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Investigating the relationship between two home numeracy measures: A questionnaire and observations during Lego building and book reading

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Home numeracy has been defined as the parent–child interactions that include experiences with numerical content in daily-life settings. Previous studies have commonly operationalized home numeracy either via questionnaires or via observational methods. These studies have shown that both types of measures are positively related to variability in children's mathematical skills. This study investigated whether these distinctive data collection methods index the same aspect of home numeracy. The frequencies of home numeracy activities and parents' opinions about their children's mathematics education were assessed via a questionnaire. The amount of home numeracy talk was observed via two semi-structured videotaped parent–child activity sessions (Lego building and book reading). Children's mathematical skills were examined with two calculation subtests. We observed that parents' reports and number of observed numeracy interactions were not related to each other. Interestingly, parents' reports of numeracy activities were *positively* related to children's calculation abilities, whereas the observed home numeracy talk was *negatively* related to children's calculation abilities. These results indicate that these two methods tap on different aspects of home numeracy.

Statement of contribution

What is already known on this subject?

- Home numeracy, that is, parent–child interactions that include experiences with numerical content, is supposed to have a positive impact on calculation or mathematical ability in general.
- Despite many positive results, some studies have failed to find such an association.
- Home numeracy has been assessed with questionnaires on the frequency of numerical experiences and observations of parent–child interactions; however, those two measures of home numeracy have never been compared directly.

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What does this study add?

- This study assessed home numeracy through questionnaires and observations in the 44 parent–child dyads and showed that home numeracy measures derived from questionnaires and observations are not related.
- Moreover, the relation between the reported frequency of home numeracy activities and calculation on the one hand, and parent–child number talk (derived from observations) and calculation on the other hand is in opposite directions; the frequency of activities is positively related to calculation performance; and the amount of number talk is negatively related to calculation.
- This study shows that both measures tap into different aspects of home numeracy and can be an important factor explaining inconsistencies in literature.

It has been known that environmental factors, such as number experiences at home, play a role in children's mathematical skills (Saxe, Guberman, & Gearhart, 1987). More recently, these experiences were referred to as 'home numeracy' and have been defined as parent–child interactions that include experiences with numerical content in daily life (e.g., Blevins-Knabe & Austin, 2016). Home numeracy has been commonly operationalized by two methods, that are questionnaires and observations. Studies using one of these methods have shown that both measures of home numeracy are related to children's mathematical skills (e.g., questionnaires: LeFevre *et al.*, 2009; observations: Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010). Although questionnaires and observations are technically two distinctive data collection methods, there are hardly studies that have tested in one sample whether these methods index the same aspects of home numeracy. This study investigated how these two measures of home numeracy were related to each other, and how they were related to children's calculation skills.

Questionnaire data and children's mathematical skills

In home numeracy questionnaires, parents are asked how often they jointly do various numeracy activities with their children. Findings demonstrated that children whose parents reported to be more involved in numeracy activities performed better on mathematical tasks (LeFevre *et al.*, 2009). However, a consensus regarding which specific types of home numeracy activities are related to children's mathematical skills has not been reached. Blevins-Knabe and Musun-Miller (1996) found that children's basic numerical skills (e.g., counting, comparison) as well as calculation skills were positively correlated with some home numeracy activities (e.g., mentioning number facts such as $1 + 1 = 2$) but negatively with other activities (e.g., reciting the numbers 1–10).

LeFevre *et al.* (2009) suggested a distinction between different types of home numeracy activities, that is, formal and informal ones. Formal activities, such as 'counting objects' and 'reading number storybooks', were defined as parents' explicit attempts to teach children numeracy. Informal activities, such as 'playing card games' and 'measuring ingredients while cooking', were defined as incidental numeracy teaching that occurs as a by-product of the actual activity. A principal components analysis on a list of several activities by LeFevre and colleagues revealed four factors of home numeracy: (1) *number skills* (e.g., counting objects), (2) *number books* (e.g., reading number storybooks), belong to the category of formal activities, (3) *games* (e.g., playing card games), and (4) *applications* (e.g., playing with calculator), belong to the category of informal activities. LeFevre *et al.* (2009) showed that children's basic numerical skills were related to informal activities (i.e., games) but not to the formal ones, whereas children's calculation fluency was related to both formal and informal activities.

This distinction between *formal* and *informal* home numeracy activities has further resulted in inconsistent findings. Some studies also showed that formal home numeracy activities were positively related to children's basic numerical skills (LeFevre, Polyzoi, Skwarchuk, Fast, & Sowinski, 2010; Segers, Kleemans, & Verhoeven, 2015). Others reported that a total score including both formal and informal activities was not related to children's basic numerical and calculation skills (Blevins-Knabe, Austin, Musun, Eddy, & Jones, 2000; Missall, Hojnoski, Caskie, & Repasky, 2015). Ciping, Silinskas, Wei, and Georgiou (2015) even reported a negative correlation between formal activities and calculation fluency in children.

Another categorization of home numeracy activities was proposed by Skwarchuk (2009). Based on the difficulty level of the task, Skwarchuk (2009) classified activities as *basic* (count objects, recite numerals, etc.) versus *complex* (add, subtract objects, etc.), and observed that children's basic numerical skills were positively associated with complex home numeracy activities, but negatively with basic home numeracy activities. Skwarchuk, Sowinski, and LeFevre (2014) integrated the former and more recent classification of home numeracy activities and divided up formal home numeracy into two factors: *basic* (helping to recite number in order, etc.) and *advanced* (helping to learn simple sums, etc.) formal home numeracy. Their results showed that informal home numeracy was uniquely related to children's non-symbolic calculation skills (abilities to non-symbolically represent and manipulate quantities), whereas children's basic numerical skills were uniquely related to the advanced but not basic formal activities. In sum, questionnaire data suggest that formal home numeracy activities – especially the advanced ones – are related to children's mathematical performance.

Not only parents' reports of home numeracy activities but also their opinions about mathematics education were found to be correlated with their children's mathematical skills (Blevins-Knabe *et al.*, 2000). For example, parents' numeracy *expectations* for their children (e.g., it is important that my child counts up to 10 by the end of kindergarten) were associated with their reported frequency of home numeracy activities and with children's basic numerical skills (Kleemans, Peeters, Segers, & Verhoeven, 2012; LeFevre *et al.*, 2010). Furthermore, parents' *attitudes* towards mathematics (e.g., I enjoy math) were found to be positively related to children's basic numerical skills, but not to home numeracy activities (Skwarchuk *et al.*, 2014). In contrast, Missall *et al.* (2015) found a positive association between parents' *beliefs* regarding mathematics education (e.g., I can influence my child's math skills) and home numeracy activities, but not with children's basic numerical skills.

Observations and children's mathematical skills

In home numeracy observations, parent–child dyads are typically asked to do certain activities together either in a (semi)structured (e.g., cooking, book reading, or playing games) or unstructured way (e.g., conducting activities as they would normally do daily) while being videotaped. The recordings are transcribed to code the frequency and the type of numeracy talk of dyads. Levine *et al.* (2010) designed an elaborate, longitudinal study where dyads were videotaped in their homes for 90 min while engaged in daily-life activities. Recordings took place every 4 months and started when children were 14 months and ended when they were 30 months. They observed that children's basic numerical skills at 46 months were predicted by the amount of parental numeracy talk, even after controlling for socio-economic status (SES), parental non-numerical, and children's numeracy talk (see also Susperreguy & Davis-Kean, 2016).

Several studies have shown that numeracy talk of parent–child dyads mainly involves counting and labelling cardinal values of sets (Ramani, Rowe, Eason, & Leech, 2015; Zhou *et al.*, 2006). Following Levine *et al.* (2010), Gunderson and Levine (2011) investigated the specific characteristics of the talk involving counting and labelling cardinal values of sets. The numeracy talk was coded in two ways based on whether the talk refers to, (1) present, visible (e.g., books, apples) sets of objects or non-present, intangible sets (e.g., time, counting songs) and (2) small (1–3) or larger (4–10) sets. The strongest predictor of children's basic numerical skills was the talk about large sets of present objects even after controlling for SES and other types of parental numeracy and non-numeracy talk.

Methodological differences between questionnaires and observations

Questionnaires and observations are two technically distinctive methods that have their own methodological strengths and weaknesses (Gravetter & Forzano, 2006). For example, questionnaires are more frequently used to address opinions, which are harder to capture via observations. Furthermore, questionnaires are easy to apply, but the responses rely on memory and are possibly influenced by a social desirability bias. Observations, on the other hand, are simultaneous and less influenced by social desirability if a cover story that masks the aim of the study is presented (Harmon-Jones, Amodio, & Zinner, 2007). However, observations can be influenced by the presence of the observer and by observer bias. Consequently, although home numeracy assessed with either questionnaires or observations is expected to lead to similar conclusions, they should be considered as complementary methods.

To date, only two studies included both questionnaires and observations to assess home numeracy. Ramani *et al.* (2015) addressed home numeracy in low-income families with questionnaires and observations during parent–child book reading, puzzle making, and board game playing sessions. Additionally, children were examined on basic (verbal counting and number identification) and advanced (counting principles, enumeration and cardinality, number line estimation and comparison) numerical skills. Results indicated that formal home numeracy activities positively predicted children's basic numerical skills but not advanced skills. The numeracy talk during the observations was categorized as *foundational* (counting and identifying numbers) or *advanced* (labelling number of elements in a set, ordering numbers, and arithmetic). While neither types of talk were related to children's basic numerical skills, the advanced talk was positively related to the advanced numerical skills. However, the relationship between the home numeracy measures obtained via questionnaires and observations was not reported.

Exploring the relationship between parent self-report data and parent–child numeracy interactions was the explicit goal of a very recent study by Missall, Hojnoski, and Moreano (2017). Results showed that these two types of home numeracy measures were not related. However, the relation between these indicators and mathematical skills was not examined. Moreover, their questionnaire contained only formal activities, making a comparison with previous studies that distinguish between different types of activities more difficult.

The current study

The goal of this study was to explore the relationship between two indicators of home numeracy (questionnaires and observations). Two previous studies that included both indicators (Missall *et al.*, 2017; Ramani *et al.*, 2015) are inconclusive concerning these relations. First, we examined whether parents' reported numeracy activities and the observed numeracy interactions were correlated. Second, positive correlations were expected between children's calculation skills and both home numeracy measures. Third, positive correlations were expected between parents' reported opinions about mathematics education and home numeracy activities and children's calculation skills.

Method

Participants and procedure

Participants were 44 Belgian last-year kindergartners (M_{age} = 5.64 years; SD = 0.35; range = 4.33–6.12 years; 20 females) and their parents. In Flanders, compulsory education starts at the age of six, but the majority of the children already enrols in a kindergarten programme, starting when they are about 2.5–3 years old and focusing on non-mandatory learning goals. From the present sample, all children attended kindergarten on a permanent basis. All participants were native Dutch speakers, except for one Dutch/French bilingual child.

The data were collected by 22 undergraduate students as an assignment during their bachelor programme. The assignment was supervised by the second author of this study. Before data collection, the students were intensively trained. First, they completed a seminar introducing the topic and providing the students with detailed instructions on how to administer the measures (e.g., how to approach the dyads with the cover story, administer the questionnaire and calculation test, and conduct and score the observations). The seminar also included a practice session where the students coded examples of parent–child interactions. First, they scored the example videos in groups with the help of the instructor, and then, they scored another example individually. They received feedback in group from the instructor. The students were given written step-by-step instructions to follow during data collection to ensure a standardized protocol of the procedure. After the seminar, each student had to contact two families with a last-year kindergartner, leading to 44 parent–child dyads. Parents were approached with a cover story that the study was about general parent–child interactions during two different types of activities. When parents were interested, an appointment was made for a moment in which the student could visit the participants at their homes. The parents received a written informed consent form, also stating confidentiality of all information, that had to be signed both by the parents and the student.

Data collection started with the observations. First, parent–child dyads were asked to play with Lego blocks and afterwards to read a book. Although parents were not explicitly asked to follow instructions for Lego building, all of them used the instruction paper included in the original Lego box. The activity sessions were videotaped by the students. Afterwards, the parents were asked to complete the home numeracy questionnaire, while the students evaluated the children's calculation skills. Furthermore, the students were asked to submit an individual report about their experiences with the assignment, including the issues that could have affected the data, which was checked by the instructor. None of the students reported any possible issues that could have affected the data.

Materials

Home numeracy

Questionnaire. Parents' reports of home numeracy activities and parents' opinion about their children's mathematics education were assessed with a Dutch translation of the questionnaire from LeFevre *et al.* (2009; see Appendix A). The current translation has been validated in a Flemish sample (see Mutaf Yıldız, Sasanguie, De Smedt, & Reynvoet, 2016) and revealed a four-factor structure (number skills, number books, games, and applications) of the activities similar to LeFevre *et al.* (2009). In the present study, only the questions about home numeracy activities from the questionnaire (Table 1) on which parents indicated how often they engaged in these activities with their children on a 5-point scale (1 = never to 5 = everyday) were used. Furthermore, parents' opinion about mathematics education was assessed with the following statement, 'I find it important for my child to be exposed to mathematical concepts every day'. on which parents indicated to which extent they agreed with it on a 5-point scale (1 = strongly disagree to 5 = strongly agree). This question served as a general indicator of attitudes, expectations, and beliefs about mathematics education.

Parents were asked to report their education level as an indicator of the SES of the families, because parental education directly influences children's educational success after controlling for other SES indices (Dubow, Boxer, & Huesmann, 2009; see also Davis-Kean, 2005). In the descriptive analyses, education level of the parent who played with the child during the observations was used. Twenty-five per cent of the parents had a degree of secondary education (n = 11), 50% had a bachelor/undergraduate degree (n = 22), and 25% had a master degree (n = 11), indicating that families were from middle-to-high SES. The questionnaire was completed by mothers (n = 33) or fathers

Table 1. Descriptive statistics of home numeracy activities and parents' opinion about mathematics education

	M	*SD*	Min	Max	Theoretical max
Number practices	2.86	0.72	1.40	4.40	5
Identifying names of written numerals	3.18	1.22	1	5	5
Counting objects	3.41	0.97	1	5	5
Sorting things by size, colour, or shape	2.20	1.07	1	5	5
Learning simple sums	2.73	1.15	1	5	5
Writing numbers	2.80	1.09	1	5	5
Number books	1.98	0.69	1	3.33	5
Doing 'connect-the-dot' activities	1.80	0.73	1	4	5
Using number activity books	2.43	1.15	1	4	5
Reading number storybooks	1.70	0.82	1	4	5
Games	2.75	0.94	1	5	5
Playing card games	2.95	1.03	1	5	5
Playing board games with die or spinner	2.95	1.02	1	5	5
Applications	2.86	0.68	1.40	4	5
Talking about money when shopping	2.82	1.04	1	5	5
Measuring ingredient while cooking	1.95	0.75	1	4	5
Being timed	3.66	1.16	1	5	5
Collecting objects	2.48	1.25	1	5	5
Using calendars and dates	3.41	1.53	1	5	5
Parents' opinion	3.70	0.82	1	5	5

(n = 9). In all but one case, the same parent was involved in both filling in the questionnaire and the activity sessions. Information about who filled in the questionnaire was missing for two parents.

Observations. Home numeracy talk was evaluated from two semi-structured videotaped parent–child activity sessions (5 min each): (1) Building 'LEGO 60072 City Demolition Starter Set' and (2) Reading a commercially available storybook 'Max Krijgt Een Vriendje' ['Max finds a friend']. These two activities were chosen for three reasons: (1) They allowed for elicitation of interactions that were addressed in the questionnaire, (2) similar activities were used in previous studies (Ramani *et al.*, 2015; Zhou *et al.*, 2006), and (3) these activities were not explicitly designed to elicit number talk, allowing parent and child to shape the content of the conversation.

The Lego set consists of 85 pieces and is recommended for the ages between 5 and 12, did not explicitly focus on number, but provided parents the opportunity to focus on numerical aspects if they preferred to. Similarly, 'Max finds a friend' is a storybook, without any specific focus on numeracy. This gives the parents the opportunity to focus on the numerical content of the book if they preferred to (e.g., a picture of three rabbits that was part of the storybook). Twenty-five per cent of the dyads involved fathers (n = 11), 68% mothers (n = 30), and in 7% of the dyads (n = 3), father and mother each engaged in one activity. The video recordings were coded for the utterances of numeracy talk by two independent raters. The numeracy talk was coded separately for Lego building and book reading activities, as well as for parent and child with a coding scheme consisting of 10 categories: counting up, counting down, counting wrong, determining the number of a set, operations, sorting things, identifying written numerals, distinguishing quantities, ordering quantities, and other numerical words (see Appendix 2). The coding scheme was developed to capture numeracy talk that matches the items in the questionnaire on the 'number practices' factor. Additional categories were included based on the study of Toll and Van Luit (2014) who found that specific math language was a predictive factor in early numeracy growth of at-risk kindergartners.

The bachelor student who collected the data was the first rater that coded the numeracy talk. The second rater was a master student that also worked on this project for her master's thesis, who was intensively trained to code (all) the observations. Inter-rater reliability for the coding was calculated with an intraclass correlation coefficients (ICC) analysis, with a two-way random-effects model (Hallgren, 2012). A satisfactory degree of reliability was found between the ratings of the independent raters. The average-measures ICC was .784, which quantifies the reliability of the ratings based on the averages of ratings provided by several coders, indicated that the raters were consistent on their coding.

Calculation

Two calculation subtests of the TediMath (Grégoire, Noël, & Van Nieuwenhoven, 2004) were administered to examine children's calculation skills: (1) the pictorial calculations subtest comprised six (addition and subtraction) problems. The problems were read aloud by the experimenter (e.g., 'Here you see two red balloons and three blue balloons. How many balloons are there all together?'). For each correct answer, the children gained one point. (2) The symbolic calculations subtest consisted of 18 horizontally presented (addition) problems (e.g., 6 + 3 = ?). According to the test instructions, only the first problem was read aloud by the experimenter. Children were instructed to solve as many problems as possible, and the examination was stopped after five consecutive errors. The total score was the number of correctly answered problems.

Results

Home numeracy

Questionnaire

The less frequent or not reported home numeracy activities were identified by checking the distributions of the 20 numeracy items. Similar to LeFevre *et al.* (2009) and Mutaf Yıldız *et al.* (2016), the items on which more than 55% of the parents replied 'never' were excluded from further analyses: 'Playing with number fridge magnets' (79.5%), 'Counting down' (56.8%), 'Playing with calculator' (77.3%), 'Having your child wear a watch' (61.4%), and 'Using number or arithmetic flash cards' (61.4%). Internal consistency of the remaining numeracy items (n = 15) was .71, indicating that the home numeracy questionnaire was reliable.

The number of variables was further reduced into groups of highly related activities based on the results of the principal components analysis in our previous work (Mutaf Yıldız *et al.*, 2016). The internal consistency of the factors was .66 for number practices, .60 for number books, .80 for games, and .51 for applications. The scores used in the subsequent analyses were computed by averaging the frequencies on the items belonging to the same factor. Table 1 represents the descriptive statistics of the activities and parents' opinion about mathematics education.

Observations

Some types of numeracy talk (counting down and wrong counting) were never observed. Means and standard deviations of the remaining types of home numeracy talk are presented in Table 2. The results showed that the numeracy talk was mainly uttered by parents (83%). The frequency of parents' total numeracy talk during the Lego building and book reading did not differ significantly, $t(43) = -0.45$, $p = .65$. However, there were some differences in the kind of numeracy talk that was uttered during both activities. 'Determining the number of a set', $t(43) = -6.83$, $p < .01$, and 'ordering quantities', $t(43) = -3.82$, $p < .01$, were more used during Lego building. In contrast, 'identifying

Table 2. Mean (*SD*) frequency of numeracy talk during Lego building and book reading activities for parents and children

	LEGO		BOOK	
	Parents	Children	Parents	Children
Counting	0.34 (0.99)	0.68 (1.44)	0	0
Determining the number of a set	3.45 (2.75)	1.41 (1.87)	0.32 (0.77)	0.23 (0.56)
Operations	0.59 (1.65)	0.07 (0.33)	0.07 (0.25)	0.02 (0.15)
Sorting things	0.11 (0.39)	0.05 (0.21)	0	0
Identifying written numerals	2.45 (3.05)	1.02 (1.97)	5.14 (2.13)	0.07 (0.45)
Distinguishing quantities	0.07 (0.25)	0.02 (0.15)	0.07 (0.25)	0
Ordering quantities	3.98 (2.99)	0.57 (0.90)	2.27 (1.11)	0
Other numerical talk	1.73 (1.92)	0.70 (1.12)	4.34 (1.38)	0.14 (0.35)
Total	12.73 (6.72)	4.52 (4.10)	12.20 (2.83)	0.45 (0.82)

names of written numerals', $t(43) = 4.58, p < .01$, and the utterances of 'other numeracy related words' such as none, both, all, $t(43) = 7.52, p < .01$, were more observed during book reading. Children's numeracy talk was observed more during Lego play than during book reading $t(43) = -6.86$, $p < .01$. More specifically, in the categories 'counting', $t(43) = -3.13$, $p < .01$, 'determining the number of a set', $t(43) = -4.31$, $p < .01$, 'identifying names of written numerals', $t(43) = -3.24, p < .01$, 'ordering quantities', $t(43) = -4.19$, $p < .01$, and 'other numeracy related words', $t(43) = -3.40$, $p < .01$, children expressed numeracy talk more during Lego play than book reading. To investigate the correlations with parents' reports of home numeracy activities and calculation, the total scores were calculated for both activities and for parent and child separately.

Calculation

On the pictorial calculations subtest, the average score of the children was 5.24 ($SD = 0.93$; range = 3–6). On the symbolic calculations subtest, the performance was lower ($M = 3.69$, $SD = 3.39$; range = 0–10). There were no outliers in both tasks ($M \pm 3$ SD). Due to the ceiling effect in the pictorial calculations and the floor effect in the symbolic calculations subtest, the average score of the two subtests was used as an index of the children's calculation skills.

To rule out that the differences in children's calculation performance were driven by the parents' education level, an ANOVA was conducted with parents' education as between-subjects factor. The analysis showed that children's calculation skills did not differ according to their parents' education level, $F(2,39) = 1.82, p = .17$.

Correlations

The relations between home numeracy activities, home numeracy talk, and children's calculation skills were examined with Pearson correlations (Table 3). There was no significant association between the home numeracy activities assessed via the

Table 3. Correlations among and between parents' opinion about mathematics education, home numeracy activities, home numeracy talk, and children's calculation skills

	1	2	3	4	5	6	7	8	9
1. Parents' opinion	–								
2. Number practices	.44**	–							
3. Number books	.49**	.52**	–						
4. Games	.10	.07	.43**	–					
5. Applications	.26†	.14	.09	.26†	–				
6. Parent talk (book)	.11	.13	.22	.03	.04	–			
7. Child talk (book)	.02	−.10	−.04	.00	.22	.22	–		
8. Parent talk (Lego)	.08	.11	.07	.10	−.05	−.16	−.01	–	
9. Child talk (Lego)	.18	.16	.11	.02	.12	.07	.30*	.00	–
10. Calculation	.44**	.31*	.17	−.03	.16	−.05	.00	−.35*	.20

Notes. Pearson correlations were conducted between and among home numeracy activities, home numeracy talk, and children's calculation skills, and Spearman's correlations were conducted between parent's opinion and home numeracy activities, home numeracy talk, and children's calculation skills.
$^{*}p < .05$; $^{**}p < .01$; $^{\dagger}p = .08$.

questionnaire and the home numeracy talk. Children's calculation skills correlated with the two home numeracy measures but in opposite directions. The number practices factor was positively correlated with children's calculation skills: Children of which the parents reported that they were more engaged in number practices activities had more advanced calculation skills. On the other hand, parents' numeracy talk during the Lego building activity was negatively correlated with children's calculation skills: Children of parents who uttered more numeracy talk during Lego building performed worse on calculation.

Spearman's correlations were computed to investigate the relationship between parents' opinion about mathematics education and home numeracy measures and calculation skills. Parents' opinion about mathematics education was positively correlated with the home numeracy questionnaire (number practices and number books) and children's calculation skills, but it was not related to the home numeracy talk in the observations. These results indicate that the parents who find it more important for their children to be exposed to mathematical concepts reported number practices and number book activities more often and had children with better calculation skills.

Discussion

The current study investigated the relationship between two data collection methods of home numeracy, that is, questionnaires and observations, and their relationship with children's calculation skills. We observed that home numeracy when assessed with questionnaires was not associated with home numeracy assessed via observations. Interestingly, self-reports of formal home numeracy activities (i.e., number practices) were *positively* related to children's calculation abilities. However, home numeracy talk during Lego building was *negatively* related to children's calculation abilities. Additionally, parents' opinion about mathematics education was positively related to formal home numeracy activities as derived from the questionnaire (i.e., number practices and number books) and to children's calculation skills, but not to the number of observed numeracy interactions.

In line with Missall *et al.* (2017), there were no associations between the two measures of home numeracy; questionnaires versus observations. This indicates that these two measures tap into different aspects of home numeracy. It is important to emphasize that similar materials and activities were used as in previous studies (LeFevre *et al.*, 2009; Ramani *et al.*, 2015) The inter-rater reliability of the numeracy talk coding was satisfactory, and the distribution of the numeracy talk during observations was in line with previous findings. Results showed that parents' numeracy talk was more frequent than the children's numeracy talk (e.g., Levine *et al.*, 2010), and children's numeracy talk was less frequent during the book reading compared to Lego building (e.g., Ramani *et al.*, 2015). Furthermore, the four factors from the home numeracy questions were similar to LeFevre *et al.* (2009) with Cronbach's alphas ranging from .71 to .84. Therefore, it is unlikely that the absence of the relation between the two methods is due to low validity or reliability. Additionally, the children's age in our study was comparable with previous home numeracy studies (e.g., Benavides-Varela *et al.*, 2016; Segers *et al.*, 2015).

Findings demonstrated that only parents' numeracy talk during Lego building was negatively associated with children's calculation performance. This might possibly be explained by the parents' additional efforts to help and compensate for the lower calculation abilities of their child. It is also possible that the parents of children with higher calculation scores found the numeracy talk that could be elicited during Lego building not advanced enough to engage in a lot of numeracy interactions. For example, numeracy talk about arithmetic operations was almost absent. On the other hand, the questionnaire data revealed that activities such as practicing simple sums were reported frequently. This interpretation of the results is supported by the study of Ramani *et al.* (2015), who showed that only advanced numeracy talk was related to children's mathematics performance (see also Skwarchuk *et al.*, 2014). It should be noted that these interpretations are based on the assumption that parents were aware of their children's mathematical level. It has been demonstrated that parents adjust their teaching behaviour according to their children's achievement (Saxe *et al.*, 1987). For example, children's mathematical skills in grade 1 negatively predicted home numeracy at later stages (Ciping *et al.*, 2015; Silinskas, Leppänen, Aunola, Parrila, & Nurmi, 2010), indicating that parents presented less effort to stimulate their children because they knew their children were already performing well.

The observation of a *negative* relation between parental numeracy talk and children's mathematical skills is in contrast with Ramani *et al.* (2015) who documented a positive relation. This could be explained by differences in samples between their study and ours. Their research was conducted in Head Start families representing a sample of low-income families whereas the participants in the present study were characterized by a middle- to high-SES background. It has been reported that low-SES children fall behind their peers from middle- to high-SES in their mathematical skills (Starkey, Klein, & Wakeley, 2004). Because families in Ramani *et al.* (2015) were participating in the Head Start programme, it is plausible that these parents were aware of this risk and put more effort to help their children. As a consequence, knowing that helping their children improve their children's mathematical skills motivated parents further to stimulate their children. This reasoning is in line with the above argument that parents adjust their behaviour according to their children's achievement trajectory, assuming that in these low-income families, the parents were also aware about their children's level of achievement.

The observation that only parents' and not children's talk was related to children's calculation skills is consistent with the literature. For instance, Levine *et al.* (2010) reported that only parents' number talk, but not children's number talk, was predictive of children's cardinality knowledge. The absence of an association between parents' numeracy talk during book reading and children's calculation skills could be due to the more structured nature of a book. For example, during book reading most of the talk belonged to 'identifying names of written numerals' (42%) and 'other numeracy related words' (33%), which can be assumed to be uttered by most of the parents based on the story itself. More than half of the parents identified names of written numerals and used other numeracy-related words to the same extent. Consequently, there was low variability in number talk between parents, and this likely explains the absence of the relationship with children's calculation skills.

An interesting result that supports the idea of multidimensionality of home numeracy is the observation of an opposite direction of the association between different home numeracy measures and children's calculation skills. Of the four factors of home numeracy activities, only number practices factor was found to be positively associated with children's calculation skills (see also LeFevre *et al.*, 2010). Additionally, parents who find it more important for their child to be exposed to mathematical events daily engaged in more formal home numeracy activities and their children scored higher on the calculation tasks. These results suggest that doing number practices activities, such as learning simple sums and writing numbers at home, might play a role in children's calculation performance.

Limitations and future directions

The current study has some limitations. First, only the calculation performance was used as an indicator of mathematical skill. Future research addressing various mathematical skills of children is needed to evaluate whether the current conclusion can be generalized to other mathematical skills. Second, semi-structured observations of relatively basic activities were used to record numeracy talk. It is possible that the current settings were not of sufficient complexity to trigger advanced numeracy talk. Future research is needed in structured observation settings with the potential of triggering more advanced numeracy talk and unstructured settings to evaluate whether the current results can be replicated. Finally, due to the cross-sectional design of the current study, no directional inferences about the associations between home numeracy measures and children's calculation skills can be made. Therefore, longitudinal designs are recommended to gain more insight in the direction of the relations between attitudes, home numeracy measures, and calculation.

Conclusion

Current results indicate that questionnaires and observations tap into different aspects of home numeracy. Therefore, including both questionnaires and observations in the same study provides a broader perspective on the relation between home numeracy and calculation. Including both measures in future studies will also reveal whether the dissociation between questionnaires and observations is due to the particular setting in which the numeracy talk was observed, or whether it is due to methodological differences between the two.

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Appendix 1: Home numeracy questionnaire

1. Schat het aantal kinderboeken dat u thuis heeft.

   ……………………………………………………

2. Schat het aantal boeken voor volwassenen dat u thuis heeft.

   ……………………………………………………

3. Tot hoeveel kan uw kind tellen?

   ……………………………………………………

4. Hoe belangrijk is het voor u dat uw kind volgende doelstellingen bereikt voordat hij/zij naar het 1^{e} leerjaar gaat? (plaats telkens één kruisje in het vakje dat overeenstemt met uw antwoord; niet belangrijk, een beetje belangrijk, belangrijk, heel belangrijk, extreem belangrijk)

   Tellen tot 10
   Tellen tot 100
   Herkennen van geschreven cijfers (bv. 3 = drie)
   Kennen van eenvoudige sommen (bv. 2 + 2)
   Opzeggen van het alfabet

Schrijven van zijn/haar naam
Schrijven van letters
Herkennen van letters van het alfabet

5. Hoe vaak voert (u samen met) uw kind onderstaande activiteiten uit? (plaats telkens één kruisje in het vakje dat overeenstemt met uw antwoord; nooit, 1 tot 3 keer per maand, 1 keer per week, meerdere keren per week, dagelijks)

Namen van geschreven cijfers herkennen (bv. 3 = drie)
Spelen met cijfermagneten op de koelkast
Voorwerpen tellen
Voorwerpen sorteren op kleur, grootte of vorm
Tellen in omgekeerde volgorde (10, 9, 8, 7. . .)
Eenvoudige sommen aanleren (vb. 2 + 2 = 4)
Getallen schrijven
Praten over geld wanneer je gaat winkelen (bv. hoeveel kost dat/wat kost het meest?)
Ingrediënten wegen tijdens het koken
Spelletjes spelen, oefeningen maken,. . . tegen tijd
Spelen met rekenmachines
Voorwerpen verzamelen
Cijfertekeningen maken
Kalender en data gebruiken
Zorgen dat uw kind een horloge draagt
Gebruiken van spelletjesboeken over cijfers
Kinderboeken over cijfers lezen
Spelen van gezelschapspelletjes met een dobbelsteen
Kaartspelletjes spelen
Voorwerpen of stokken oprapen
Telliedjes zingen (bv. 10 kleine visjes)
Spelen met muziekinstrumenten
Puzzelen
Parels rijgen
Spelen met klei of plasticine
Spelen met blokken
Schilderen op nummers
Veters binden
Knopen dicht doen
'Winkeltje' spelen
Tekenen, schilderen, schrijven
'Schooltje' spelen
Knutselen met schaar en lijm
Kijken naar educatieve tv-programma's
Educatieve computerspelletjes spelen
Constructies bouwen (vb. Lego, Duplo. . .)
Namen of geschreven letters herkennen
Letterklanken herkennen
Letters schrijven

6. Geef aan in hoeverre u akkoord gaat met de volgende stellingen. (plaats telkens één kruisje in het vakje dat overeenstemt met uw antwoord; helemaal niet akkoord, niet akkoord, neutraal, akkoord, helemaal akkoord)

   Toen ik zelf op school zat, was ik goed in wiskunde.
   Toen ik zelf op school zat, vond ik wiskunde leuk.
   Tijdens het uitoefenen van mijn beroep krijg ik vaak te maken met wiskunde.
   Toen ik zelf op school zat, was ik goed in taal.
   Toen ik zelf op school zat, vond ik taal leuk.
   Ik vind wiskunde leuk.
   Ik vind lezen leuk.
   Ik vind het belangrijk dat mijn kind elke dag met wiskunde in contact komt.
   Ik vind het belangrijk om mijn kind elke dag voor te lezen.

7. Dit deel van de vragenlijst bevat enkele demografische vragen over uw gezin.
   (a). Wat is het hoogst behaalde diploma van de vader en de moeder?
   lager onderwijs
   lager secundair onderwijs
   hoger secundair onderwijs
   professionele bachelor
   (of hoger niet-universitair onderwijs van het korte type)
   academische bachelor of master aan een hogeschool
   (of hoger niet-universitair onderwijs van het lange type)
   academische bachelor of master aan een universiteit
   (of universitair onderwijs)
   andere, onbekend
   (b). In welke categorie situeert zich het gezamenlijk netto-maandinkomen van het huishouden, alle mogelijke inkomsten meegerekend?

   1. minder dan 1000 euro (40.000 Bef)
   2. tussen 1000 euro (40.000 Bef) en 2000 euro (80.000 Bef)
   3. tussen 2000 euro (80.000 Bef) en 3000 euro (120.000 Bef)
   4. tussen 3000 euro (120.000 Bef) en 4000 euro (160.000 Bef)
   5. tussen 4000 euro (160.000 Bef) en 5000 euro (200.000 Bef)
   6. meer dan 5000 euro (200.000 Bef)

Appendix 2: Numeracy talk coding scheme for children

Type of interaction	Frequency	Total
A. *Counting (up)*: When the child counts in sequence, specify the quantity under the *type of interaction* column and put a '+' sign under the column of *frequency*. If an incident is repeated remark it by putting another '+' to the *frequency* column. List the different incidents below in the lines. In the first example, child counts up to 7 (1–2–3–4–5–6–7) only once. In the second example, child counts up to 5 (1–2–3–4–5) three times		
e.g., 7	+	1

Continued

Table A2. (*Continued*)

Type of interaction	Frequency	Total
e.g., 5	+ + +	3
i.e., 'We need one, two, three blocks'		
B. *Counting (down)*: Same as counting up! In the example, child counts down from 4 (4–3–2–1) twice		
e.g., 4	++	2
N.A.		
C. *Wrong counting:* There might be two kinds of mistakes: type 1, child skips some numbers in the sequence while counting; type 2, while counting with objects child counts in the correct sequence but fails in the attempt of indicating to the correct correspondent of the numbers (says three but indicates to the second object again)		
e.g., type 1 (1–2–4)	+	1
N.A.		
D. *Set to number*: When the child utters the quantity of a set without counting in sequences. In the example, child says 'there are four blocks!' without counting from one (1–2–3)		
e.g., 4	+++	3
i.e., 'I used three blocks.'		
E. *Operations*: There might be two kinds of operations; additions or subtractions. In the first example, child says 'there are *two blocks* with *one more* there are *three*' twice (different occasions/sentences). In the second example, child says 'there are *three* men, *one* gone, *two* men left'. However, attention! The underlined words in the sentence are coded accordingly and plus a credit is given to addition operation		
e.g., Addition (2 + 1)	++	2
e.g., Subtraction (3–1)	+	1
i.e., 'I have one, you have one we have two'		
F. *Sorting things*: There might be three kinds of sorting by colour, shape, or size (tall-short-wide-narrow so on). In the example, the child groups square and triangular pieces separately		
e.g., Shape (square, triangle)	++	2
i.e., 'We need yellow round for the head'		
G. *Identifying written numerals*: When the child indicates to a written numeral and utters the numerals. For example, the child sees the page number 6 and says 'page six'		
e.g., 6	+	1
i.e., 'We can go to page four'		
H. *Distinguishing quantities*: When the child utters a comparative adjective such as more-most-less-least-smallest-larger-bigger-greatest and so on for distinguishing quantities		
e.g., Many	++	2
i.e., 'We have more pieces'		
I. *Ordering quantities*: When the child utters a ordinal word that refers to the position in a sequence such as first-second-third-last-before-above-next-between- and so on		
e.g., Last	+	1
i.e., 'Let's make the man first, then the car next'		
J. *Other numerical words*: when the child utters a word with a numerical meaning such as double-half-pair-many-little-a lot-all- and so on		
e.g., All	+	1
i.e., 'Both are beautiful'		