstrate that the acquisition of counting and relational skills before formal schooling are predictive of the acquisition of basic arithmetical skills and overall mathematical performance in grade one, above and beyond the effects of demographic factors.

1. Introduction

This paper reports a follow-up study on children's mathematical skills from kindergarten to primary one. A number of longitudinal studies have been published recently on mathematical development in the transition phase from kindergarten (non-formal teaching) to primary school (formal teaching) among normally developing children. These studies have targeted cognitive antecedents (Aubrey, & Godfrey, 2003; Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; DeSmedt et al., 2009; Fayol, Barrouillet, & Marinthe, 1998; Kavkler, Tancig, & Magajna, 2003; Passolunghi, Mammarella, & Altoè, 2008; Stevenson, & Newman, 1986), family socioeconomic status and gender (Aunola et al., 2004) motivational factors related to learning mathematics and teachers' teaching goals (Aunola, Leskinen, & Nurmi, 2006), and parents' beliefs and parenting style (Aunola, & Nurmi, 2004; Huntsinger, Jose, Larson, Krieg, & Shaligram, 2000; Natale, Aunola, & Nurmi, 2009) as predictors of mathematical performance and development. In this study, we focused on early numeracy, the set of skills to operate with number–word sequence and to make relational statements in a numerical context, as a predictor of arithmetic skills and general mathematical competence in the first year of primary school, which deepens the current literature on the developmental relationships between different sets of mathematical skills.

1.1. Early numeracy and mathematical competence at the beginning of primary school

Bryant, and Nunes (2002) suggested that logical thinking, teaching of conventional counting systems, and a meaningful context for learning mathematics form the basis for children's early mathematical development. According to the research on logical principles (see Smith, 2002), the development of mathematical thinking is related to the children's growing abilities to understand and make relational statements (e.g., learning what it means that a number is equal to or more or less than another number), that is, the ability to compare, classify and understand one-to-one correspondence and seriation. Being able to detect one-to-one correspondence and to seriate is essential for understanding cardinality and ordinality, which, in turn, is important for understanding the number–word sequence (Bryant, 1996). The ability to numerically compare two sets is a vital aspect of conservation ability and other related forms of numerical reasoning (e.g., Sophian, 1998), while the ability to classify is a fundamental element of mathematical reasoning in general (Smith, 2002).

The learning of a conventional counting system in early childhood begins with the acquisition of whole-number–word sequence skills. Some authors consider these skills as the basis of children's growing number awareness (Fuson, 1988; Gelman, & Gallistel, 1978), which is a view different from that of emphasizing logical principles (Smith, 2002). It is possible to distinguish six stages in the development of such skills: primary understanding of amounts, and acoustic, asynchronic, synchronic, resultative and shortened counting (e.g., Fuson, 1988; Van de Rijt, 1996). Primary understanding of amounts emerges at around two years of age when children show knowledge of how the different number–words refer to a different number of objects, but at this stage only very basic discrimination of amounts is possible. When they are at the acoustic

* Corresponding author. Niilo Mäki Institute, P.O. Box 35, 40014 University of Jyväskylä, Finland. Tel.: +385 50 4343 408; fax: +358 14 260 29 08.
E-mail address: pirjo.aunio@nmi.fi (P. Aunio).

1041-6080/$ – see front matter
doi:10.1016/j.lindif.2010.06.003

counting stage, at around the age of three, they can say number–words, but not in the correct order, and they do not necessarily begin with one; it is as if they are reciting a nursery rhyme. When they reach the asynchronic stage, at around the age of four, they are able to say number–words in the correct order and to point to objects, but the words and pointing are not coherent. Six months later, at the synchronic stage, they are able to recite number–words and to mark the counted objects correctly, by, for instance, pointing at or moving the objects. The resultative counting stage emerges at around the age of five, when children are able to say number–words correctly starting with one, and to understand that countable objects should be marked once and that the last said number–word indicates the number of objects in a set. During the shortened counting stage, at around five-and-a-half years of age, they are able to recognize the figure five, for instance, and can continue counting upwards from that. Thus, their ability to operate with the number–word sequence for whole numbers, and to use that in problem solving, increases substantially during these developmental shifts. It is important to recognize that in this development, the ability to make relational statements, is necessary in order to correctly solve tasks that require the counting of objects. For instance, to get a correct answer in an object counting task (which requires number–word sequence skills), the child needs to know what objects are to be counted (i.e., classification skills) and count all the included items once and only once (i.e., one-to-one correspondence). In addition, depending on the task, the child might need to decide based on the counting results which of the sets has more or less than the others (i.e., comparison and seriation skills).

In the first grade of Finnish primary school, children are expected to learn the basic skills of addition and subtraction. First graders usually operate with numbers between 0 and 100, although the emphasis in addition and subtraction is on numbers 0 to 20. First graders learn to use these skills in their basic form (e.g., $2+3=5$) and in the context of problem solving tasks (e.g., "Mum has two cupcakes and she buys three more, how many does she have altogether?"). Usually, children begin to solve addition and subtraction tasks by using counting-based strategies and memory aids (e.g., cubes, fingers) (Fuson, 1982). Through practice, children develop more strategies (e.g., memory-based strategies) and become more efficient in their strategy use, which, evidently, makes problem solving less error prone and faster (Barrouillet & Fayol, 1998; Geary, Hamson, & Hoard, 2000; Siegler, & Shrager, 1984). This is what makes the early numeracy skills highly relevant for basic arithmetic skills learning.

Early numeracy skills, especially counting skills, have been found to be good predictors of later mathematics performance (Aubrey, Dahl, & Godfrey, 2006; Aubrey, & Godfrey, 2003; Kavkler et al., 2003), and counting skills in kindergarten, such as number–word sequence skills and enumeration skills, have shown to predict basic arithmetic skills in the early grades of primary schools (Aunola et al., 2004; Desoete, Stock, Schepense, Baeyens, & Roeyers, 2009; Jordan, Kaplan, Locuniak, & Ramineni, 2007; Koponen, Aunola, Ahonen, & Nurmi, 2007; Kurdek, & Sinclair, 2001; LeFevre et al., 2006). Research also demonstrates that children's mathematical development begins earlier than early numeracy development, which usually appears at the ages between two to seven years. Preverbal number sense, an approximate representation of magnitude, which is already present prior to the emergence of symbolic number representations (Lipton, & Spelke, 2005), is suggested to be a base for later mathematics development. This conceptualization limits number sense into processes where an approximate evaluation of magnitudes or symbols representing magnitudes is used. Based on neuropsychological studies (e.g., Butterworth, 1999; Dehaene, 1997; Feigenson, Dehaene, & Spelke, 2004; Piazza, Izard, Pinel, Le Bihan, & Dehaene, 2004), the ability to represent and process numerical magnitude information is potentially crucial for normally developing mathematical skills. A related competence, subitizing, the fast verbal naming of small quantities without counting the items separately, also seem to precede and support the development of counting skills (Le Corre, Van de Walle, Brannon, & Carey, 2006).

1.2. Other factors contributing to children's mathematical learning

Age is a well-known factor contributing to children's mathematical competence (Fayol et al., 1998, Jordan, Kaplan, Oláh, & Locuniak, 2006; Ransdell, & Hecht, 2003). Very young children's competence is basic by nature, but as children grow up they learn more complex mathematical skills. The preschool age is especially interesting as during those years the children's competence seem to transit from biologically primary qualitative skills to more complex and culturally bound, biologically secondary number, counting and arithmetic skills (Geary, 1994, 2000). Age is also an educationally relevant factor since the variation in children's chronological age in one kindergarten or first grade classroom can be up to 12 months, and even more in terms of the actual skill level (Boardman, 2006; Dowker, 2008; Hojnoski, Silberglitt, & Floyd, 2009).

Several studies suggest that girls and boys possess identical primary numerical abilities (e.g., Dehaene, 1997; Nunes, & Bryant, 1996). However, research focusing on the British National Curriculum Key Stage 1 measurements (with children aged four to seven years) report gender differences favoring girls in basic arithmetic tasks (Demie, 2001; Gorard, Rees, & Salisbury, 2001; Strand, 1997;1999). More precisely, a study by Strand (1999) showed that girls performed better than boys at the age of four years (Baseline measurement) and at the age of seven (Key Stage 1 measurement), but that the progress of boys was greater than that of girls between the two measurement points. Similarly, compared to same aged boys, better early numeracy skills have been found in Finnish girls aged 4–7 years (Aunio, Aubrey, Godfrey, Yuejuan, & Liu, 2008; Aunio, Hautamäki, Heiskari, & Van Luit, 2006) and in Australian girls aged 5–6 years (Boardman, 2006). In contrast, Jordan et al. (2006) found that kindergarten boys outperformed girls in the overall number sense, nonverbal calculation and estimation skills. Yet, in the early grades, no clear gender differences have been found in mathematical performance (Aubrey, & Godfrey, 2003, Aunola et al., 2004; Carr, & Jessup, 1997, Fennema, Carpenter, Jacobs, Franke, & Levi, 1998). Current findings on gender differences in children's mathematical performance are thus rather mixed and potentially confounded with skill- and age-related differences.

Parents' education is considered as a proxy variable for socioeconomic status: as the educational level of parents increase, their children are more likely to enjoy improved socioeconomic conditions. It can be assumed that parental education covaries with children's early numeracy and mathematics achievements at school. The existence of a socioeconomic gap in children's mathematical competence in early childhood education and in the early grades of primary school is well documented (Aunola et al., 2004; Jordan, Huttenlocher, & Levine, 1992: Jordan et al., 2006; Sammons, & Smeeds, 1998; Saxe, Guberman, & Gearhart, 1987; Strand, 1999; Tzouriadou, Barbas, & Bonti, 2002). For instance, Jordan et al. (1992) reported that middle-income kindergarten children performed better than their low-income peers in verbal calculation tasks, while the groups did not differ in performance on nonverbal calculation tasks. These findings suggest that nonverbal task formats are less sensitive than verbal task formats to socioeconomic variation. Siegler (2009) has proposed that the differences in mathematical knowledge between children from more versus less affluent backgrounds reflect differences in the environmental support for learning: middle-income parents engage in a broader range of explicit mathematical activities with their children and do so more frequently than low-income parents (Clements & Sarama, 2007; Starkey, Klein, & Wakeley, 2004).

1.3. Rationale for the present study

Kindergarteners' counting skills, the skills to recite the number–word sequence and to use it to enumerate (i.e., count numerosity), have found to be a good predictor of mathematical skills assessed in the primary grades. Regarding the role of demographics factors, the research demonstrates mixed gender effects and some age-related effects favoring older children in early mathematics performance. A positive influence has also been attributed to higher parents' educational level and socioeconomic status. Following this, the present study is an attempt to examine in more detail the extent to which specific aspects of early numeracy at six years of age predict mathematics performance and school-related mathematics achievement in the first grade of primary school, after controlling for the effects of age, gender and parents' level of education.

2. Method

2.1. Participants and procedure

Finnish children start their primary school at the age of seven. Until then, education in kindergarten mainly prioritizes general social and literacy development (National Board of Education, 2000); less emphasis is put on mathematical development. The formal mathematics education begin in the first grade and focuses on addition and subtraction skills with numbers 1–100.

The participants in the study were 212 (107 girls and 105 boys) Finnish children from one southern and from one northern Finnish town. The sample came from the norming study of the Finnish Early Numeracy Test (ENT; Aunio, Hautamäki, et al., 2006; Van Luit, Van de Rijt, & Aunio, 2006), and at the time of the first measurement (in spring 2003), the mean age of the children was six years (in months, M 72.26; SD 3.49). Parental consent was obtained from each participating child.

The assessment of early numeracy was conducted by the volunteer teachers trained to use the ENT in kindergarten, and the first grade assessment was conducted with the help of classroom teachers, who carried out the mathematics school test and provided mathematics grades for each child (see below). The test material and instructions were mailed to the classroom teachers, who then returned the children's tests to the researchers for scoring and analysis.

2.2. Measurements

2.2.1. Early numeracy

Kindergarteners' early numeracy skills were assessed using the Early Numeracy Test (Van Luit et al., 2006). The test takes a developmental perspective on children's early numeracy, and aims at tapping eight aspects of numerical knowledge, including the concepts of comparison, classification, one-to-one correspondence, seriation, the use of number words, structured counting, resultative counting, and the general understanding of numbers (see Appendix A for examples of items). The target group is four- to seven-year-old children. The test is given individually and takes about 30 minutes for a child to complete. The 40 items are scored by giving one point for a correct answer and zero for a wrong answer, with a maximum score of 40 (e.g., Van de Rijt, Van Luit, & Pennings, 1999). The children are not given feedback as to whether their response is correct or incorrect, and the test situation is not timed.

Although the ENT is assumed to yield a unidimensional measure of children's early numeracy (Van de Rijt et al., 1999), previous studies (e.g. Aunio, Hautamäki, et al., 2006; Aunio et al., 2006) have shown that the ENT differentiates two closely related factors reflecting slightly different aspects of children's early numeracy. The first four scales of the instrument concerns the logical principles often identified as the key factors underlying children's understanding of quantities and relations (i.e., relational skills) (Piaget, 1965), while the other four scales focus more explicitly on the use and understanding of number–word sequence (i.e., counting skills) (Fuson, 1988; Gelman & Gallistel, 1978). In order to test the given two-factor structure (i.e., relational and counting skills) of the test scores, we conducted a confirmatory factor analysis on all the included items. To optimize the psychometric properties of the measures, we first eliminated items that were either too easy or too difficult (response probability above .95 or below .05, respectively) and items that otherwise fit the model poorly (as a part of measurement model modification). The Mplus statistical program (Muthén & Muthén, 1998–2001) was used for this purpose, because the robust weighted-least square estimation procedure implemented in Mplus provides correct parameter estimates and mean- and variance-adjusted chi-square test statistics for binary data. The final two-factor model consisted correlated factors representing relational skills (10 items) and counting skills (15 items), which corresponded well with the findings of our earlier study (Aunio et al., 2006). According to the common recommendations for the assessment of goodness of fit (Bentler, 1990; Steiger, 1990), the two-factor solution fitted the data well [$\chi^2(85) = 113.11$, $p = .02$; CFI = .95, RMSEA = .04]. The disattenuated correlation between the two factors was .79.

2.2.2. Basic and applied arithmetic skills

The first graders' basic arithmetic skills were assessed using items from the Mathematics school test (Makeko by Ikäheimo, Putkonen, & Voutilainen, 2002), which is a group test and takes a maximum of 45 minutes to complete. For the present purposes, only tasks measuring addition and subtraction skills (using a maximum of two digits), either basic or applied (see Appendix B), were used. A correct answer in each item resulted in one point, thus leading to a maximum score of 15. As with the Early Numeracy Test, we also examined the presumed factorial structure of arithmetic skills by means of confirmatory factor analysis. Again, the robust weighted-least square estimates as implemented in Mplus were used. Based on the fit indices, our two-factor model reflecting basic and applied arithmetic skills fitted the data well [$\chi^2(19) = 34.11$, $p = .02$; CFI = .95, RMSEA = .06]. The disattenuated correlation between the two factors was .67.

2.2.3. Mathematical competence

Mathematics grades in the first grade were provided by the children's classroom teachers, who were asked to evaluate the children's mathematical competence in relation to their mathematics curriculum and to what had been taught during the first grade. Corresponding to the general grading system in Finland, the teachers gave each child a school grade ranging from four to ten.

2.2.4. Parental education

Information on parental education was provided by the kindergarten teachers and the children's parents at the time of the first measurement point. Fathers' and mothers' educational background was assessed in terms of basic education (scored as follows: 1 = primary school, 2 = elementary school, 3 = vocational school, 4 = senior secondary school) and professional education (scored as follows: 0 = none, 1 = lower vocational, 2 = higher vocational and 3 = university education). For the sake of simplicity, the two questions were merged into one score (ranging from 1 to 7) for further analysis.

2.2.5. Additional control variable: inattentive behavior

As a part of the assessment of children's early numeracy (first measurement point), we also conducted a behavioral rating of children's task-related behavior, which follows an observational procedure commonly applied in Finnish standardization studies and psychological test development (e.g., Korkman, Kirk, & Kemp, 2008; Wechsler, 2009). In this case, the examiners rated the extent to which the participating child exhibited task-related inattentive behavior (e.g., lack of concentration) during the test with a scale ranging from 0 to 2 (0 = no; 1 = little; 2 = a lot). The purpose of this rating is to aid the evaluation of the actual testing procedure and test functioning. However, in the process of evaluating variation of children's behavior in the test situation we discovered some unexpected but intriguing and potentially relevant effects of inattentive behavior not only on the given test performance but also on later measures of mathematics achievement. Therefore, although this variable is somewhat limited in terms of psychometric quality (e.g., only one rating per child was recorded thus eliminating the possibility to evaluate inter-rater reliability), we decided to include it in further analyses as an ad hoc variable in order to consider the broader implications of the given findings in the present context.

2.3. Data analysis

We used partial least squares (PLS) path modeling to test the predictions incorporated into our hypothetical model (see Fig. 1). Like any structural equation model (SEM), a PLS model consists of a structural part, which reflects the relationships between the latent variables, and a measurement part, which shows how the latent variables and their indicators are related. However, unlike covariance-based structural equation modeling, which seek to minimize the difference between the sample covariances and those predicted by the theoretical model, PLS modeling focuses on maximizing the variance of the dependent variables explained by the independent ones (Chin, & Newsted, 1999). In general, PLS modeling, as compared to covariance-based SEM, is considered as a more exploratory (as opposed to confirmatory) and prediction-oriented (as opposed to parameter-oriented) approach to SEM, as it can handle complex models with numerous indicators and correlated variables. Moreover, the PLS approach imposes little or no demands on the sample size, scale type, and variable distribution, which makes it especially suitable for the present purposes.

Before the analyses, the few random missing values found in the data were imputed using the EM imputation algorithm as implemented in SPSS 17 statistical software. For the PLS-modeling, SmartPLS software was used.

3. Results

In order to answer our research question, we tested our hypothetical model (Fig. 1) by means of PLS modeling. Early numeracy and arithmetic skills were specified and estimated as latent factors with reflective indicators (i.e., the latent factor "causes" the variation in indicators), whereas parental education was specified and estimated as an emergent factor with formative indicators (i.e., the indicators "cause" the variation in the emergent factor). With respect to the sequential predictive design, the two latent factors reflecting basic and applied arithmetic skills and the observed measure of teacher-rated mathematics competence at grade one were regressed on the two latent factors reflecting early numeracy, relational and counting skills, respectively, measured when the children were in kindergarten. These factors, in turn, were regressed on the observed measure of task-related inattention, and, finally, all the above factors were regressed on the emergent factor of parental education and the observed measures of gender and age. Basic and applied arithmetic skills and teacher-rated mathematics performance were allowed to correlate with each other, as were relational and counting skills. The composite reliability estimates (Chin, 1998) for the latent factors of basic and applied arithmetic skills, and relational and counting skills were .78, .88, .79, and .85, respectively, which are all above the recommended level of .7 and thus provide

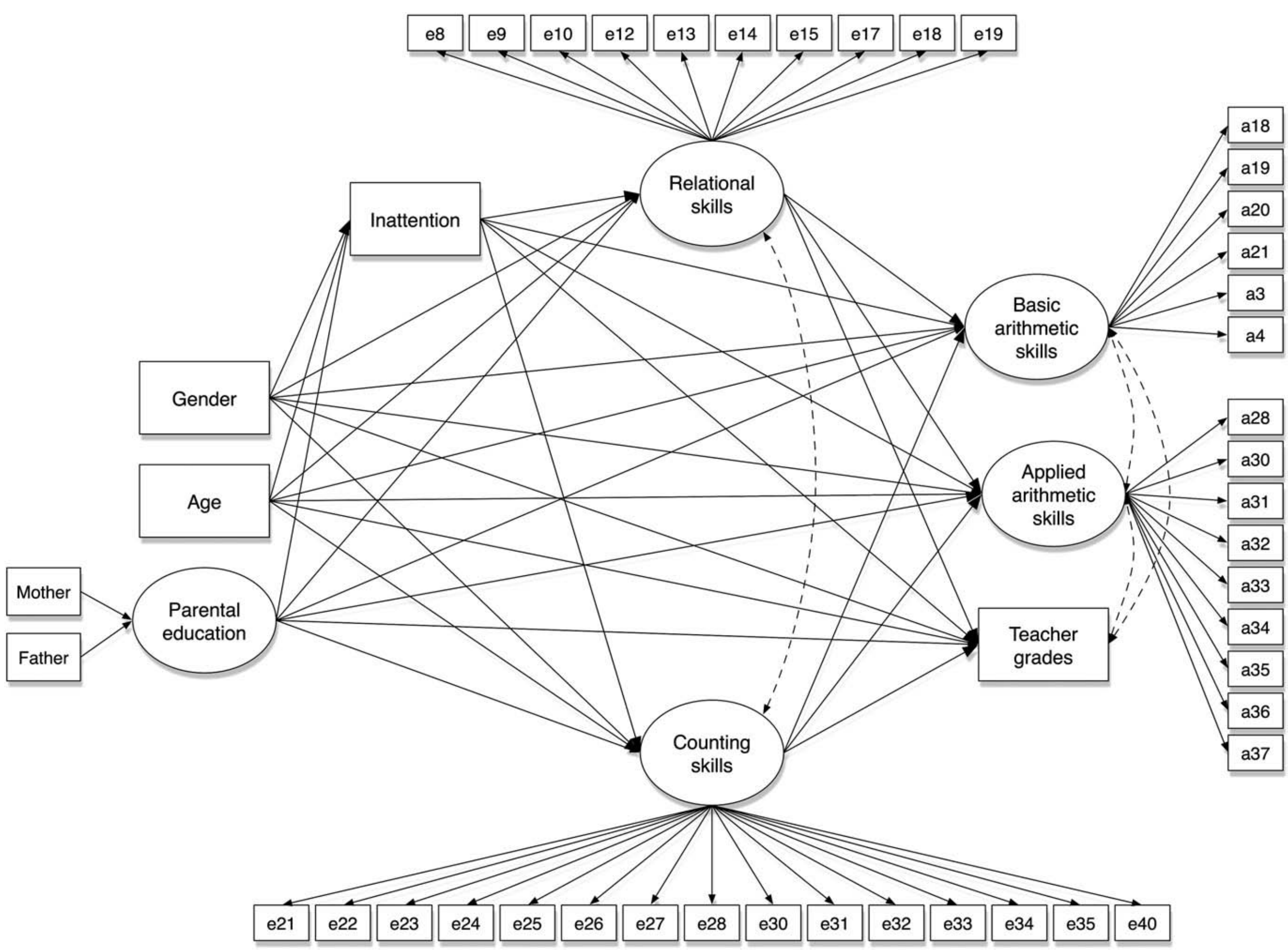

Fig. 1. A hypothetical model illustrating predictive relationships between background variables, early numeracy, arithmetic and mathematics performance.

support for the quality of the measurements. Descriptive statistics for all variables and individual item loadings for the measurement models are reported in Appendices C and D, respectively.

With this model, we were able to explain 47% of the variance in teacher-graded mathematics performance, 21% of the variance in basic arithmetic skills, and 28% of the variance in applied arithmetic skills. As expected, both relational and counting skills were significant predictors of all the three dependent factors, counting skills having the strongest influence on teacher-graded performance (see Fig. 2 for an illustration of statistically significant effects, and Table 1 for all direct and total effects).

Interestingly, the level of parental education had a marginally significant effect on graded performance, and a significant effect on applied arithmetic skills but not on basic arithmetic skills. Relational and counting skills were both negatively predicted by task-related inattention. The explained variance in these two factors was 13% and 7%, respectively. Age had a significant effect on counting skills but only a marginally significant effect on relational skills. Gender predicted neither early numeracy nor arithmetic skills and grades, but it did influence inattention. The positive effect of gender on inattention indicated that boys had more trouble focusing on the given task than girls did. Especially intriguing was the fact that inattention, assessed as part of the test of early numeracy in kindergarten, also directly predicted teacher-graded mathematics performance, but not arithmetic test scores, measured a year later. However, the total effects of inattention, that is, the direct effects combined with the indirect effects through relational and counting skills, on both teacher-rated mathematics performance and applied arithmetic skills, were significant.

4. Discussion

The aim of this study was to examine how early numeracy assessed in kindergarten (at the age of six years) predicts mathematics performance in grade one, after controlling for the effects of age, gender, and parental education. With the inclusion of an ad hoc variable of task-related inattentive behavior – assessed in relation to the early numeracy testing – we were able to explain the 47% of the variance in the grade given by the teacher, 29% in the applied arithmetic tasks, and 21% in the basic arithmetic tasks. As the majority of predictive power was attributed to the measures of early numeracy, the results clearly show that the acquisition of relational and counting skills before formal schooling are predictive of the learning of basic and applied arithmetical skills and of later overall mathematical performance. Parents' education had a marginally significant effect on graded performance and a significant effect on applied arithmetic skills so that higher level of education was predictive of higher level of skill. Age had a marginally significant effect on relational skills and a significant effect on counting skills, thus implying a developmental effect on early numeracy. Gender did not influence measures of early numeracy or later mathematics performance, but did predict task-related inattention. That is, compared to girls, boys were more likely to exhibit lack of concentration. Finally, after controlling for the effects of demographics factors, task-related inattention had an effect on the early numeracy test performance and a significant direct effect on teacher-graded mathematics performance a year later.

The findings showing associations between relational and counting skills and later performance in basic and applied arithmetic tasks

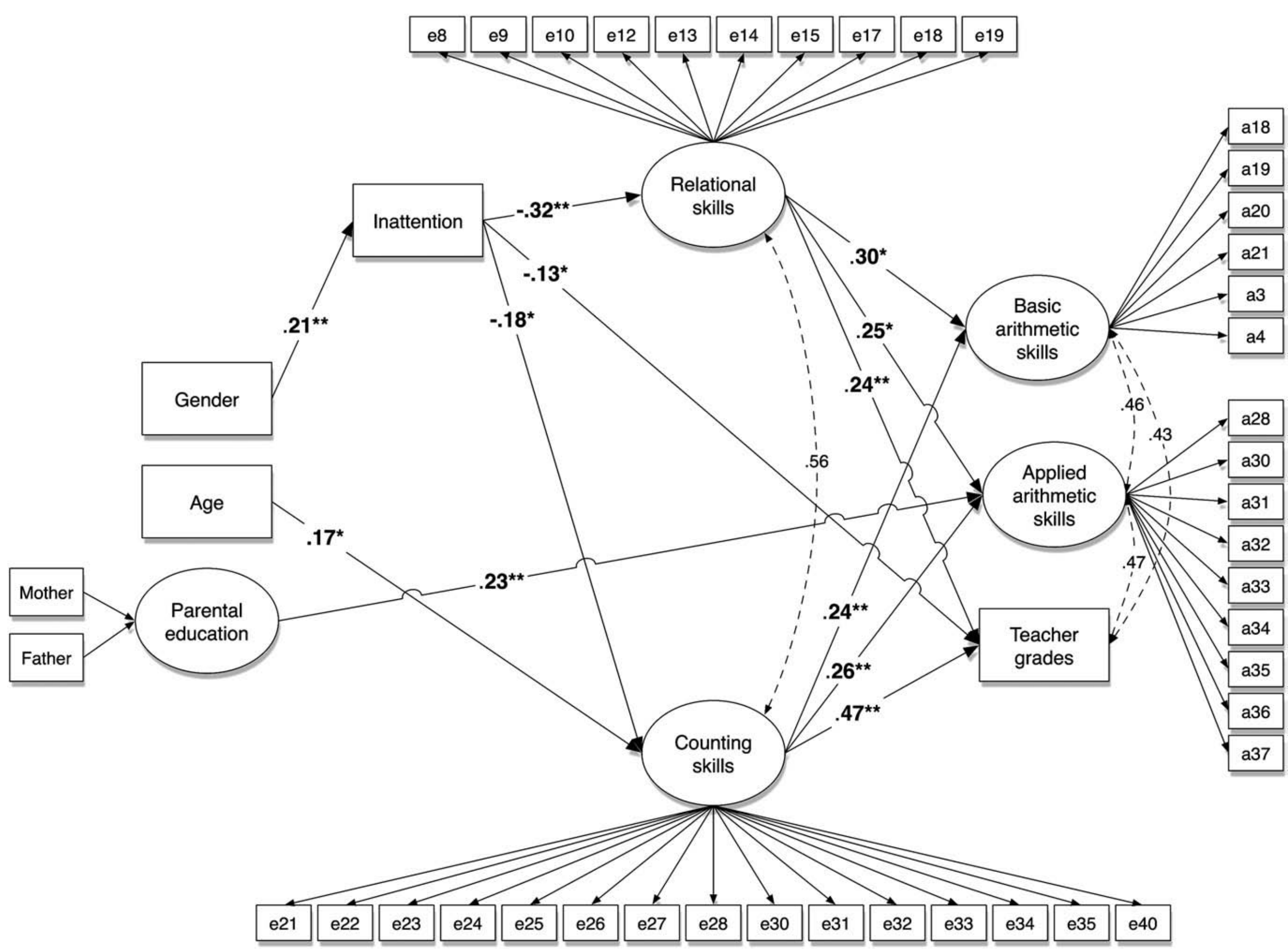

Fig. 2. The empirical model illustrating significant direct effects (solid lines) and correlations (dashed lines) between background variables, early numeracy, arithmetic and mathematics performance.

Table 1
Direct and total effects in the empirical model.

	Inattention		Relational skills		Counting skills		Basic arithmetic skills		Applied arithmetic skills		Teacher-graded performance	
	β (se.)	*t*	β (se.)	*t*	β (se.)	*t*	β (se.)	*t*	β (se.)	*t*	β (se.)	*t*
Direct effects												
Gender	.21 (.06)	3.13**	−.08 (.07)	1.07	−.04 (.07)	0.54	−.02 (.07)	0.30	−.05 (.06)	0.89	.03 (.05)	0.49
Age	−.06 (.06)	1.02	.12 (.07)	1.73†	.17 (.07)	2.31*	−.05 (.08)	0.73	−.05 (.05)	0.84	−.05 (.05)	1.13
Parental education	−.02 (.09)	0.16	.11 (.08)	1.16	.08 (.08)	0.96	.07 (.08)	0.85	.23 (.07)	3.23**	.09 (.06)	1.76†
Inattention			−.32	4.21**	−.18 (.08)	2.30*	.04 (.07)	0.52	−.06 (.08)	0.70	−.14 (.06)	2.39*
Relational skills							.30 (.11)	2.48*	.25 (.12)	2.06*	.24 (.07)	3.64**
Counting skills							.24 (.08)	3.31**	.26 (.09)	2.63**	.47 (.06)	7.48**
Total effects												
Gender			−.15 (.07)	1.94†	−.08 (.07)	1.07	−.07 (.08)	0.90	−.12 (.07)	1.82†	−.07 (.07)	1.06
Age			.14 (.07)	1.96*	.18 (.07)	2.45*	.03 (.08)	0.35	.03 (.06)	0.67	.07 (.07)	1.03
Parental education			.12 (.08)	1.23	.08 (.08)	0.94	.12 (.09)	1.25	.28 (.09)	3.30**	.16 (.08)	2.09*
Inattention							−.10 (.08)	1.10	−.18 (.08)	2.13*	−.29 (.08)	3.89**
R^2	.04		.13		.07		.21		.28		.47	

Note. **p<.01, * p<.05, †<.10, se. = standard error.

point out the importance of early mathematical learning. Since the first grade mathematics curriculum focuses on arithmetic skills, mathematical learning difficulties may occur if children's early numeracy, the base to build their arithmetic skills on, is weak (Desoete et al., 2009; Koponen et al., 2007). As shown by several studies, it is quite likely that the gap between weak and well-performing children entering primary school widens in every subsequent grade (Jordan, Kaplan, Ramineni, & Locuniak, 2009, see also Aunola et al., 2004). However, as the predictive influence of early numeracy seems to differ to some extent as a function of the type of skill in question, it is important to identify in more detail the developmental dynamics between early mathematical skills and later performance. The conceptualization of early numeracy in this study was somewhat narrow compared, for example, to the one introduced by Sarama, and Clements (2009) and perhaps a more comprehensive scope would be informative when seeking to determine which early math skills are essential both for enhancing later mathematics learning and for avoiding related learning difficulties. In future, the assessment of relational skills could be combined with measures of pattern and structure, which potentially explain later algebraic reasoning and, conversely, problems in it (Mulligan, Mitchelmore, Kemp, Marston, & Highfield, 2008; Mulligan, Prescott, Mitchelmore, & Outhred, 2005). Moreover, a more explicit focus on children's conceptual understanding of the counting process (Muldoon, Lewis, & Freeman, 2003; Muldoon, Lewis, & Towse, 2005) might be of specific importance, especially in the context of identifying long term learning difficulties. In this study, we only looked at children's counting performance using their spontaneous answers to question assessing reciting number–word sequence and enumeration.

Children's age was a stronger predictor of their performance in tasks of counting skills than in tasks of relational skills. This may simply reflect the fact that in kindergarten, children are repeatedly exposed to everyday activities that require basic counting skills, and thus longer experience and more frequent opportunities to practice those skills are likely to result in better mastery of counting in older children. Regarding relational skills, this natural practice period seems to occur somewhat earlier (Aunio, Hautamäki, et al., 2006), due to which age differences in kindergarten appear to play a lesser role in the developing mastery of these skills. Although age-related effects were rather weak and they do not seem to bear an independent role in explaining differences in later mathematics performance, they nevertheless have some implications in relation to research and educational practices; not only when assessing individual differences in early mathematics skills, but also when considering special educational support, chronological age should be explicitly taken into account (cf. Boardman, 2006; Dowker, 2008; Hojnoski et al., 2009).

The finding of no clear gender differences in any of our mathematical tasks is in contrast with the results reported from the British Key Stage 1 studies (Demie, 2001; Gorard et al., 2001; Strand, 1997, 1999) and with studies on younger children (e.g. Aunio, Hautamäki, et al., 2006; Boardman, 2006), but is in line with some others (Aubrey & Godfrey, 2003). As there is evidence suggesting differences in the growth rate of children's skill development as a function of gender (Aunola et al., 2004), and that gender effects may vary as a function of the specific skill assessed and the age of the child (e.g., Goodchild & Grevholm, 2009; Liu, Wilson, & Paek, 2008) and even some psychosocial and cultural factors (Geary, 1994), future studies should focus more precisely on the moderating factors influencing gender differences in the developmental trajectories of specific skills.

Several studies (Clements & Sarama, 2007; Siegler, 2009; Starkey et al., 2004) suggest that in affluent families more support is provided for children's early math learning than in less-affluent families. Our results differ from these in that the level of parents' education only had a significant positive effect on applied arithmetic skills in the first grade and a marginally significant positive effect on teacher-graded math performance. Following the observation by Grolnick, Ryan, and Deci (1991) that the level of mother's school involvement increases when the child performs poorly at school, our finding may indicate that the role of supportive home environment becomes more influential when learning tasks become more challenging and complex. Moreover, it also likely that the parents become more involved with their children's learning activities when the children move from an informal learning environment (i.e., kindergarten) to a formal learning environment (i.e., school). In other words, support is calibrated according to the need of the child and the formal expectations set for the child. The fact that higher parental educations predicts better performance may be an indication of differences in parents' educational values and their commitment to the child's school activities (e.g., Sy, 2006) . However, this is purely speculative in the present context, and since it may relate to the complex interplay of parental involvement, gender and achievement level (see Desimone, 1999; Hill & Craft, 2003; Lahaie, 2008; Tan & Goldberg, 2009), it needs to be more explicitly addressed in future studies. One possible way to disentangle such complex interactions and the various sources of influence might be to engage in specific interventions that systematically investigated the different ways parents' could support their children's learning (cf. Bjorklund, Hubertz, & Reubens, 2004; LeFevre et al., 2009; Siegler, 2009).

A somewhat unexpected finding in our study was that inattention assessed as a part of the early numeracy testing not only influenced the actual test performance, but also predicted the teacher-given grade in mathematics one year later. These effects suggest that children's scores in the ENT are partly influenced by the children's ability to focus on the task, which importantly reminds us about the fact that no test is a pure measure of the underlying skill or ability. Consequently, as this may contribute to the validity of the actual measure, more attention should paid in future studies to evaluate how sensitive the ENT is to such individual differences. More interestingly, the fact that a task-specific measure of inattentive behavior predicted teacher-graded performance a year later, but not the test scores reflecting mathematical skills, raises questions about how the competence displayed in the classroom is in fact evaluated by the teacher. Our finding implies that teacher ratings might incorporate a behavioral component that, as such, is independent of the child's actual mathematical skills. In other words, could it be that restless children or children with some attentional problems are evaluated somewhat more negatively just because of their behavior? This is a matter of some concern. If children's behavior significantly affects the evaluation of their competence, they are being given undeserved negative feedback, which, again, may set up a vicious evaluative circle directly affecting the child's future interest, commitment and behavior in the given subject domain. This may be especially detrimental to boys (who usually exhibit more problem behavior than girls, as found in this study as well) and children with an attention deficit (Aro, Ahonen, Tolvanen, Lyytinen, & Todd de Barra, 1999; Carlson, Lahey, & Neeper, 1986).

Our study also has some methodological limitations. As stated by, for instance, Rittle-Johnson, and Siegler (1998), problems of validity can occur in studies suggesting that acquiring one type of knowledge has a causal influence on the future acquisition of another type of knowledge. Since such relationships could fully or partly be explained by a other variables, such as working memory (Kyttälä, Aunio, & Hautamäki, 2010) or motivation (Aunola et al., 2006; Gottfried, Marcoulides, Gottfried, Oliver, & Guerin, 2007), future studies should replicate the study of similar predictive relationships within a more comprehensive design. And even though Byrnes and Wasik (2009) convincingly reported that propensity factors (e.g. pre-existing mathematical skills) were the most important determinants of mathematical achievement in kindergarten, over and above the antecedent factors (e.g. family socioeconomic status) and opportunity factors (e.g. frequency of being exposed to mathematical content), one source of variation likely to influence individual differences in children's level of early mathematical skills that was not considered here but should be taken into account in future studies is the quality and length of the history of children's early childhood education.

The present study also has some implications for educational practice. Most importantly, it should be understood that early mathematic skills are composed of qualitatively different kinds of skills, which may require specifically targeted support in order to provide a more optimal platform for future learning of mathematics in primary school (Clements & Sarama, 2009; Dowker, 2008). This is especially relevant for early childhood education, and therefore, as it may be crucial in preventing future learning problems or inferior performance (Aunio, Hautamäki, & Van Luit, 2005; Hannula & Lehtinen, 2005), invites educational practice to provide all children with possibilities to practice their emerging mathematical skills in early childhood education.

From the educational perspective, the challenge is to determine what the children need to learn in preschool to be able to learn mathematics at school. By this we mean that it is essential to know, particularly in the context of special education, what constitutes the minimum requirements for learning primary school mathematics. At present, many skills are deemed important, such as preverbal number sense (Lipton & Spelke, 2005, Piazza et al., 2004) or subitizing (Le Corre et al., 2006), but very few studies have utilized an appropriate longitudinal approach and/or sufficiently comprehensive or differentiated measures of mathematics skills to draw conclusive inferences. We also need to learn more about factors other than mathematical skills that contribute to early mathematics learning. For instance, which cognitive antecedents are the most important, which aspects of the learning environment are especially important, and what are the best practices for parents to supports their children's learning of early mathematics. Such knowledge would also contribute more generally to educational and special educational planning and decision-making, for example, in terms of more accurate evaluation and diagnosing, establishing of supportive social networks, and designing and providing appropriate learning material.

Acknowledgment

This study was supported by grants from Helsinki University Research Funds (to P.A.) and the Academy of Finland (to M.N.). We wish to thank the children, parents and educators who participated in our study.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.lindif.2010.06.003.

References

Aro, T., Ahonen, T., Tolvanen, A., Lyytinen, H., & Todd de Barra, H. (1999). Contribution of ADHD characteristics to academic treatment outcome of children with learning difficulties. *Developmental Neurospsychology*, *15*(2), 291−305.

Aubrey, C., Dahl, S., & Godfrey, R. (2006). Early mathematics development and later achievement: Further evidence. *Mathematics Education Research Journal*, *18*(1), 27−46.

Aubrey, C., & Godfrey, R. (2003). The development of children's early numeracy through Key Stage 1. *British Educational Research Journal*, *29*(6), 821−840.

Aunio, P., Aubrey, C., Godfrey, R., Yuejuan, P., & Liu, Y. (2008). Children's early numeracy in England, Finland and People's Republic of China. *International Journal of Early Years Education*, *16*(3), 203−221.

Aunio, P., Hautamäki, J., Heiskari, P., & Van Luit, J. E. H. (2006). The Early Numeracy Test in Finnish: Children's norms. *Scandinavian Journal of Psychology*, *47*, 369−378.

Aunio, P., Hautamäki, J., & Van Luit, J. E. H. (2005). Mathematical-thinking intervention programmes for preschool children with normal and low number sense. *European Journal of Special Needs Education*, *20*, 131−146.

Aunio, P., Niemivirta, M., Hautamäki, J., Van Luit, J., Shi, J., & Zhang, M. (2006). Young children's number sense in China and Finland. *Scandinavian Journal of Educational Research*, *50*(5), 483−502.

Aunola, K., Leskinen, E., Lerkkanen, M. -K., & Nurmi, J. -E. (2004). Developmental dynamics of math performance from preschool to grade 2. *Journal of Educational Psychology*, *96*(4), 699−713.

Aunola, K., Leskinen, E., & Nurmi, J. -E. (2006). Developmental dynamics between mathematical performance, task motivation, and teacher's goals during the transition to primary school. *British Journal of Educational Psychology*, *76*, 21−40.

Aunola, K., & Nurmi, J. -E. (2004). Maternal affection moderates the impact of psychological control on a child's mathematical performance. *Developmental Psychology*, *40*(6), 965−978.

Barrouillet, P., & Fayol, M. (1998). From algorithmic computing to direct retrieval: Evidence from number and alphabetic arithmetic in children and adults. *Memory & Cognition*, *26*(2), 355−368.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*, 238−246.

Bjorklund, D., Hubertz, M., & Reubens, A. (2004). Young children's arithmetic strategies in social context: How parents contribute to children's strategy development while playing games. *International Journal of Behavioral Developments*, *28*(4), 347−357.

Boardman, M. (2006). The impact of age and gender on prep children's academic achievements. *Australian Journal of Early Childhood*, *31*(4), 1−6.

Bryant, P. (1996). Children and arithmetic. In L. Smith (Ed.), *Critical readings on Piaget* (pp. 312−346). London, UK: Routledge.

Bryant, P., & Nunes, T. (2002). Children's understanding of mathematics. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (pp. 412−439). Malden, The Netherlands: Blackwell.

Butterworth, B. (1999). *The mathematical brain.* Oxford, UK: Macmillan.

Byrnes, J. P., & Wasik, B. A. (2009). Factors predictive of mathematics achievement in kindergarten, first and third grade: An opportunity-propensity analysis. *Contemporary Educational Psychology*, *34*(2), 167−183.

Carlson, C., Lahey, B., & Neeper, R. (1986). Direct assessment of the cognitive correlates of attention deficit disorders with and without hyperactivity. *Journal of Psychopathology and Behavioral Assessment*, *8*(1), 69−86.

Carr, M., & Jessup, D. (1997). Gender differences in first grade mathematics strategy use: Social and metacognitive influences. *Journal of Educational Psychology*, *89*, 318−328.

Chin, W. W. (1998). The partial least squares approach for structural equation modeling. In G. A. Macoulides (Ed.), *Modern methods for business research* (pp. 295−336). Mahwah, NJ: Lawrence Erlbaum Associates.

Chin, W. W., & Newsted, P. R. (1999). Structural equation modeling analysis with small samples using partial least squares. In Rick Hoyle (Ed.), *Statistical Strategies for Small Sample Research* (pp. 307−341). Thousand Oaks, California: Sage Publications.

Clements, D. H., & Sarama, J. (2007). Effects of a preschool mathematics curriculum: Summative research on the Building Blocks project. *Journal for Research in Mathematics Education*, *38*, 136−163.

Clements, D. H., & Sarama, J. (2009). *Learning and teaching early math — The learning trajectories approach.* Routledge: New York.

Dehaene, S. (1997). *The number sense. How the mind creates mathematics.* London, UK: Penguin Books.
Demie, F. (2001). Ethnic and gender differences in educational achievement and implications for school improvement strategies. *Educational Research*, *43*(1), 91−106.
Desimone, L. (1999). Linking parent involvement with student achievement: Do race and income matter? *The Journal of Educational Research*, *93*(1), 11−30.
DeSmedt, B., Janssen, R., Browens, K., Verschaffel, L., Boets, B., & Ghesquière, P. (2009). Working memory and individual differences in mathematics achievement: A longitudinal study from first grade to second grade. *Journal of Experimental Child Psychology*, *103*, 186−201.
Desoete, A., Stock, P., Schepense, A., Baeyens, D., & Roeyers, H. (2009). Classification, seriation, and counting in grades 1, 2, and 3 as two-year longitudinal predictors for low achieving in numerical facility and arithmetical achievement? *Journal of Psychoeducational Assessment*, *27*(3), 252−264.
Dowker, A. (2008). Individual differences in numerical abilities in preschoolers. *Developmental Science*, *11*(5), 650−654.
Fayol, M., Barrouillet, P., & Marinthe, C. (1998). Predicting achievement from neuropsychological performance: A longitudinal study. *Cognition*, *68*, B63−B70.
Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences*, *8*(7), 307−314.
Fennema, E., Carpenter, T. P., Jacobs, V. R., Franke, M. L., & Levi, L. W. (1998). A longitudinal study of gender differences in young children's mathematical thinking. *Educational Researcher*, *27*(5), 6−11.
Fuson, K. C. (1982). An analysis of the counting on solution procedure in addition. In T. P. Carpenter, J. M. Moser, & T. A. Romberg (Eds.), *Addition and subtraction: A cognitive perspective* (pp. 67−81). Hillsdale NJ: Lawrence Erlbaum Associates, Inc.
Fuson, K. C. (1988). *Children's counting and concept of number.* New York: Springer Verlag.
Geary, D. C. (1994). *Children's mathematical development.* Washington, DC: APA.
Geary, D. C. (2000). From infancy to adulthood: The development of numerical abilities. *European Child & Adolescent Psychiatry*, *9*, II/11−II/16.
Geary, D. C., Hamson, C. O., & Hoard, M. K. (2000). Numerical and arithmetical cognition: A longitudinal study of process and concept deficits in children with learning disability. *Journal of Experimental Child Psychology*, *77*, 236−263.
Gelman, R., & Gallistel, C. (1978). *The child's understanding of number.* Cambridge, UK: Harvard University Press.
Goodchild, S., & Grevholm, B. (2009). An exploratory study of mathematics test results: What is the gender effect? *International Journal of Science and Mathematics Education*, *7*, 161−182.
Gorard, S., Rees, G., & Salisbury, J. (2001). Investigating the patterns of differential attainment of boys and girls at school. *British Educational Research Journal*, *27*(2), 125−139.
Gottfried, A., Marcoulides, G., Gottfried, A., Oliver, P., & Guerin, D. (2007). Mulitvariate latent change modeling of development decline in academic intrinsic math motivation and achievement: Childhood through adolescence. *International Journal of Behavioral Development*, *31*(4), 317−327.
Grolnick, W., Ryan, E., & Deci, R. (1991). The inner resources for school achievement: Motivational mediators of children's perceptions of their parents. *Journal of Educational Psychology*, *83*, 508−517.
Hannula, M. M., & Lehtinen, E. (2005). Spontaneous focusing on numerosity and mathematical skills of young children. *Learning and Instruction*, *15*(3), 237−257.
Hill, N., & Craft, S. (2003). Parent–school involvement and school performance: Mediated pathways among socioeconomically comparable African American and Euro-American families. *Journal of Educational Psychology*, *95*(1), 74−83.
Hojnoski, R. L., Silberglitt, B., & Floyd, R. G. (2009). Sensitivity to growth over time of the preschool numeracy indicators with a sample of preschoolers in Head Start. *School Psychology Review*, *38*(3), 402−418.
Huntsinger, C., Jose, P. E., Larson, S., Krieg, D. B., & Shaligram, C. (2000). Mathematics, vocabulary, and reading development in Chinese American and European American children over the primary school years. *Journal of Educational Psychology*, *92*(4), 745−760.
Ikäheimo, H., Putkonen, H., & Voutilainen, A. (2002). *Matematiikan keskeisten käsitteiden diagnoosi esiopetuksen alussa ja lopussa sekä 1.luokan alussa [The assessment of mathematical basic concepts in the beginning of the preschool and primary grade].* Helsinki, Finland: Opperi.
Jordan, N. C., Huttenlocher, J., & Levine, S. C. (1992). Differential calculation abilities in young children from middle- and low-income families. *Developmental Psychology*, *28*(4), 644−653.
Jordan, N. C., Kaplan, D., Locuniak, M. N., & Ramineni, C. (2007). Predicting first-grade math achievement from developmental number sense trajectories. *Learning Disabilities Research & Practice*, *22*(1), 36−46.
Jordan, N. C., Kaplan, D., Oláh, L. N., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development*, *77*(1), 153−175.
Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology*, *45*(3), 850−867.
Kavkler, M., Tancig, S., & Magajna, L. (2003). Follow-up study of children with very low and very high mathematical competence in preschool years. *Paper presentation in EARLI conference, 2003, Padova Italy*.
Koponen, T., Aunola, K., Ahonen, T., & Nurmi, J. -E. (2007). Cognitive predictors of single-digit and procedural calculation and their covariation with reading skills. *Journal of Experimental Child Psychology*, *97*(3), 220−331.
Korkman, M., Kirk, U., & Kemp, S. L. (2008). *NEPSY-II – Lasten neuropsykologinen tutkimus [Children's neurospychological testing].* Helsinki, Finland: Psykologien kustannus Oy.
Kurdek, L. A., & Sinclair, R. J. (2001). Predicting reading and mathematics achievement in fourth-grade children from kindergarten readiness scores. *Journal of Educational Psychology*, *93*(3), 451−455.
Kyttälä, M., Aunio, P., & Hautamäki, J. (2010). Working memory resources in young children with mathematical difficulties. *Scandinavian Journal of Psychology*, *51*, 1−15.
Lahaie, C. (2008). School readiness of children of immigrants: Does parental involvement play a role? *Social Science Quaterly*, *89*(3), 684−705.
Le Corre, M., Van de Walle, G. A., Brannon, E., & Carey, S. (2006). Re-visiting the performance/competence debate in the acquisition of counting as a representation of the positive integers. *Cognitive Psychology*, *52*(2), 130−169.
LeFevre, J. -A., Smith-Chant, B. L., Fast, L., Skwarchuk, S. -L., Sargala, E., Arnup, J. S., et al. (2006). What counts as knowing? The development of conceptual and procedural knowledge of counting from kindergarten through Grade 2. *Journal of Experimental Child Psychology*, *93*, 285−303.
LeFevre, J. -A., Smith-Chant, B. L., Skwarchuk, S. -L., Fast, L., Kamawar, D., & Bisanz, J. (2009). Home numeracy experiences and children's math performance in the early school years. *Canadian Journal of Behavioural Sciences*, *41*(2), 55−66.
Lipton, J. S., & Spelke, E. S. (2005). Preschool children's mapping of number words to nonsymbolic numerosities. *Child Development*, *76*(5), 978−988.
Liu, O. L., Wilson, M., & Paek, I. (2008). A multidimensional Rasch analysis of gender differences in PISA mathematics. *Journal of Applied Measurement*, *9*(1), 18−35.
Muldoon, K., Lewis, C., & Freeman, N. H. (2003). Putting counting to work: Preschoolers' understanding of cardinal extension. *International Journal of Educational Research*, *39*, 695−718.
Muldoon, K., Lewis, C., & Towse, J. (2005). Because it's there! Why some children count, rather than infer numerical relationships. *Cognitive Development*, *20*, 472−491.
Mulligan, J., Mitchelmore, M., Kemp, C., Marston, J., & Highfield, K. (2008). Encouraging mathematical thinking through pattern and structure — An intervention in the first year of schooling. *Australian Primary Mathematics Classroom*, *13*(1), 10−15.
Mulligan, J., Prescott, A., Mitchelmore, M., & Outhred, L. (2005). Taking closer look at young students' images of area measurement. *Australian Primary Mathematics Classroom*, *10*(2), 4−8.
Muthén, L. K., & Muthén, B. O. (1998–2001). *Mplus user's guide.* Los Angeles, CA: Muthén & Muthén.
Natale, K., Aunola, K., & Nurmi, J. -E. (2009). Children's school performance and their parents' causal attributions to ability and effort: A longitudinal study. *Journal of Applied Developmental Psychology*, *30*, 14−22.
National Board of Education (2000). *Core curriculum for pre-school education in Finland 2000.* Helsinki, Finland: National Board of Education.
Nunes, T., & Bryant, P. (1996). *Children doing mathematics.* Oxford, UK: Blackwell.
Passolunghi, M. C., Mammarella, I. C., & Altoè, G. (2008). Cognitive abilities as precursors of the early acquisition of mathematical skills during first through second grades. *Developmental Neuropsychology*, *33*(3), 229−250.
Piaget, J. (1965). *The child's conception of number.* New York: Norton.
Piazza, M., Izard, V., Pinel, P., Le Bihan, D., & Dehaene, S. (2004). Tuning curves for approximate numerosity in the human intraparietal sulcus. *Neuron*, *44*(3), 547−555.
Ransdell, S., & Hecht, S. (2003). Time and resource limits on working memory: Cross-age consistency in counting span performance. *Journal of Experimental Child Psychology*, *86*, 303−313.
Rittle-Johnson, B., & Siegler, R. (1998). The relation between conceptual and procedural knowledge in learning mathematics. In C. Donlan (Ed.), *The development of mathematical skills* (pp. 75−109). Hove, UK: Psychology Press.
Sammons, P., & Smeeds, R. (1998). Measuring pupil progress at Key Stage 1: using baseline assessment to investigate valued added. *School Leadership & Management*, *18*(3), 389−407.
Sarama, J., & Clements, D. H. (2009). *Early childhood mathematics education research — Learning trajectories for young children.* Routledge: New York.
Saxe, G., Guberman, S., & Gearhart, M. (1987). Social processes in early number development. *Monographs of the society for research in child development*, *216*(52), 2.
Siegler, R. (2009). Improving the numerical understanding of children from low-income families. *Child Development*, *3*(2), 118−124.
Siegler, R. S., & Shrager, J. (1984). Strategy choices in addition and subtraction: How do children know what to do? In C. Sophian (Ed.), *Origins of cognitive skills* (pp. 229−293). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
Smith, L. (2002). *Reasoning by mathematical induction in children's arithmetic.* Oxford, UK: Pergamon Press.
Sophian, C. (1998). A developmental perspective on children's counting. In C. Donlan (Ed.), *The development of mathematical skills* (pp. 27−46). Hove, UK: Psychology Press.
Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quaterly*, *19*, 99−120.
Steiger, J. H. (1990). Structural model evaluation and modification: An interval estimation approach. *Multivariate Behavioral Research*, *25*, 173−180.
Stevenson, H. W., & Newman, R. S. (1986). Long-term prediction of achievement and attitudes in mathematics and reading. *Child Development*, *57*, 646−659.
Strand, S. (1997). Pupil progress during Key Stage 1: A value-added analysis of school effects. *British Educational Research Journal*, *23*(4), 471−487.
Strand, S. (1999). Ethnic group, sex, and economic disadvantage: Associations with pupils' educational progress from Baseline to the end of Key Stage 1. *British Educational Research Journal*, *25*(2), 179−202.
Sy, S. R. (2006). Rethinking parent involvement during transition to first grade: A focus on Asian American Families. *The School Community Journal*, *16*(1), 107−125.

Tan, E., & Goldberg, W. (2009). Parental school involvement in relation to children's grades and adaption to school. *Journal of Applied Developmental Psychology*, *30*, 442−453.

Tzouriadou, M., Barbas, G., & Bonti, E. (2002). Socio-cultural environment as a factor of differentation in mathematical reasoning. *Psychology*, *9*, 281−294.

Van de Rijt, B. A. M. (1996). *Voorbereidende rekenvaardigheiden bij kleuters* [Early mathematical competence in young children]. Doctoral dissertation. Utrecht University. Doetinchem, The Netherlands: Graviant.

Van de Rijt, B., Van Luit, J. E. H., & Pennings, A. (1999). The construction of the Utrecht early mathematical competence scales. *Educational and Psychological Measurement*, *59*(2), 289−309.

Van Luit, J. E. H., Van de Rijt, B. A. M., & Aunio, P. (2006). *Early Numeracy Test, Finnish Edition [Lukukäsitetesti].* Helsinki, Finland: Psykologien kustannus.

Wechsler, D. (2009). Wechsler Preschool and Primary Scale of Intelligence (3rd ed.). (WPPSI-III). NCS Pearson, Inc. USA. Helsinki, Finland: Psykologien Kustannus.