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Multi-factorial approach to early numeracy—The effects of cognitive skills, language factors and kindergarten attendance on early numeracy performance of South African first graders

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ABSTRACT

The aim of the study was to investigate the influence of cognitive skills (executive function), language factors (listening comprehension, English as a second language, ESL) and kindergarten attendance on early numeracy in a cross-sectional sample of South African children (N = 442) in the beginning of Grade 1. The mean age of children was 81.62 months (SD = 5.40). Structural equation path models showed that kindergarten attendance predicted children's early numeracy performance even when controlling for executive function and language skills. Listening comprehension skills predicted the early numeracy skills more strongly than did executive function skills. ESL was associated with weaker early numeracy performance.

1. Introduction

Early numeracy (EN) skills are relevant for children's mathematics learning at school (Jordan, Glutting, & Ramineni, 2010). However, many children do not have enough opportunities to learn and practice EN skills. For instance, in South Africa it is evident that many children perform very low at the beginning of primary school (Spaull & Kotze, 2015; Taylor & Von Fintel, 2016). The lack of early opportunities for learning essential numeracy skills or weaknesses in cognitive skills can cause continuous low performance in mathematics (Geary, 2013). Furthermore, EN consist of several different subcomponents, yet EN skills are often operationalized as a single-factor construct. In this study we seek to understand what factors have an impact on EN skills, taking a multi-factorial approach to EN skills by investigating the influence of cognitive skills (executive functions), language factors (listening comprehension, English as a second language status) and kindergarten attendance in South African first graders.

1.1. EN skills and low performance

EN includes several skills which are important for later math learning (Aunio & Räsänen, 2015; Merkley & Ansari, 2016).

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Especially early performance in understanding the mental number line and differences in magnitudes (Merkley & Ansari, 2016; Muldoon, Towse, Simms, Perra, & Menzies, 2013; LeFevre et al., 2010), recognition and naming of number symbols (Göbel, Watson, Lervåg, & Hulme, 2014; Pinto, Bigozzi, Tarchi, Vezzani, & Accorti Gamannossi, 2016), numerical relational and counting skills (Aunio & Niemivirta, 2010; Purpura & Reid, 2016), cardinal knowledge (Chu, VanMarle, & Geary, 2015), basic addition and subtraction skills and early arithmetical word problem solving skills (Jordan et al., 2010), predict later mathematics performance. Low performance in EN skills is a potential indicator for later mathematical learning difficulties (Morgan, Farkas, & Wu, 2011; Jordan, Kaplan, Oláh, & Locuniak, 2006; Morgan, Farkas, & Wu, 2009). Such low performance in EN skills can, for instance, be observed during children's typical classroom activities as weak counting (e.g. recite number word sequence, enumerate), numerical relational (e.g. compare, seriate) and basic addition and substraction skills (Aunio & Niemivirta, 2010; Desoete, Stock, Schepense, Baeyens, & Roeyers, 2009; Jordan et al., 2006). The development of numeracy skills does not occur in a vacuum, but is related to a child's learning of cognitive and language skills (Kleemans, Segers, & Verhoeven, 2011; LeFevre et al., 2010), and environmental factors (Kleemans, Peeters, Segers, & Verhoeven, 2012; Melhuish et al., 2013).

1.2. Executive function

There are different ways to define executive function (EF) skills (Titz & Karbach, 2014), but often EF is seen as a set of higher-order processes that aid the regulation of cognition in the service of planning, problem-solving and goal-directed actions (Miyake & Friedman, 2012). It includes specific cognitive control processes such as inhibition, cognitive flexibility and update of the contents of working memory. In older children and adults, these skills constitute three independent processes (Miyake et al., 2000), but increasing evidence suggests that these three core functions form a unitary process in young children (Hughes, Ensor, Wilson, & Graham, 2009; Willoughby, Blair, Wirth, & Greenberg, 2010). In line with these results, Espy and colleagues (2004) found working memory, inhibition and cognitive flexibility, not to be dissociable from each other in a group of 2–5 years old children as did Wiebe, Espy and Charak (2008) in group of 2–6 years old children. But to the contrary, Gandolfi, Viterbori, Traverso, and Usai (2014) reported separate factors for inhibition and working memory at the age of 4–6 years.

Executive function (EF) skills have been found to be a good predictor of both mathematics and literacy achievement (Allan & Lonigan, 2011; Bull, Espy, Wiebe, Sheffield, & Nelson, 2011; Dilworth-Bart, 2012; Lan, Legare, Ponitz, Li, & Morrison, 2011). Research has also shown a direct association between children's EF and EN skills in cross-sectional (Andersson & Lyxell, 2007; Espy et al., 2004; Xenidou-Dervou, De Smedt, Van der Schoot, & Van Lieshout, 2013) and in longitudinal studies (Bull, Espy, & Wiebe, 2008; Lee & Bull, 2016; Welsh, Nix, Blair, Bierman, & Nelson, 2010). EF skills have been shown to be even more important for EN than early literacy learning (Blair & Razza, 2007; Bull et al., 2008; Duncan et al., 2007; Raghubar, Barnes, & Hecht, 2010). For example Schmitt, Geldhof, Purpura, Duncan and McClelland (2017) found that growth in EF was more strongly correlated to early arithmetical skills than to language skills.

Earlier research related to children's EF skills and EN offers some evidence of the links between specific EF and EN skills. Updating has in general been found to have the most robust association to EN skills (Bull & Lee, 2014). Previous studies have found updating to predict numerical magnitude comparison skills (Kolkman, Hoijtink, Kroesbergen, & Leseman, 2013), and counting skills (Lan et al., 2011). Passolunghi and Lanfranchi (2012) reported that in kindergarten, children's inhibition and working memory had a significant impact on EN (i.e. numerical relational and counting skills). Similar results are reported by Harvey and Miller (2017) who found inhibition and working memory to predict children´s numeracy and counting skills. Shaul and Swartz (2014) results demonstrated that EF skills (inhibition and cognitive flexibility) in 5–6 years old children contributed significantly to numeracy knowledge (i.e. simple addition skills). In addition, Merkley, Thompson, and Scerif (2015) specified that inhibitory processes in young children were strongly related to mathematical operations when they require inhibiting stimulus dimensions that are in conflict with number (e.g., number sense tasks with non-symbolic number comparison).

1.3. Language skills

The development of language skills and EN have also been found to be interconnected (Duncan et al., 2007; Toll & Van Luit, 2014). Research has shown that early language skills are related to existing EN performance and predictive of later mathematical performance (Hooper, Roberts, Sideris, Burchinal, & Zeisel, 2010; Romano, Babchishin, Pagani, & Kohen, 2010). More precisely, speech and language competence is related to EN skills, when symbolic learning increases and when, specifically in multilingual setting such as South African schools, children have language switching challenges (Henning, 2012; Henning et al., 2013).

Prior research has found significant relations between phonological awareness and EN skills (Fuchs et al., 2010; Krajewski & Schneider, 2009a, 2009b). Simmons and Singleton (2008) argued that limited ability of phonological awareness affected aspects of arithmetic that involve the manipulation of verbal codes (i.e. counting speed and number fact recall). Purpura, Hume, Sims and Lonigan (2011) found that all three early literacy skills' (vocabulary, print knowledge and phonological awareness) domains were individually related to, and predictive of children's EN. In contrast, Purpura, Hume, Sims, and Lonigan (2011) found that only vocabulary and print knowledge were uniquely predictive of later numeracy performance when accounting for initial numeracy performance and nonverbal cognitive ability. Further support for the relation of print knowledge (i.e. written letter identification and number symbol identification) to EN skills have been found among preschoolers (Piasta, Purpura, & Wagner, 2010) and kindergarteners (Ponitz, McClelland, Matthews, & Morrison, 2009). Also, grammatical ability and EN have been found to be related (Kleemans et al., 2011; LeFevre et al., 2010).

In addition to phonological awareness, vocabulary, print knowledge and grammatical ability (i.e. precursors for reading), oral language comprehension skills, specifically listening comprehension skills, have been identified as important for EN (Levine & Baillergeon, 2016). Good listening comprehension skills include both lower-level semantic components such as expressive and receptive word knowledge, and higher-level semantic components like inferential skills and the ability to use context (Florit, Roch, & Levorato, 2014; Lepola, Lynch, Laakkonen, Silvén, & Niemi, 2012; Strasser & Río, 2014). The results in an intervention study by Young-Loveridge (2004) showed that a storybook reading intervention (with number concept content), which required children to use their listening comprehension skills and at the same time enhanced these skills, had effects on children's EN skills.

There are also a few studies that have examined the joint effect of language skills and EF skills on EN in young children. Both receptive vocabulary and letter knowledge have been found to explain children´s EN skills above and beyond the effects of EF (Harvey & Miller, 2017; Moll, Snowling, Göbel, & Hulme, 2015; Zhang, 2016). Similar results were reported by Duncan et al. (2007) who used a broader measure of language skills. However, a recent study by Schmitt, Geldhof, Purpura, Duncan and McClelland (2017) found that growth in EF skills were a stronger predictor of EN skills compared to growth in language skills.

Receiving instruction in your second language further challenges the comprehension of instruction and thus learning at school (McLeod, Harrison, Whiteford, & Walker, 2015; Paradis, Schneider, & Duncan, 2013; Romaine, 2013). Studies from the US show that English as a Second Language (ESL) learners in kindergarten, especially those from low-income families, fall behind their English speaking peers in vocabulary, early reading, letter recognition, and EN (Denton, West, & Walston, 2003; Hoff, 2006). The achievement differences between the ESL learners and the children having English as a home language continue to exist in mathematics, reading, and social skills throughout the school years (Rouse, Brooks-Gunn, & McLanahan, 2005). The research on first and second language learners from the Netherlands shows that second language learners with weaker language skills remain behind in the acquisition of EN (Kleemans et al., 2011). There is also evidence showing that the status of second language learning does not affect all mathematical skills' learning. Studies on mathematics performance differences between native English speakers and ESL learners (Bautista, Mitchelmore, & Mulligan, 2009; Chang, Singh, & Filer, 2009; Martiniello, 2009) show that children with low language skills perform more poorly than their higher ability peers on mathematics word problems, but these differences did not extend to general nonverbal calculation skills, which is in line with other research on basic numerical skills (Spelke & Tsvikin, 2001). In addition, McLeod et al. (2015) found that ESL status did not contribute to poorer educational and socio-emotional outcomes at school, but it was the children's speech and language competence (regardless of whether they spoke English-only or were multilingual) at age 4–5 that made a difference to their educational outcomes at school. In general, it seems that children who are second language learners have more difficulties in learning mathematics, especially if their knowledge of second language is weak.

1.4. Kindergarten attendance

Children's individual differences in numeracy skills are also related to variations in the early learning environment (LeFevre et al., 2009; Levine & Baillargeon, 2016). In general, early childhood education programmes have been proven to have an impact on life-course outcomes necessary for economic success and good health (Reynolds, Temple, Ou, Arteaga, & White, 2011). More explicitly, Melhuish et al. (2013) showed that high-quality preschools had consistent effects that were reflected not only in improved attainment in Key Stage 2 English and mathematics, but also in improved progress in mathematics over primary school (2008b, Melhuish, Phan et al., 2008; Sammons et al., 2008). Specific programmes at preschool or kindergarten level, such as Head Start, have been found to reduce disparities in school readiness by enriching early learning opportunities for socio-economically disadvantaged children (Bierman, Welsh, Heinrichs, Nix, & Mathis, 2015; Raver et al., 2011; Zhai, Raver, & Jones, 2012). In addition, Chang (2012) found that kindergarten attendance per se, supports the learning of children from low socio-economic status families and dual language speaking families.

1.5. The present study

Previous studies show that EN skills are predicted by, for instance, EFs and language skills (e.g. listening comprehension and ESL status). In addition, the possibility to participate in early childhood education and kindergarten can support the learning of early academic (e.g., numeracy) skills in a significant way. Little research has been conducted to examine the relation between language and numeracy skills at school entry (Purpura et al., 2011), and even fewer studies have been done combining several potential factors affecting EN performance (Chu et al., 2015; Chu, vanMarle, Rouder, & Geary, 2018). Furthermore, although early numeracy have been found to be multi-componential (Dowker, 2008; Sarnecka & Carey, 2008) previous research designs have not provided possibilities to investigate the effects of potential contributing factors to various early numeracy skills, which are essential to understand the developmental dynamics in early years of school. Moreover, most of the studies in developmental dynamics in early numeracy have been done in rich educational contexts, namely in United State, Europe, Singapore and Australia; studies outside these contexts are to our knowledge non-existent. This study responds to the aforementioned research gaps, with a multi-factorial approach to EN skills, investigating the influence of cognitive skills, language factors, and kindergarten attendance on EN in South African first graders (Fig. 1). As a proxy for cognitive skills, we measured EF skills. To be able to get a general picture of children's language performance, we measured their listening comprehension skills, as the children had not yet learned to read. It is potentially important factor especially when we study ESL children. In addition, we collected information from their teachers whether the child was an ESL learner (measure for language skills) and had attended kindergarten (measure for prior exposure to early childhood education). Furthermore, children´s age and gender were included as covariates in the analyses.

Based on the previous research we set the following hypotheses:

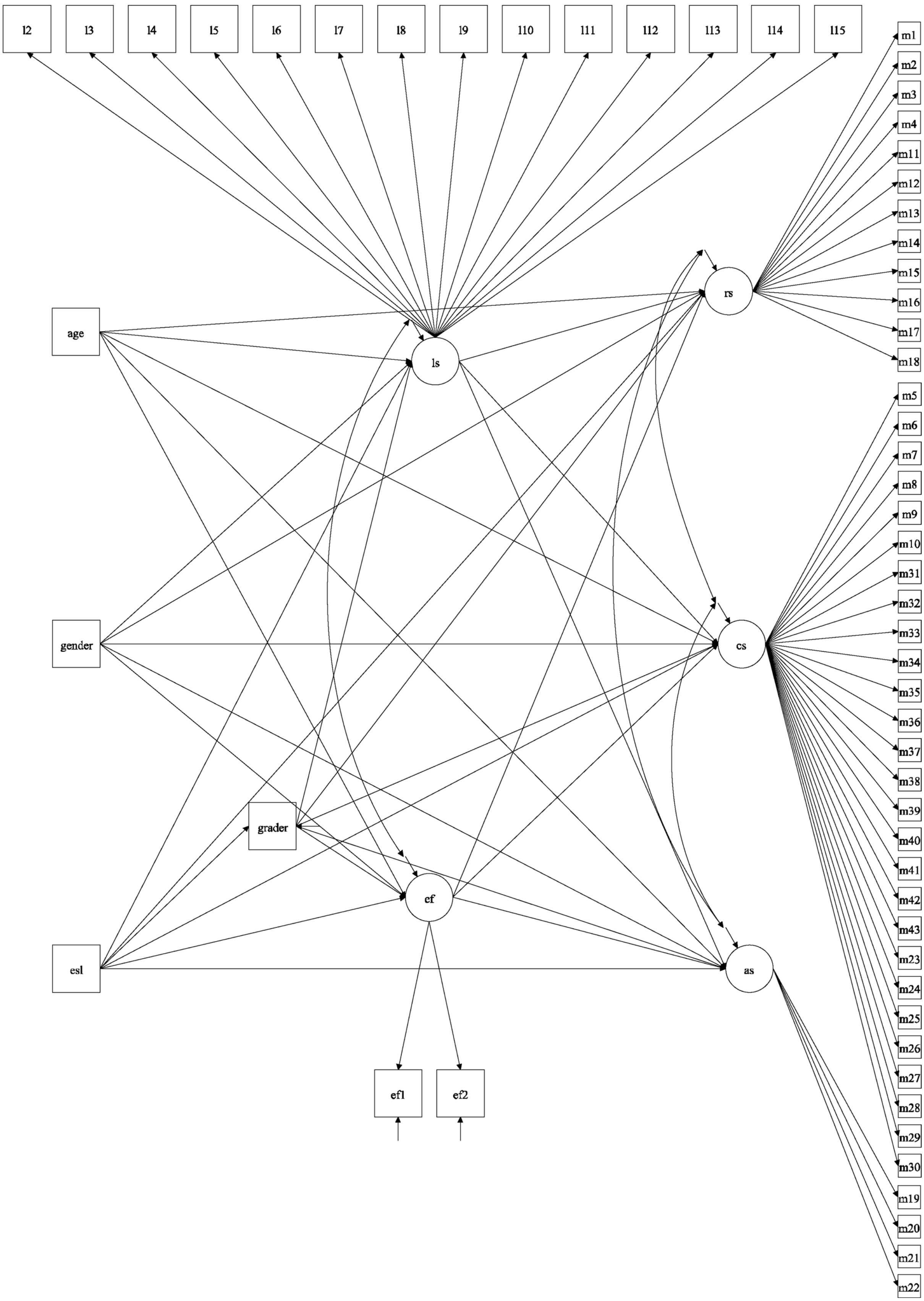

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Fig. 1. Theoretical path model predicting early numeracy skills. CS = counting skills; RS = mathematical relational skills; AS = arithmetical word problems; LS = listening comprehension; EF = executive functions; GRADER = kindergarten attendance; ESL = English as second language.

H1. EF skills predict EN skills.

H2. Listening comprehension skills predict EN skills.

H3. Kindergarten attendance predicts EN skills.

H4. English as a Second Language (ESL) predicts EN skills.

H5. Kindergarten attendance and ESL predict listening comprehension and EF skills.

2. Methods

2.1. Participants

This study is part of the research project that investigates the EN learning and evidence-based pedagogical support in South African schools. The sample in this cross-sectional study consisted of 443 children (204 girls and 239 boys). The mean age of children was 81.62 months (6 years 10 months, $SD = 5.40$ months). The study used convenient samples, collected in schools using English as a means of instruction, in the greater Johannesburg area of the Gauteng Province. Four public (334 children) and three private (109 children) schools were included. The children in this study were in the beginning of their Grade 1 year. Teachers were asked to report the children's home language and kindergarten attendance. The home language (HL) was reported for 443 children: Setswana (n = 132), isiXhosa (n = 14), isiZulu (n = 58), Sesotho (n = 20), English (n = 164) Afrikaans (n = 13), or other language (n = 42). Taken together, 279 (63.0%) of all the children in the current study were ESL learners and 355 (80.1%) had attended kindergarten.

2.2. Context of this study

In South Africa, schools can choose their language of instruction, although the national Department of Basic Education (DBE) recommends that children are taught in their home language until Grade 3. Having eleven official languages in the country, the schools should provide the content of the curriculum in these languages. Increasingly, more parents in South Africa select schools using English as an instructional language because of the social capital they believe it will bring their children in the future.

In the first grade, the South African curriculum for mathematics specifies five different learning areas which include 1) numbers, operations and relationships; 2) patterns, functions and algebra; 3) space and shape; 4) measurement and 5) data handling (South Africa, Department of Basic Education, 2011). Teachers are expected to follow the curriculum chronologically, spending on average of one hour per day on mathematics teaching, although some schools devise a plan to spend more time on it. Teachers make use of mathematics workbooks, supplied by the public education authorities, to supplement their pedagogy. There have been numerous efforts to improve early mathematics education in South Africa, but with weak results (2014, Fritz-Stratmann, Balzer, Herholdt, Ragpot, & Ehlert, 2014; Graven & Venkat, 2017; Henning, 2013).

Typically, children in private schools attend compulsory kindergarten before Grade 1, whereas it is somewhat less common in public schools. Kindergarten is the first year of schooling and forms part of the four years that comprise the 'foundation phase' (i.e. elementary school phase). Because of transport and school costs some rural parents only place their children in formal schooling from Grade 1 onward. Even though compulsory attendance of kindergarten had been introduced in 2014, many parents still adhere to the former policy, that kindergarten is not required and that Grade 1 is the first year of school (South African Schools Act, 1996).

2.3. Measures

EN skills were assessed using an English version of the originally Finnish ThinkMath test (Aunio & Mononen, 2012). This test was selected for economical and practical reasons, namely ThinkMath was developed by the research team members and there was no other validated early numeracy test in South Africa at that time. The original aim of the test is to identify the lowest performing children in EN, who are in need of extra educational support. The test is a group-based paper-pencil test, focusing on measuring the core EN skills, founded on the model of Aunio and Räsänen (2015). The test includes tasks of numerical relational skills (comparison concepts with quantities and comparison of numbers) (alpha = .71), counting skills (number sequences forwards and backwards with missing number, and number word-quantity-number symbol relations) (alpha = .91), and simple arithmetic word problems (verbal addition and subtraction problems) (alpha = .68). The internal consistency of the whole measure was excellent (alpha = .92). One point is scored for a correct answer and zero for a wrong answer, with the highest possible score being 43. Descriptive statistics and correlations for the measures can be found in Table 1.

Listening comprehension skills were measured using a text from a children's story, *Gogo's dog* (Hartmann & Rankin, 2013), with a listening comprehension scale (Ragpot & Brink, 2016) based on the Shell-K listening comprehension protocol (Snow, Burns, & Griffin, 1998). The test consists of one story (fiction), with 15 questions, ranging in difficulty from basic factual questions to questions which required the child to infer answers from the text. The child responded orally and the research assistant filled in the answer sheet. One

Table 1
Correlations and descriptive statistics for EN, EF and listening comprehension measures.

	1.	2.	3.	4.	5.	6.	7.	M(SD)
EN total	1							27.6(9.5)
Relational skills	.85***	1						7.3(2.8)
Counting skills	.96***	.70***	1					18.7(6.4)
Arithmetic word problems	.71***	.59***	.58***	1				1.5(1.3)
Listening comprehension	−.55**	.51***	.50***	.45***	1			10.3(2.7)
EF total	.34***	.33***	.31***	.29***	.24***	1		0.03(1.2)
EF reaction time	.12*	.11*	.11*	.11*	.10*	.80***	1	0.02(.77)
EF accuracy	.40***	.40***	.35***	.31***	.27***	.80***	.28***	0.00(.79)

Note: ** = $p < .01$ *** = $p < .001$. EN = Early numeracy skills; EF = executive functions skills.

point was scored for a correct answer and zero for a wrong answer, with the highest total score being 15. The internal consistency of the measure was adequate (alpha = .68).

The EFs measurement used in the present study was a child-appropriate adaptation of the Erikson Flanker test (Eriksen & Eriksen, 1974; Roebers & Kauer, 2009) run with ePrime software. The test was administered with the use of laptop computers. The test aims to measure three cognitive control processes: cognitive flexibility, update of the contents of working memory and inhibition. There were, in total, 80 items. The program records the children's reaction times and the accuracy of their answers per item.

Background information of the child was requested from the teachers in a short questionnaire at the beginning of the study. We collected information on children´s age, gender, kindergarten attendance (yes/no), and home language.

2.4. Procedure

A native speaker of both Finnish and English translated the ThinkMath test into English. The accuracy of the translation was checked by the research team. Permission to conduct research in the schools was obtained from the Gauteng Department of Education (GDE), the school management teams and governing bodies. Consent letters were sent to 500 families to inform and obtain parents' permission for children's participation (n = 443). Children´s skills were assessed at the beginning of the school year. The tests were administered during the regular school day. The EN test was done with group of 10 children in a separate classroom. The listening comprehension test was administered individually in a separate venue at school. The EF tasks were done individually, using laptop computers with response buttons. Trained research assistants and one of the authors administered the tests and scored the papers.

2.5. Data analysis

Confirmatory factor analyses were used to examine the dimensionality of the ThinkMath test, and structural equation path modeling was used to answer the research questions. We used individual items as factor indicators for the EN and listening comprehension factors, while a reaction time composite score and an accuracy composite score of the Flanker test were used as factor indicators for the EFs factor. Weighted least squares with mean and variance adjusted standard errors (WLSMV) were used as the estimator in all the analyses due to categorical factor indicators. Because $\Delta\chi^2$ cannot be directly computed between nested models when using the WLSMV estimator, we used the DIFFTEST command in Mplus to compare different factor structures for the EN scale. Model fit was assessed with the χ^2, the comparative fit index (CFI), the Tucker-Lewis index (TLI), and the root mean square error of approximation (RMSEA).

3. Results

3.1. Confirmatory factor analyses

To investigate the dimensionality of the ThinkMath test, a series of nested models was fitted to the data. The a priori three-factor model, consisting of counting tasks, numerical relational tasks, and arithmetical word problem tasks, was compared to a one- (representing one overall EN skills factor) and two-factor (numerical relational skills and counting skills + arithmetical word problem skills) model, respectively. All models showed good model fit (Table 1) but the three-factor model fitted the data better than the one-factor [$\Delta\chi^2(3) = 120.79$, $p < .001$], and the two-factor [$\Delta\chi^2(2) = 76.86$, $p < .001$] models. Furthermore, the correlations between the factors ranged from .77 to .87, supporting the distinction between the different EN skills. Next, we fitted a five-factor model to the data that included the three EN factors, a listening comprehension factor and an EF factor. This model fitted the data well [$\chi^2(1642) = 2737.84$, $p < .001$; CFI = .93; TLI = .92; RMSEA = .04] so we could proceed to test the hypotheses of the study.

3.2. Main analysis

To test the hypotheses a series of structural equation path models was fitted to the data. In line with H1 and H2, EF tasks and listening comprehension tasks were set to predict the three EN factors (counting tasks, numerical relational tasks and arithmetical

Table 2
Dimensionality of the ThinkMath scale.

Model	χ^2 (*df*)	p	CFI	TLI	RMSEA
One-factor	2257.405 (860)	.000	.901	.896	.061
Two-factor	2190.063 (859)	.000	.905	.901	.059
Three-factor	2095.909 (857)	.000	.912	.907	.059

word problem tasks). In addition, one background variable at a time was set to predict EF task performance, listening comprehension task performance and the three EN factors, before fitting the full model to the data. All single background variable models fitted the data well (Table 2). EF and listening comprehension task performance were significant predictors for three EN factors in all models. Kindergarten attendance positively predicted all five factors (i.e., EN, EF and listening comprehension performance). ESL learners performed poorer in listening comprehension and EN tasks. Gender differences in favor of girls emerged in counting tasks. Age positively predicted performance in all three EN latent factors (Table 3).

As the models with a single background variable fitted the data well, we proceeded to test a full model including all variables under study. When all variables were included in the analysis, the CFI model fit value declined to 0.84, indicating that the model did not fit the data that well. After testing models with different combinations of background variables it was clear that the reason for the decline in model fit was due to a strong dependency between kindergarten attendance and ESL, as children with English as a first language were more likely to also have attended kindergarten [$\chi^2(1) = 20.07$, $p < .001$] compared to children with ESL. Consequently, we let ESL predict kindergarten attendance and this modified model fit the data better [$\chi^2(1860) = 2983.48$, $p < .001$; CFI = .89; TLI = .88; RMSEA = .04]. This model explained 51.6% of the variance in counting performance, 66.8% of the variance in performance in numerical relational tasks, and 60.0% of the variance in word problem solving tasks. EF and listening comprehension tasks predicted performance in all three EN latent factors (Fig. 2), thus confirming H1 and H2. Listening comprehension performance had moderate effects, while EF performance had small effects on performance in all three EN latent factors. H3 and H4 were also confirmed as kindergarten attendance (positively) and ESL (negatively) predicted EN performance. All the effects could be interpreted as minor but kindergarten attendance had a stronger effect on counting performance compared to ESL. H5 was partly confirmed as kindergarten attendance and ESL both predicted listening comprehension, but only kindergarten attendance had a small positive effect on EF performance. The effects of gender and age were similar in the full model as in the single predictor models; girls had better counting performance, and age was positively related to all three EN latent factors.

4. Discussion

This study investigated the effects of cognitive skills (EFs), language factors (listening comprehension, ESL) and kindergarten attendance on EN skills in South African school beginners. Hypotheses 1 and 2 were supported, as EF and listening comprehension skills predicted the EN skills. Hypothesis 3 and 4 were also supported; both kindergarten attendance and ESL were good predictors for EN skills in the beginning of the first grade, so that those children who attended kindergarten or had English as home language (non-ESL) had better EN skills when school started. Hypothesis 5 was partly supported, as both kindergarten attendance and ESL predicted listening comprehension skills, meaning that those children attending kindergarten or those who had English as home language (non-ESL children) had better listening comprehension skills when school started. In addition, related to hypothesis 5, only kindergarten attendance predicted EF performance. Overall, this multi-factorial model successfully explained children's performance in EN at the beginning of the first grade. Kindergarten attendance was clearly an important factor for children's learning in South Africa.

In accordance with findings from literature, both EF (Blair & Razza, 2007; Bull et al., 2008) and language skills (Hooper et al., 2010; Romano et al., 2010) were found to be relevant for children's EN performance. Concerning the relative importance of EF and language skills for numeracy development, previous research has reported mixed results. The results in this study indicate that language skills are a stronger predictor than EF performance on EN skills, which is in line with results from both Duncan and his colleagues (2007), who used a more broad operationalization of language skills, as well as with studies that have used more specific language measures (e.g., receptive vocabulary, word recognition) (Chu et al., 2018; Harvey & Miller, 2017; Moll et al., 2015; Zhang, 2016). On the other hand, in a recent study, growth in early arithmetical skills was more strongly correlated to growth in EFs compared to language skills (Schmitt, Geldhof, Purpura, Duncan, & McClelland, 2017). There are some plausible explanations for these mixed results. First, in the Schmitt et al. (2017) study, language skills were operationalised with letter identification and word

Table 3
Goodness of fit for the single background variable models explaining early numeracy skills.

Model	χ^2 (*df*)	p	CFI	TLI	RMSEA
Kindergarten attendance as predictor	2783.683 (1696)	.000	.886	.881	.038
ESL as predictor	2789.775 (1696)	.000	.896	.892	.038
Gender as predictor	2796.697 (1696)	.000	.925	.922	.038
Age as predictor	2799.549 (1696)	.000	.920	.917	.038

Note. Executive functions and listening comprehension are included as predictors in all the models. ESL = English as second language.

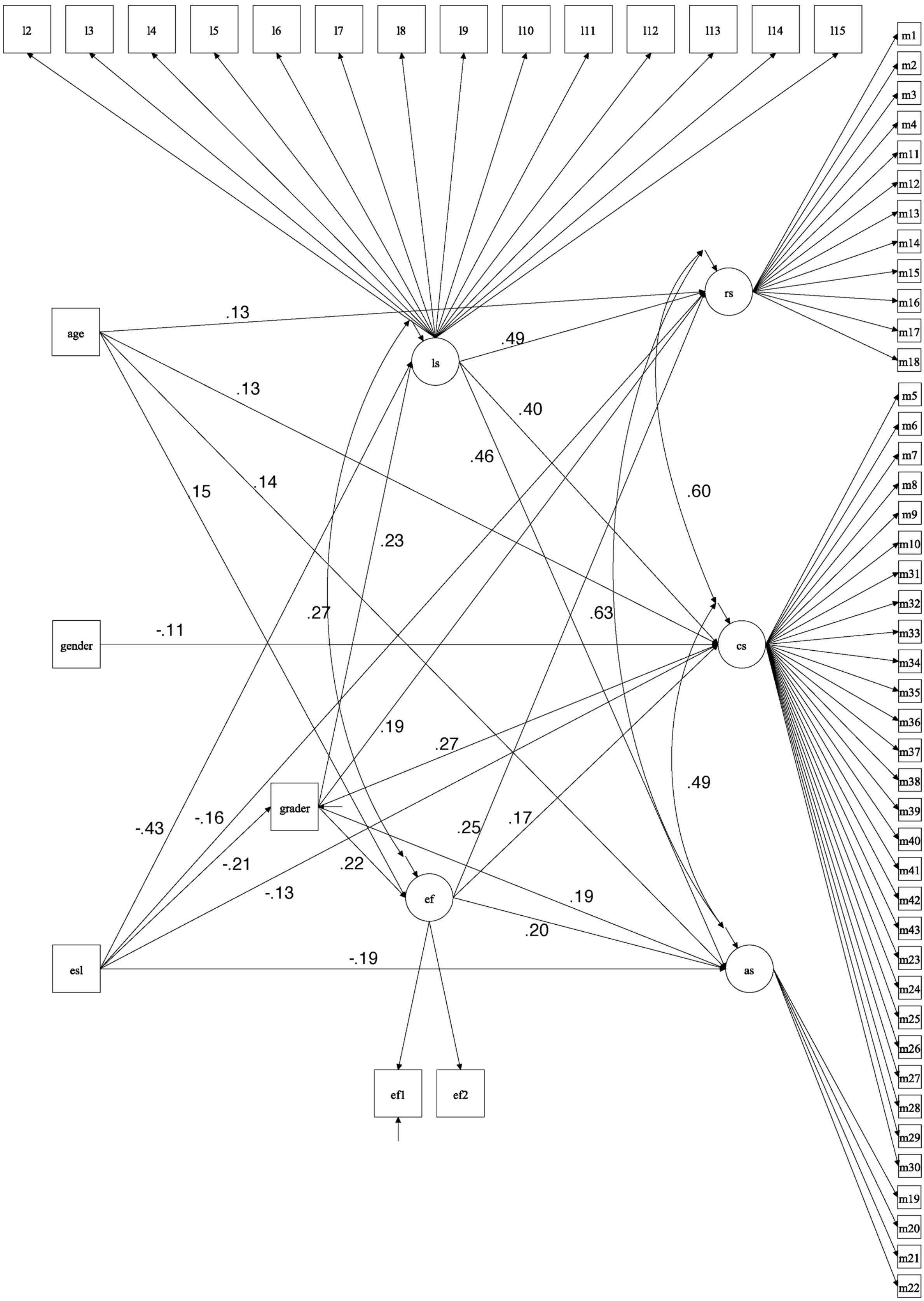

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Fig. 2. Multifactorial pathways to early numeracy skills. CS = counting skills; RS = mathematical relational skills; AS = arithmetical word problems; LS = listening comprehension; EF = executive functions; GRADER = kindergarten attendance; ESL = English as second language.

reading tasks, while Duncan et al. (2007) used a broader set of language measures. Moreover, this study used growth factors as predictors that also could explain the differing results. Previous research has shown that listening comprehension skills is a broad competence, including understanding of vocabulary, various combinations of words and using them in context (Florit et al., 2014; Lepola et al., 2012). If children have good listening comprehension skills, they use them successfully in solving EN tasks (Young-Loveridge, 2004). Thus, the stronger effect of language skills found in our study and by Duncan and his colleagues (2007) can be due to broader measures of language skills compared to those used in the study by Schmitt and his colleagues (2017). Another reason for these contradicting results can originate from the EFs measurement we used. The Flanker test did not have a separate updating component in it, which in turn has been found to be the most reliable predictor of mathematical skills in the field of EFs research (Bull & Lee, 2014). A third possible explanation for the diversity in findings can originate from the EN skills measured: Duncan and co-authors (2007) used a combined score including various math skills, while Schmitt and co-authors (2017) used very basic arithmetic skills to measure EN. We used EN performance including three set of essential numerical skills, namely numerical relational skills, counting skills and arithmetical word problem skills (see also Chu et al., 2015, 2018).

As reported in previous research, kindergarten attendance and ESL affected children's EN (Chang, 2012; LeFevre et al., 2010; Raver et al., 2011; Taylor & Van Flintel, 2016; Zhai et al., 2012). These results indicate that kindergarten provides children with language skills that enable them to solve various types of EN skills. In our study, especially counting skills were predicted by kindergarten attendance, suggesting that children are provided with good opportunities to practice counting skills in kindergarten. In line with Chang (2012), these results support the notion that kindergarten attendance supports children's learning in general, and children with proficiency in several languages in particular. Notwithstanding for ESL children who had attended kindergarten, all three EN skills were more challenging, than for those who were native English speakers who had attended kindergarten. This result slightly contrasts with findings that ESL children have challenges mostly in mathematical word problems and not in non-verbal counting tasks (Bautista et al., 2009; Chang et al., 2009; Martiniello, 2009). Our test assessment was conducted in oral English, and thus required the children to understand the instruction is English.

Both kindergarten attendance and ESL explained listening comprehension skills at the beginning of school. It can be that the kindergarten environment supports the development of task-focused behavior that has been shown to relate to the development of oral language comprehension skills and reading development later on (Lepola, Lynch, Kiuru, Laakkonen, & Niemi, 2016). The problems in listening comprehension skills faced by children with ESL is logical (McLeod et al., 2015) and emphasise the need for educational support at the beginning of the school career (Bierman et al., 2015; Melhuis et al., 2013). Related to EFs skills, only kindergarten attendance explained EF skills. This is in line with previous studies, which report that children who start to receive formal education are supported in the development of their EF skills (Brod, Bunge, & Shing, 2017; Weiland & Yoshikawa, 2013).

Related to the gender and age of children in this study, the results partially replicated the findings in the previous studies. When controlling for other variables, girls had better counting skills. There is contradictory evidence about the effect of gender on EN skills, as the differences in findings seem to originate from the skills measured and country of the children (Aunio & Niemivirta, 2010; Aunio, Korhonen, Bashash, & Khoshbakht, 2014; Penner & Paret, 2008). So far, the research has not produced constant or universal gender effects in EN. As found in several other studies, the older children in this study had better EN, EF and listening comprehension skills (Jacobsen, Mello, Kochhann, & Fonseca, 2017; Jordan et al., 2006;).

4.1. Limitations

There are at least three limitations that should be taken into consideration when interpreting the results of this study. First, this study was cross-sectional and although the models were based on previous research, the ordering of the predictor variables could not, therefore, be empirically validated. There might be other plausible models that describe the relations between the variables we studied. Second, the results concerning the relative importance of listening comprehension and EFs for EN skills might have changed if our EFs skills measure had incorporated updating skills (Bull & Lee, 2014) or if we had had measured different math skills (Schmitt et al., 2017). Although different EF skills do not seem to be separable in this age group (Wiebe, Espy, & Charak, 2008), it would be valuable in the future to include tasks that also measure updating skills; perhaps that would allow us to understand the relations between various EF and EN components (Passolunghi & Lanfranchi, 2012; Shaul & Swartz, 2014). Due to practical limitations we only had two indicators for language skills. In order to investigate the connection between EN and language, a wider set of measurements would have been valuable (e.g. Lepola et al., 2016). The final limitation is related to the ESL variable: the information concerning whether the child's ESL status was reported by the teacher and not the parents. Another related issue in the South African context is that our ESL variable might have been confounded by the family's socioeconomic status, which needs to be measured explicitly with culturally valid indicators in future studies. It would also be valuable to take into account the health and wealth level of the nations and make a cross-national comparison to be able to understand what factors in education environment really explains the effect in learning and what are explained with nations' health and wealth factors (www.gapminder.org/whc).

4.2. Implications

A framework on predictors of EN learning is still being revised, because we have not established yet which individual and learning environment variables can be used to account for the variation in EN learning (Kleemans et al., 2012). Our study had three implications for scientific studies aiming to understand EN development. First, so far in EF studies, EN has been studied as one factor, whereas we provide evidence that EF affects three subgroups of numeracy skills (i.e. numerical relational, counting, and arithmetical word problem skills). Second, in addition to domain-general, domain-specific and language skills, we suggest that exposure to education is a valuable factor to be included into analysis. Third, educational environments outside United States and Europe provide new possibilities to understand the diversity in the variables affecting learning.

Kleemans and colleagues (2012) suggest that intervention studies should account for both child and home factors in improving children's EN skills. Based on our experience with South African families with young children and their challenges in everyday life, we do not fully agree with Kleemans and her colleagues (2012), but rather suggest that the general education system should be developed so that all children will have possibilities to learn early academic skills (Melhuish et al., 2013; Tran, Luchters, & Fisher, 2017).

References

Allan, N. P., & Lonigan, C. J. (2011). Examining the dimensionality of effortful control in preschool children and its relation to academic and socioemotional indicators. *Developmental Psychology, 47*(4), 905.

Andersson, U., & Lyxell, B. (2007). Working memory deficit in children with mathematical difficulties: A general or specific deficit? *Journal of Experimental Psychology, 96*(3), 197–228.

ThinkMath-scale, Kindergarten. Unpublished.

Aunio, P., Korhonen, J., Bashash, L., & Khoshbakht, F. (2014). Children's early numeracy in Finland and Iran. *International Journal of Early Years Education, 22*(4), 423–440.

Aunio, P., & Niemivirta, M. (2010). Predicting children's mathematical performance in grade one by early numeracy. *Learning and Individual Differences, 20*(5), 427–435. https://doi.org/10.1016/j.lindif.2010.06.003.

Aunio, P., & Räsänen, P. (2015). Core numerical skills for learning mathematics in children aged five to eight years—A working model for educators. *European Early Childhood Education Research Journal*. https://doi.org/10.1080/1350293X.2014.996424 Advanced online publication.

Bautista, D., Mitchelmore, M., & Mulligan, J. (2009). Factors influencing Filipino children's solutions to addition and subtraction word problems. *Educational Psychology, 29*(6), 729–745.

Bierman, K. L., Welsh, J. A., Heinrichs, B. S., Nix, R. L., & Mathis, E. T. (2015). Helping head start parents promote their children's kindergarten adjustment: The research based developmentally informed parent program. *Child Development, 86*(6), 1877–1891.

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*(2), 647–663.

Brod, G., Bunge, S. A., & Shing, Y. (2017). Does one year of schooling improve children's cognitive control and alter associated brain activation? *Psychological Science*956797617699838. https://doi.org/10.1177/0956797617699838 May 1.

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33*(3), 205–228.

Bull, R., Espy, K. A., Wiebe, S. A., Sheffield, T. D., & Nelson, J. M. (2011). Using confirmatory factor analysis to understand executive control in preschool children: Sources of variation in emergent mathematic achievement. *Developmental Sciences, 14*(4), 679–692.

Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives, 8*(1), 36–41. https://doi.org/10.1111/cdep.12059.

Chang, M. (2012). Academic performance of language-minority students and all-day kindergarten: A longitudinal study. *School Effectiveness and School Improvement, 23*(1), 21–48.

Chang, M., Singh, K., & Filer, K. (2009). Language factors associated with achievement grouping in math classrooms: A cross-sectional and longitudinal study. *School Effectiveness and School Improvement, 20*(1), 27–45.

Chu, F. W., VanMarle, K., & Geary, D. (2015). Early numerical foundations of young children's mathematical development. *Journal of Experimental Psychology, 132*, 205–212.

Chu, F. W., vanMarle, K., Rouder, J., & Geary, D. (2018). Children's early understanding of number predicts their later problem-solving sophistication in addition. *Journal of Experimental Child Psychology, 169*, 73–92.

Dilworth-Bart, J. E. (2012). Does executive function mediate SES and home quality associations with academic readiness? *Early Childhood Research Quarterly, 27*(3), 416–425.

Denton, K., West, J., & Walston, J. (2003). *Reading—Young children's achievement and classroom experiences: Findings from the condition of education, 2003.* U.S. Department of Education, Institute of Education Sciences NCES 2003-070.

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. D. (2008). Individual differences in numerical abilities in preschoolers. *Developmental Science, 11*, 650–654.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428–1446.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a non search task. *Perception & Psychophysics, 16*, 143–149. https://doi.org/10.3758/BF03203267.

Espy, K. A., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neurospychology, 26*(1), 465–486.

Florit, E., Roch, M., & Levorato, M. C. (2014). Listening text comprehension in preschoolers: A longitudinal study on the role of semantic components. *Reading and Writing, 27*(5), 793–817.

Fritz-Stratmann, Balzer, L., Herholdt, R., Ragpot, L., & Ehlert, A. (2014). A mathematics competence test for Grade 1 children migrates from Germany to South Africa. *South African Journal of Childhood Education, 4*(2), 114–133.

Fuchs, L. S., Geary, D. C., Compton, D. L., Fuchs, D., Hamlett, C. L., Seethaler, P. M., et al. (2010). Do different types of school mathematics development depend on different constellations of numerical versus general cognitive abilities? *Developmental Psychology, 46*(6), 1731.

Gandolfi, R., Viterbori, P., Traverso, L., & Usai, M. C. (2014). Inhibitory processes in toddlers: A latent-variable approach. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2014.00381 30 April 2014.

Geary, D. C. (2013). Early foundations for mathematics learning and their relations to learning disabilities. *Current Directions in Psychological Science, 22*(1), 23–27. https://doi.org/10.1177/0963721412469398.

Graven, M., & Venkat, H. (Eds.). (2017). *Improving primary mathematics education, teaching and learning research for development in resource-constrained contexts*. Hampshire, UK: Palgrave Macmillan UK.

Göbel, S. M., Watson, S. E., Lervåg, A., & Hulme, C. (2014). Children's arithmetic development: It is number knowledge, not the approximate number sense, that counts. *Psychological Science, 25*(3), 789–798.

Hartmann, W., & Rankin, J. (2013). *Sisi goes to school and other stories.* Cape Town, SA: Human & Rousseau.

Harvey, H. A., & Miller, G. E. (2017). Executive function skills, early mathematics and vocabulary in Head Start Preschool Children. *Early Education and Development,*

28(3), 290–307. https://doi.org/10.1080/10409289.2016.1218728.
Henning, E. (2014). Teachers understanding of mathematical cognition in childhood: Towards a shift in pedagogical content knowledge? *Perspectives in Education, 31*(3), 139–154.
Henning, E. (2013). Forging a research community of practice to find out how South African children make their world mathematical. Special issue edited by A Fritz-Stratmann and G Dampier. *South African Journal of Childhood Education, 3*(2), 141–155.
Henning, E. (2012). Learning concepts, language, and literacy in hybrid language codes: The multilingual maze of urban grade 1 classrooms in South Africa. *Perspectives in Education, 30*, 61–77.
Henning, E., Fritz, A., Ehlert, A., Ragpot, L., Balzer, L., & Mawila, D. (2013). Testing the mathematical n Germany and South Africa: First pilot studies. In E. Henning (Ed.). *Symposium Presented at the Conference of the European Association of Research on Learning and Instruction (EARLI)* Munich, August.
Hoff, E. (2006). How social contexts support and shape language development. *Developmental Review, 26*, 55–88.
Hooper, S. R., Roberts, J., Sideris, J., Burchinal, M., & Zeisel, S. (2010). Longitudinal predictors of reading and math trajectories through middle school for African American versus Caucasian students across two samples. *Developmental Psychology, 46*, 1018–1029.
Hughes, C., Ensor, R., Wilson, A., & Graham, A. (2009). Tracking executive function across the transition to school: A latent variable approach. *Developmental Neuropsychology, 35*(1), 20–36.
Jacobsen, G. M., Mello, M. C., Kochhann, R., & Fonseca, R. P. (2017). Executive functions in school-age children: Influence of age, gender, school type and parental education. *Applied Cognitive Psychology, 31*(4), 404–413.
Jordan, N. C., Glutting, J., & Ramineni, C. (2010). The importance of number sense to mathematics achievement in first and third grades. *Learning and Individual Differences, 20*, 82–88. https://doi.org/10.1016/j.lindif.2009.07.004.
Jordan, N. C., Kaplan, D., Oláh, L., & 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. https://doi.org/10.1111/j.1467-8624.2006.00862.x.
Kleemans, T., Segers, E., & Verhoeven, L. (2011). Cognitive and language precursors to numeracy in kindergarten: Evidence from first and second language learners. *Learning and Individual Differences, 21*(5), 555–561.
Kleemans, T., Peeters, M., Segers, E., & Verhoeven, L. (2012). Child and home predictors of early numeracy skills in kindergarten. *Early Childhood Research Quarterly, 27*, 471–477.
Kolkman, M. E., Hoijtink, H. J. A., Kroesbergen, E. H., & Leseman, P. P. M. (2013). The role of executive functions in numerical magnitude skills. *Learning and Individual Differences, 24*, 145–151.
Krajewski, K., & Schneider, W. (2009a). Early development of quantity to number-word linkage as a precursor of mathematical school achievement and mathematical difficulties: Findings from a four-year longitudinal study. *Learning and Instruction, 19*, 513–526. https://doi.org/10.1016/j.learninstruc.2008.10.002.
Krajewski, K., & Schneider, W. (2009b). Exploring the impact of phonological awareness, visual–spatial working memory, and preschool quantity–number competencies on mathematics achievement in elementary school: Findings from a 3-year longitudinal study. *Journal of Experimental Child Psychology, 103*(4), 516–531.
Lan, X., Legare, C., Ponitz, C. C., Li, S., & Morrison, F. J. (2011). Investigating the links between the subcomponents of executive function and academic achievement: A cross-cultural analysis of Chinese and American preschoolers. *Journal of Experimental Child Psychology, 108*, 677–692.
Lee, K., & Bull, R. (2016). Developmental changes in working memory, updating, and math achievement. *Journal of Educational Psychology, 108*(6), 869–882.
LeFevre, J. A., Skwarchuk, S. L., Smith-Chant, B. 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 Science, 41*(2), 55.
LeFevre, J.-A., Fast, L., Skwarchuk, S.-L., Smith-Chant, B. L., Bisanz, J., Kamawar, D., et al. (2010). Pathways to mathematics: Longitudinal predictors of performance. *Child Development, 81*(6), 1753–1767. https://doi.org/10.1111/j.1467-8624.2010.01508.x.
Lepola, J., Lynch, J., Kiuru, N., Laakkonen, E., & Niemi, E. (2016). Early oral language comprehension, task orientation, and foundational reading skills as predictors of grade 3 reading comprehension. *Reading Research Quarterly, 51*(4), 373–390.
Lepola, J., Lynch, J., Laakkonen, E., Silvén, M., & Niemi, P. (2012). The role of inference making and other language skills in the development of narrative listening comprehension in 4–6 year old children. *Reading Research Quarterly, 47*(3), 259–282.
Levine, S., & Baillargeon, R. (2016). Different factors of language in numerical development: Exact number and individuation. In D. Barner, & S. Baron (Eds.). *Core knowledge and conceptual change* (pp. 127–150). Oxford: University Press.
Martiniello, M. (2009). Linguistic complexity, schematic representations, and differential item functioning for English language learners in math tests. *Educational Assessment, 14*(3-4), 160–179.
McLeod, S., Harrison, L. J., Whiteford, C., & Walker, S. (2015). Multilingualism and speech-language competence in early childhood: Impact on academic and social-emotional outcomes at school. *Early Childhood Research Quarterly, 34*, 53–66.
Melhuish, E., Quinn, L., Sylva, K., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (2013). Preschool affects longer term literacy and numeracy: Results from a general population longitudinal study in Northern Ireland. *School Effectiveness and School Improvement, 24*(2), 234–250.
Melhuish, E. C., Phan, M. B., Sylva, K., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (2008). Effects of the home learning environment and preschool center experience upon literacy and numeracy development in early primary school. *The Journal of Social Issues, 64*(1), 95–114.
Melhuish, E. C., Sylva, K., Sammons, P., Siraj-Blatchford, I., Taggart, B., Phan, M., et al. (2008). Preschool influences on mathematics achievement. *Science, 321*(5893), 1161–1162.
Merkley, R., & Ansari, D. (2016). Why numerical symbols count in the development of mathematical skills: Evidence from brain and behavior. *Current Opinion in Behavioral Sciences, 10*, 14–20.
Merkley, R., Thompson, J., & Scerif, G. (2015). Of huge mice and tiny elephants: Exploring the relationship between inhibitory processes and preschool math skills. *Frontiers in Psychology, 6*, 1903.
Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*(1), 8–14.
Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wagner, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontallobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100. https://doi.org/10.1006/cogp.1999.0734.
Moll, K., Snowling, M. J., Göbel, S. M., & Hulme, C. (2015). Early language and executive skills predict variations in number and arithmetic skills in children at family-risk of dyslexia and typically developing controls. *Learning and Instruction, 38*, 53–62. https://doi.org/10.1016/j.learninstruc.2015.03.004.
Morgan, P. L., Farkas, G., & Wu, Q. (2009). Five-year growth trajectories of kindergarten children with learning difficulties in mathematics. *Journal of Learning Disabilities, 42*, 306–321. https://doi.org/10.1177/0022219408331037.
Morgan, P. L., Farkas, G., & Wu, Q. (2011). Kindergarten children's growth trajectories in reading and mathematics: Who falls increasingly behind? *Journal of Learning Disabilities, 44*(5), 472–488.
Muldoon, K., Towse, J., Simms, V., Perra, O., & Menzies, V. (2013). A longitudinal analysis of estimation, counting skills, and mathematical ability across the first school year. *Developmental Psychology, 49*(2), 250.
Paradis, J., Schneider, P., & Duncan, T. S. (2013). Discriminating children with language impairment among English-language learners from diverse first-language backgrounds. *Journal of Speech Language and Hearing Research, 56*(3), 971–981.
Passolunghi, M. C., & Lanfranchi, S. (2012). Domian-spefici and domain-general precursors of mathematical achievement: A longitduninal study from kindergarten to first grade. *The British Journal of Educational Psychology, 82*(1), 42–63.
Penner, A. M., & Paret, M. (2008). Gender differences in mathematics achievement: Exploring the early grades and the extremes. *Social Science Research, 37*(1), 239–253. https://doi.org/10.1016/j.ssresearch.2007.06.012.
Piasta, S., Purpura, D., & Wagner, R. K. (2010). Fostering alphabet knowledge development: A comparison of two instructional approaches. *Reading and Writing, 23*(6), 607–626.
Pinto, G., Bigozzi, L., Tarchi, C., Vezzani, C., & Accorti Gamannossi, B. (2016). Predicting reading, spelling, and mathematical skills: A longitudinal study from kindergarten through first grade. *Psychological Reports, 118*(2), 413–440.

Ponitz, C. C., McClelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology, 45*(3), 605.
Purpura, D. J., Hume, L. E., Sims, D. M., & Lonigan, C. J. (2011). Early literacy and early numeracy: The value of including early literacy skills in prediction of numeracy development. *Journal of Experimental Child Psychology, 110*, 647–658.
Purpura, D. J., & Reid, E. E. (2016). Mathematics and language: Individual and group differences in mathematical language skills in young children. *Early Childhood Research Quarterly, 36*, 259–268.
Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference and cognitive approach. *Learning and Individual Differences, 20*, 110–122.
Ragpot, L., & Brink, S. (2016). *Grade 1 listening comprehension scale.* Johannesburg: University of Johannesburg Centre for Childhood Education Practice (CEPR).
Raver, C. C., Jones, S. M., Li-Grining, C., Zhai, F., Bub, K., & Pressler, E. (2011). CSRP's impact on low income preschoolers' preacademic skills: Self-regulation as a mediating mechanism. *Child Development, 82*(1), 362–378.
Reynolds, A. J., Temple, J. A., Ou, S. R., Arteaga, I. A., & White, B. A. B. (2011). School-based early childhood education and age -28 well-being: Effects by timing, dosage and subgroups. *Science, 333*, 360–364.
Roebers, C., & Kauer, M. (2009). Motor and cognitive control in a normative sample of 7- year-olds. *Developmental Science, 12*, 175–181.
Romaine, S. (2013). Politics and policies of promoting multilingualism in the European Union. *Language Policy, 12*(2), 115–137.
Romano, E., Babchishin, L., Pagani, L. S., & Kohen, D. (2010). School readiness and later achievement: Replication and extension using a nationwide Canadian survey. *Developmental Psychology, 46*(5), 995.
Rouse, C., Brooks-Gunn, J., & McLanahan, S. (2005). Introducing the issue. *The Future of Children,* 5–14.
Sammons, P., Sylva, K., Melhuish, E., Siraj-Blatchford, I., Taggart, B., & Hunt, S. (2008). Effective Pre-school and Primary Education 3-11 Project (EPPE 3-11): Influences on children's attainment and progress in Key Stage 2: Cognitive outcomes in Year 6. Research report DCSF-RR048.
Sarnecka, B. W., & Carey, S. (2008). How counting represents number: What children must learn and when they learn it. *Cognition, 108*, 662–674.
Schmitt, S. A., Geldhof, G. J., Purpura, D. J., Duncan, R., & McClelland, M. M. (2017). Examining the relations between executive function, math, and literacy during the transition to kindergarten: A multi-analytic approach. *Journal of Educational Psychology*. https://doi.org/10.1037/edu0000193 Advance online publication.
Shaul, S., & Swartz, M. (2014). The role of the executive functions in school readiness among preschool-age children. *Reading and Writing, 27*(4), 749–768.
Simmons, F. R., & Singleton, C. (2008). Do weak phonological representations impact on arithmetic development? A review of research into arithmetic and dyslexia. *Dyslexia, 14*(2), 77–94.
Snow, C. E., Burns, M. S., & Griffin, P. (1998). *Preventing reading difficulties in young children.* Washington, DC: Department of Education.
South Africa. Department of Basic Education. (2011). National Curriculum Statement. Foundation phase mathematics. http://www.education.gov.za/Portals/0/CD/National%20Curriculum%20Statements%20and%20Vocational/CAPS%20MATHS%20%20ENGLISH%20GR%201-3%20FS.pdf?ver=2015-01-27-160947-800. On 20/10/2016.
South African Schools Act 1996, 6th September. https://www.gov.za/sites/www.gov.za/files/Act84of1996.pdf.
Spaull, N., & Kotze, J. (2015). Starting behind and staying behind in South Africa: The case of insurmountable learning deficits in mathematics. *International Journal of Educational Development, 3*(4), 13–24.
Spelke, E. S., & Tsvikin, S. (2001). Language and number: A bilingual training study. *Cognition, 78*, 45–88.
Strasser, K., & Río, F. D. (2014). The role of comprehension monitoring, theory of mind, and vocabulary depth in predicting story comprehension and recall of kindergarten children. *Reading Research Quarterly, 49*(2), 169–187.
Taylor, S., & Von Fintel, M. (2016). Estimating the impact language of instruction in South African primary schools: A 'fixed effects approach'. *Economics of Education Review, 50*, 75–89.
Titz, C., & Karbach, J. (2014). Working memory and executive functions: Effects of training on academic achievement. *Psychological Research, 78*(6), 852–868.
Toll, S. W. M., & Van Luit, J. E. H. (2014). The developmental relationship between language and low early numeracy skills throughout kindergarten. *Exceptional Children, 81*(1), 64–78.
Tran, T. D., Luchters, S. S., & Fisher, J. (2017). Early childhood development: Impact of national human development, family poverty, parenting practices and access to early childhood education. *Child: Care, Health and Development, 43*(3), 415–426.
Young-Loveridge, J. M. (2004). Effects on early numeracy of a program using number books and games. *Early Childhood Research Quarterly, 19*(1), 82–98.
Weiland, C., & Yoshikawa, H. (2013). Impacts of a prekindergarten program on children's mathematics, language, literacy, executive function, and emotional skills. *Child Development, 84*(6), 2112–2130.
Welsh, J. A., Nix, R. L., Blair, C., Bierman, K. L., & Nelson, K. E. (2010). The Development of cognitive skills and gains in academic school readiness for children from low-income families. *Journal of Educational Psychology, 102*(1), 43–53.
Wiebe, S. A., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental Psychology, 44*(2), 575.
Willoughby, M. T., Blair, C. B., Wirth, R. J., & Greenberg, M. (2010). The measurement of executive function at age 3 years: Psychometric properties and criterion validity of a new battery of tasks. *Psychological Assessment, 22*(2), 306.
Zhai, F., Raver, C. C., & Jones, S. M. (2012). Academic performance of subsequent schools and impacts of early interventions: Evidence from a randomized controlled trial in Head Start settings. *Children and Youth Services Review, 34*(5), 946–954.
Zhang, X. (2016). Linking language, visual-spatial, and executive functions skills to number competence in very young Chinese children. *Early Childhood Research Quarterly, 36*, 178–189. science/article/pii/S0885200615300302.
Xenidou-Dervou, I., De Smedt, B., Van der Schoot, M., & Van Lieshout, E. C. D. M. (2013). Individual differences in kindergarten math achievement: The integrative roles of approximation skills and working memory. *Learning and Individual Differences, 28*, 119–129.