Verbal and action-based measures of kindergartners' SFON and their associations with number-related utterances during picture book reading

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Abstract

Background

Young children's spontaneous focusing on numerosity (SFON) as measured by experimental tasks is related to their mathematics achievement. This association is hypothetically explained by children's self-initiated practice in number recognition during everyday activities. As such, experimentally measured SFON should be associated with SFON exhibited during everyday activities and play. However, prior studies investigating this assumed association provided inconsistent findings.

Aims

We aimed to address this issue by investigating the association between kindergartners' SFON as measured by two different experimental tasks and the frequency of their number-related utterances during a typical picture book reading activity.

Sample

Participants were 65 4- to 6-year-olds in kindergarten (before the start of formal education).

Methods

Kindergartners individually participated in two sessions. First, they completed an action-based SFON Imitation task and a verbal SFON Picture task, with a short visuo-motor task in between. Next, children were invited to spontaneously comment on the pictures of a picture book during a typical picture book reading activity.

Results

Results revealed a positive association between children's SFON as measured by the Picture task and the frequency of their number-related utterances during typical picture book reading, but no such association for the Imitation task.

Conclusions

Our findings indicate that children with higher SFON as measured by a verbal experimental task also tend to focus more frequently on number during verbal everyday activities, such as picture book reading. In view of the divergent associations between our SFON measures under study with everyday number activities, the current data suggest that SFON may not be a unitary construct and/or might be task-dependent.

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Introduction

Having strong foundational skills in mathematics is fundamental to later academic success in modern Western societies (Claessens, Duncan, & Engel, 2009; Duncan et al., 2007; Torbeyns, Gilmore, & Verschaffel, 2015). Already in kindergarten, children show substantial and long-lasting individual differences in their early mathematical abilities (Jordan, Kaplan, Ramineni, & Locuniak, 2009; Torbeyns et al., 2015). For example, some kindergartners are already counting up to 20 and more, while others are only taking their very first steps in learning to count. This large variation in early mathematical abilities has been found to predict individual differences in mathematics learning in primary school (Aunio & Niemivirta, 2010; Booth & Siegler, 2006; Geary, 2011; Hannula-Sormunen, Lehtinen, & Räsänen, 2015; Jordan et al., 2009; Kolkman, Kroesbergen, & Leseman, 2013; Merkley & Ansari, 2016).

Recent evidence suggests that besides the acquisition of these well-investigated early mathematical abilities, children's mathematical dispositions also play a unique role in early mathematical development (Hannula-Sormunen, 2015). In particular, children's tendency to Spontaneously Focus On Numerosity (SFON) has been identified as an important contributor to mathematical success (Hannula, Lepola, & Lehtinen, 2010; Hannula-Sormunen et al., 2015). This SFON tendency is assumed to increase the amount of children's self-initiated practice in number recognition in everyday situations, which subsequently promotes their further mathematical development (Hannula & Lehtinen, 2005; Hannula et al., 2010). So, first, children's SFON as measured via experimental SFON tasks should be associated with their SFON during everyday activities (= part 1 of the explanation), and second, their amount of

SFON during everyday activities should be related to their math achievement (= part 2 of the explanation).

Thus far, studies investigating the assumed association between SFON in experimental tasks and SFON in everyday activities have produced inconsistent results (= part 1 of the explanation) (e.g., Batchelor, 2014; Edens & Potter, 2013; Hannula, Mattinen, & Lehtinen, 2005; Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016). This inconsistency may be explained by the way in which SFON in experimental tasks is measured. The present study attempted to evaluate this explanation by examining the association between children's SFON as measured by two different experimental tasks and children's number-related utterances during a typical picture book reading activity.

Spontaneous focusing on numerosity

Spontaneous focusing on numerosity (SFON) represents a separate attentional process of "spontaneously (i.e., in a self-initiated way not prompted by others) focusing attention on the aspect of exact numerosity of a set of items or incidents" (Hannula et al., 2010, p. 395), that can be distinguished within children's existing mathematical competencies. This attentional process is needed for triggering exact number recognition processes and using the recognized exact number in action. Previous studies revealed large inter-individual differences and stability in children's SFON across various task contexts (Hannula & Lehtinen, 2005; Hannula et al., 2010). Longitudinal studies revealed the unique and domain-specific contribution of SFON to concurrent mathematical abilities, such as counting skills and subitizing-based enumeration (Hannula & Lehtinen, 2005; Hannula, Räsänen, & Lehtinen, 2007), and to mathematics achievement at the beginning (Hannula et al., 2010) and at the end of primary school (Hannula-Sormunen et al., 2015).

In recent years, scholars have become increasingly interested in the concept of SFON. The existence of SFON and its association with mathematical ability has been replicated in many studies (see, Rathé, Torbeyns, Hannula-Sormunen, De Smedt, & Verschaffel, 2016, for a review). Studies have also tested psychometric properties of SFON tasks (e.g., Batchelor, 2014), explored the association between SFON and mathematical difficulties (e.g., Gray & Reeve, 2016; Kucian et al., 2012), and investigated SFON in a diversity of cultural settings (Batchelor, Inglis, & Gilmore, 2015; Bojorque, Torbeyns, Hannula-Sormunen, Van Nijlen, & Verschaffel, 2017; Edens & Potter, 2013; Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016; Sella, Berteletti, Lucangeli, & Zorzi, 2016). Although SFON has recently been identified as an important factor for explaining individual differences in early mathematical development, little research has been done on the potential mechanism by which this SFON tendency contributes to mathematics achievement.

Underlying mechanism of SFON

The association between SFON and mathematics achievement can be hypothetically explained by children's amount of spontaneous practice in number recognition during everyday activities: Children with higher SFON are assumed to spontaneously focus more frequently on numerosity in their everyday environments (= part 1 of the explanation), which promotes their further mathematical development (= part 2 of the explanation) (Hannula et al., 2010, 2005). The first part of this explanation has been tested by investigating the association between SFON in experimental tasks and SFON in everyday activities, yet the findings of these studies have been inconclusive: Some studies showed a positive association between children's SFON in the experimental tasks and their spontaneous attention to number in everyday situations (e.g., Batchelor, 2014, Study 3), while others did not find empirical evidence for this assumed

association (Edens & Potter, 2013; Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016), and still others found evidence for both (Hannula et al., 2005).

One reason for this inconsistency could be the way in which SFON is measured. For example, the study of Batchelor (2014, Study 3) used a *verbal* SFON task, whereas the others (Edens & Potter, 2013; Hannula et al., 2005; Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016) used primarily *action-based* SFON tasks. To the best of our knowledge, there are no studies available that related both verbal and action-based SFON measures in one sample of children to unravel their association with SFON as exhibited in everyday situations.

The current study

Against this background, the aim of the present study was to evaluate whether the inconsistent findings concerning the association between SFON in experimental tasks and SFON during everyday activities (e.g., Batchelor, 2014; Edens & Potter, 2013; Hannula et al., 2005; Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016) can be explained by the way in which SFON is measured in the experimental tasks. Specifically, we contrasted verbal and action-based measures of SFON in relation to an everyday picture book reading activity. Children aged 4 to 6 years old were first offered an action-based Imitation task (Hannula & Lehtinen, 2005) and a verbal Picture task (Batchelor et al., 2015), with a short visuo-motor task in between. Thereafter, they were invited to spontaneously comment on the pictures of a modified version of the picture book *Boer Boris* [Farmer Boris] (van Lieshout & Hopman, 2013). Based on previous studies pointing to the important difference in response mode between the Imitation task (i.e., primarily action-based response) and the Picture task (i.e., primarily verbal response) (Batchelor, 2014; Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016), we hypothesized that the association between children's SFON in the experimental tasks and

their number-related utterances during typical picture book reading would be stronger for the verbal than for the action-based SFON task.

Method

Participants

One hundred and five children were recruited from two schools in Flanders, Belgium. Thirteen children did not receive parental consent, 24 children did not have sufficient verbal and social skills to accomplish the various tasks based on their teacher's evaluation of those skills, and another 3 children were removed from the final dataset because of practical problems during data collection. The final sample included 65 kindergartners (31 boys) with ages ranging from 4.3 to 6.3 years (M = 5.4 years, SD = 7 months). Parents and teachers were not informed about the mathematical focus of the study. The children had not yet received formal instruction in mathematics and reading.

Materials and procedure

Children individually participated in two sessions. In the first session, they completed a SFON Imitation task and a SFON Picture task, with a short visuo-motor buffer task in between. During the second session, they participated in a standardized typical picture book reading activity. All the tasks were administered by the same interviewer and took place in a quiet room at the children's kindergarten with at least 3 days between both sessions.

SFON. Children's SFON was measured by the action-based Elsi bird Imitation task from Hannula and Lehtinen (2005) and the verbal Picture task from Batchelor et al. (2015). The order of the tasks was counterbalanced. There was no effect of task order: we observed no significant difference in SFON score on the Imitation task between the children who completed the Imitation task first versus the children who completed the Picture task first ($t(62) = 0.57$, p

= .57). Similarly, no significant difference in SFON score on the Picture task could be detected between the children who completed the Imitation task first and the children who were offered the Picture task first ($t(63) = 0.64$, $p = .53$).

Imitation task. The materials of the Imitation task consisted of a toy parrot and two cases with different-colored berries. The child and the interviewer sat next to each other side by side. The parrot was placed in front of the child at the table, accompanied by one case of eight colored berries on the left side and one case of eight different-colored berries on the right side of the parrot. The interviewer started the task by saying: "This is bird Elsi and she likes berries. There are [color] berries here and there are [different color] berries here. Watch carefully what I do and then you do exactly like I did, OK?". In the first trial, the interviewer put two red berries and one blue berry with a large hand movement into the parrot's beak one at a time; the berries dropped into the parrot's stomach with a bumping sound. Then the child was instructed to do exactly the same: "Ready! Now you do exactly as I did". The second trial consisted of three green and two yellow berries. In the third and fourth trial, the interviewer put, respectively, two white and three orange, and one transparent and two light blue berries into the parrot's beak. The interviewer made sure the child's attention was on the task at the beginning of each trial. She avoided giving any specific feedback by staying pleasantly neutral throughout the task.

In line with previous SFON studies, we scored children's action-based responses (i.e., response) and registered their verbal and non-verbal quantifying acts (i.e., process) for each trial. Children received a SFON score of 1 in a trial when they gave the correct response (i.e., put the correct number of different-colored berries and/or correct total number of berries into the parrot's beak) and/or they showed at least one of the following verbal or non-verbal quantifying acts: (a) utterances including number words referring to the numbers of berries fed to the parrot, (b) use

of fingers to express numbers of berries, (c) counting acts including whispering number words or indicating counting acts by fingers, (d) other comments referring to either numbers of berries or counting of them, and (e) interpretation of the goal of the task as numerical (i.e., giving the same number of berries as the interviewer had given) (Hannula & Lehtinen, 2005). The maximum score on the task was 4. The task was videotaped for all the children. To investigate inter-rater reliability, two independent researchers scored the video registrations of 11 children (17%). The percentage of agreement was 100%.

Picture task. The materials of the Picture task were three cartoon pictures displaying both non-numerical and numerical information (e.g., a girl walking in an empty meadow accompanied with three chicks). The interviewer sat in front of the child and introduced the task while saying: "This game is all about pictures. I am going to show you a picture, but I am not going to see the picture. Only you get to see the picture. This means I need your help to tell me what is in the picture." Then the interviewer showed the child the first picture and asked: "What can you see in this picture?". The folder with the pictures was in between the child and the interviewer, so the interviewer could not see the pictures. There was no time limit for the child to describe the pictures. After the child remained silent for at least 3 seconds, the interviewer asked: "Is that everything?". When the child verbally or non-verbally confirmed that (s)he was ready, the interviewer moved to the next trial. The same procedure was used for the second and third trial.

Children received a SFON score of 1 in a trial when they mentioned at least once an exact numerosity while describing the picture (e.g., "I see *two* people"), regardless of its correctness, and/or showed signs of counting (e.g., "There are *1, 2, 3* houses"). When they did not mention an exact numerosity and showed no signs of counting, they got a score of 0[1]. The maximum score on the task was 3. The Picture task was videotaped for all children. The

percentage of agreement of two independent researchers, who scored the video registrations of 11 children (17%) performing the Picture task, was 100%.

Typical picture book reading activity. Children's number-related utterances during typical picture book reading were identified by individually inviting them to spontaneously comment on the pictures of a modified version of the picture book *Boer Boris* [Farmer Boris] (van Lieshout & Hopman, 2013), describing the everyday life at the farm of farmer Boris. The storyline includes the counting sequence from 1 to 11, with numerosities increasing by one on each subsequent page. For example, page 6 shows farmer Boris with his six pigs, while page 7 displays farmer Boris and his seven cows (see Appendix A).

We modified the text of the book because it had explicit number symbols and number words in the text. This might create a situation of GFON (Guided Focusing On Numerosity, Hannula & Lehtinen, 2005), which is not the same as an everyday situation that elicits children's spontaneous focusing on numerosity on its own, not prompted by someone else. The pictures of the book were also redesigned to make the to-be-counted elements on each page more similar and the presentation of these elements more clearly and structured. The last page, which brings together all essential visual information of the previous pages, was excluded from the modified version of the picture book.

The picture book was presented to the children according the reading scenario developed by Rathé, Torbeyns, Hannula-Sormunen, and Verschaffel (2016). The interviewer introduced the picture book by showing the front cover to the child and by reading the title of the book. Then the child was told that they would read the picture book together, following the same procedure on each page. In a first step, the child was shown the double-page and was invited to spontaneously comment on the double-page. When the child stated that (s)he had no additional

comments and/or remained silent for 5 seconds, the interviewer read the rhyme (step 2). During and after reading the rhyme, the child could provide additional comments (step 3). Again, after the child stated that (s)he had no further comments and/or remained silent for 5 seconds, the interviewer turned to the next double-page.

Children's utterances generated during the picture book reading activity were scored in two steps. In a first step, all utterances were scored as number-related or not number-related. In a second step, all number-related utterances were further classified with the classification scheme of Rathé, Torbeyns, Hannula-Sormunen, and Verschaffel (2016), with the exception of recognizing a numerical symbol (N3), because no number symbols were included in the modified picture book. We distinguished between six types of number-related utterances, namely (N1) counting (e.g., "one, two, three, four"), (N2) determining the numerosity of a set of items (e.g., "two baskets"), (N4) comparing quantities (e.g., " I saw one dog on the previous page and now there is still one dog") (N5) analyzing part-whole relationships (e.g., "I see three people, one girl and two boys), (N6) using quantity concepts (e.g., "I see a lot of mice"), and (N7) using ordinal numbers (e.g., "The sixth pig plays in the mud").

The picture book activity was also videotaped. The inter-rater reliability of two independent researchers, who scored the video registrations of 11 children (17%) performing the picture book activity, revealed a Cohen's Kappa of .83 for the first step and a Cohen's Kappa of .84 for the second step of the scoring procedure.

Results

Preliminary analyses revealed no significant influence of gender on children's SFON in the Picture task ($U = 437$, $p = .51$) and in the Imitation task ($U = 429$, $p = .59$), and on the frequency of their number-related utterances during picture book reading ($U = 444$, $p = .27$).

Likewise, children's age (in months) was not significantly related with their SFON scores (Picture task, r_s = -.07, p = .61; Imitation task, r_s = .17, p = .17) and the frequency of their number-related utterances (r_s = -.07, p = .60). The total number of words formulated during the picture book activity (i.e., word count; M = 261, SD = 149, *range* = 31-657) was significantly associated with children's SFON score on the Picture task (r_s = .33, p < .01) and the frequency of their number-related utterances during picture book reading (r_s = .70, p < .01). The total number of words generated during the solution of the Picture task (M = 74, SD = 46, *range* = 10-213) was significantly associated with children's SFON score on the Picture task (r_s = .46, p < .01) and the frequency of number-related utterances during picture book reading (r_s = .56, p < .01). Therefore, as in Rathé, Torbeyns, Hannula-Sormunen, and Verschaffel (2016), word count was included as a control in subsequent correlation analyses.

Descriptive results

SFON. Figure 1 shows the number of children with SFON scores ranging from 0 to 4 in the Imitation task and the number of children with SFON scores ranging from 0 to 3 in the Picture task. As shown in Figure 1, we found large individual differences in children's SFON as measured by the Imitation task. Only 34% of the children did not spontaneously focus on numerosity during the administration of the Imitation task. The majority of the children (66%) focused at least once on numerosity in this task and received SFON scores ranging from 1 to 4. From the latter group, most SFON scores (66%) were granted on the basis of a correct action-based *response* (i.e., feeding the correct number of berries); the other SFON scores were assigned on the basis of *process* (i.e., showing verbal or non-verbal quantifying acts, 17%) or a combination of *response* and *process* (17%). In the Imitation task, children focused on average 1.62 times (SD = 1.48) on numerosity.

In the Picture task, about half of the children (43%) did not verbalize their spontaneous focusing on numerosity while describing the cartoon pictures. The other children (57%) focused on numerosity in at least one of the trials (see Figure 1). Children focused on average 0.78 times (*SD* = 0.82) on numerosity in the Picture task. In contrast to the Imitation task, the Picture task does not allow for analyses of correctness of the number recognition in the task, because it is not possible to know how the child defined the set of items (s)he has enumerated.

Number-related utterances during picture book reading. We also observed large individual differences in the type and the frequency of children's number-related utterances during picture book reading. Twenty-eight percent of the children did not state any number-related utterance during the typical picture book reading activity. The other children (72%) formulated at least one number-related utterance on at least 1 of the 11 picture book pages. Figure 2 displays the number of children per frequency of number-related utterances during the picture book reading activity in total. As shown in Figure 2, the frequency of number-related utterances varied from 0 to 34 with an average of 5.08 number-related utterances generated during the picture book activity (*SD* = 6.56).

Figure 3 presents the number of children per type of combination of number-related utterances. None of the children compared quantities (N4). Almost half of the children (43%) who formulated at least one number-related utterance, generated only one type of number-related utterance during the picture book activity, i.e., determining the numerosity of a set of items (N2; 26%) or using quantity concepts (N6; 17%). The other children (57%) generated different combinations of types of number-related utterances, with determining the numerosity of a set of items and using quantity concepts as the most frequently observed combination (N2_N6; 32%).

During the picture book reading activity, the children formulated altogether 329 number-related utterances. They most frequently determined the numerosity of a set of items (N2; 62%) and used quantity concepts (N6; 28.6%). Counting acts were observed for 27 of the 329 number-related utterances (N1; 8.2%), analyzing part-whole relationships for 3 trials (N5; 0.9%), and using ordinal numbers only for 1 trial (N7; 0.3%).

Association between SFON and number-related utterances

We examined the association between children's SFON in the experimental tasks and the frequency of their number-related utterances during picture book reading by means of Spearman's rho and partial rank correlation analyses. Results revealed no association between children's SFON in the Imitation task and the frequency of their number-related utterances during picture book reading, $r_s = .02$, $p = .88$, also not after accounting for word count in the picture book reading activity, *partial* $r_s = .02$, $p = .89$. Figure 4 shows a bubble plot of the association between SFON in the Picture task and the frequency of number-related utterances during the picture book reading activity. As shown in Figure 4, children's SFON in the Picture task and the frequency of their number-related utterances during picture book reading was positively and significantly associated, $r_s = .47$, $p < .01$, also after accounting for word count during picture book reading and word count during the Picture task, *partial* $r_s = .34$, $p < .01$. When testing for the difference between two dependent correlations retrieved from the same sample, we observed a significant difference between both partial correlations ($z = -2.04$, $p = .02$), indicating that the association between children's SFON in the picture book reading activity and their SFON in the experimental tasks is significantly smaller for the Imitation task than for the Picture task. Remarkably, children's performances on the Imitation task and the

Picture task were not significantly related (r_s = .06, p = .62), also not after accounting for word count in the Picture task (*partial* r_s = .13, p = .32).

Conclusion and discussion

Individual differences in children's SFON as measured by experimental tasks are found to be related to mathematics achievement in primary school (Hannula et al., 2010; Hannula-Sormunen et al., 2015). It is assumed that a greater SFON tendency will increase the amount of children's self-initiated practice in number recognition during everyday activities and play (= part 1 of the explanation), which in turn will enhance their further mathematical development (= part 2 of the explanation). So, first, children's SFON as measured via experimental tasks should be associated with their spontaneous attention to numerosity during everyday activities, and, second, the extent to which children spontaneously focus on numerosity during everyday activities should be related to their math achievement. Unfortunately, prior studies evaluating the first part of this potential explanation (i.e., studies testing the assumed association between SFON in experimental tasks and SFON in everyday activities) used either primarily verbal or mainly action-based SFON experimental measures and yielded inconsistent results (e.g., Batchelor, 2014; Edens & Potter, 2013; Hannula et al., 2005; Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016).

We therefore aimed to empirically test whether this inconsistency is due to the experimental measures that were used to investigate SFON. Specifically, we evaluated this explanation by contrasting children's SFON as measured by a verbal task and an action-based task with the frequency of their number-related utterances during a verbally-based picture book reading activity. Based on previous findings pointing to the important difference in response mode between the action-based Imitation task and the verbal Picture task (Batchelor, 2014;

Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016), we predicted that the association between SFON in the experimental tasks and SFON during the verbally-based picture book reading activity would be stronger for the verbal SFON task than for the action-based SFON task.

In line with our hypothesis, the association between children's SFON in the experimental tasks and their spontaneous attention to number during the verbally-based picture book reading activity was found to be more prominent for the verbal SFON task than for the action-based SFON task. This finding is in line with previous research (e.g., Batchelor, 2014, Study 3; Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016) and suggests that verbal SFON measures are more strongly related to spontaneous focusing on numerosity in verbally-based everyday settings than action-based SFON measures.

Although promising, the findings of the present study challenge the construct and measurement of SFON by showing no association between children's verbal and action-based expressions of SFON as measured by the Imitation task and the Picture task, a finding that is consistent with Batchelor et al. (2015). Furthermore, we only found a significant association between children's verbal expressions of SFON in the Picture task and their number-related utterances during a verbally-based everyday activity. Altogether, these results suggest that there is limited convergence between the action-based and verbal SFON tasks. One possible explanation for this limited convergence is that SFON is not a unitary, but rather a multidimensional construct, consisting of a verbal and an action-based component. Future studies are required to further characterize the SFON construct and its different possible dimensions, and to develop reliable and valid measures addressing SFON in all its complexity and possible multidimensionality. For example, in addition to the present study focusing on

children's SFON during verbally-based everyday activities, future research could relate action-based measures of SFON with their SFON during action-based everyday situations, such as playing with blocks or doing crafts, as indicated by Hannula et al.'s (2005) intervention study showing a significant relation at the posttest between action-based measures of SFON and children's spontaneous attention to number during everyday activities in day care. In such action-based everyday situations, we expect the action-based measures of SFON more strongly correlated than the verbal measures of SFON.

Another possible explanation for this limited convergence between the action-based and verbal SFON tasks is that SFON is heavily influenced by the task context. Initial support for this explanation comes from a recent study by Chan and Mazzocco (2017), who found discrepancies in children's attention to number across different task contexts varying in the relative salience of number. In a similar vein, Batchelor and Pickering (2017) recently showed that not only different response modes (i.e., action versus verbal), but also other task features, such as the number of competing non-numerical dimensions (i.e., few versus many dimensions to focus on) and the type of stimuli (i.e., dynamic versus static stimuli) might explain why verbal and action-based SFON tasks do not correlate, again suggesting that SFON is dependent on the task context. Future studies need to further explore this second possible explanation by studying the effect of manipulating different task features on children's performance on a given (action-based or verbal) SFON task and by investigating how these manipulations relate to children's early mathematical abilities. In doing so, these studies should use several tasks of the same type to provide a more generalizable measure of SFON tendency (Hannula, 2005).

In addition to the above considerations, it could be argued that the positive association between children's SFON in the Picture task and their number-related utterances during the

picture book reading activity is not that surprising, given that the Picture task and the picture book reading activity seem very similar. After all, both assess children's number-related utterances when they are presented with pictures and are explicitly requested to comment on them. However, as shown in Appendix B, there were some critical differences between the Picture task and the picture book reading activity as implemented in our study, which allow us to argue that they are essentially different and can be considered as representatives of an experimental task and an everyday activity, respectively.

Given the verbal demands of both the Picture task and the picture book reading activity, it could also be that the association between children's SFON in the verbal Picture task and their number-related utterances during the picture book reading activity is explained by their verbal skill. In the present study, we therefore used the total number of words formulated during the picture book reading activity and/or Picture task (i.e., word count) as a control in all our analyses to account for the verbal nature of the Picture task and the picture book reading activity. In contrast to previous studies using word count as a control for verbal skill (e.g., Batchelor et al., 2015), the current study used a more precise and reliable measure of word count by audio recording and completely transcribing children's verbal responses in both the Picture task and the picture book reading activity. Our results showed that differences in verbal skill did not explain the association between children's SFON in the experimental tasks and SFON during an everyday picture book reading activity. In order to additionally account for the verbal demands of the tasks, future studies could also consider standardized measures of language ability. Future studies on the association between SFON in experimental tasks and SFON during everyday activities should also account for children's number word knowledge, as Hannula and Lehtinen

(2005) indicated that the relation between number recognition skills and SFON may be reciprocal.

Clearly, the present study tested only the first part of Hannula et al.'s (2010) hypothetical explanation, namely the association between children's SFON as measured by experimental tasks and their spontaneous attention to numerosity during an everyday picture book reading activity. Future studies also need to address the second part of the hypothetical explanation by exploring whether children's SFON during everyday activities is associated with their math achievement. In addition to these studies, future longitudinal studies are required to test both parts of the hypothetical explanation for the association between SFON and math achievement. These studies, for example, should analyze whether children's verbal and action-based expressions of SFON in everyday activities mediate the association between children's SFON in the experimental tasks and their later math achievement. These studies will be important for education as well, as they will inform us about the specific SFON expressions that are pivotal for children's further mathematical development and about the materials that can be used to assess and stimulate these SFON expressions. Enhancing SFON during informal situations, such as reading picture books, free play, or crafts, might be a first step in preventing later mathematical difficulties and stimulating positive attitudes toward mathematics.

To conclude, the current study provided additional support for the assumed association between SFON in experimental tasks and SFON in everyday activities by contrasting, for the first time, both verbal and action-based measures of SFON in relation to a verbally-based picture book reading activity, which is an everyday activity that is quite different from the parent-child play activity investigated in Batchelor (2014, Study 3) and the free play activity investigated in Edens and Potter (2013). Our results demonstrated that the association between children's SFON

in the experimental tasks and their number-related utterances during picture book reading was more prominent for the verbal Picture task than for the action-based Imitation task. The combination of these findings urge for further research on the distinction between verbal and action-based expressions of SFON and their role in early mathematical development during typical picture book reading and other (action-based) everyday situations, but also for the use of several different SFON tasks using different response modes to capture children's general SFON tendency in a reliable and valid way.

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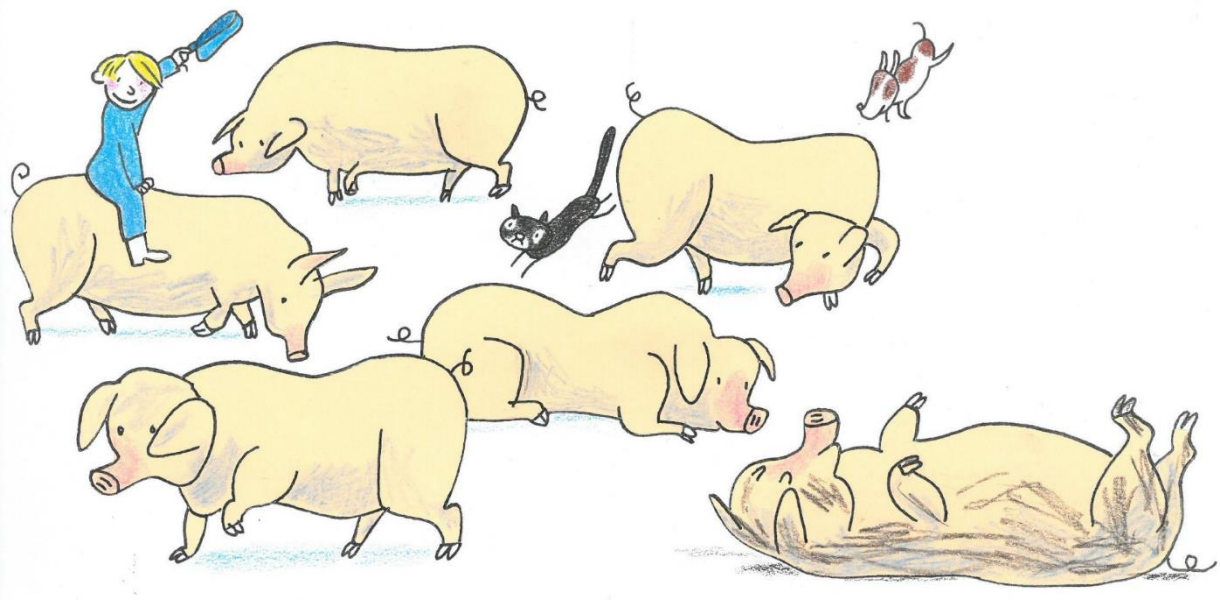
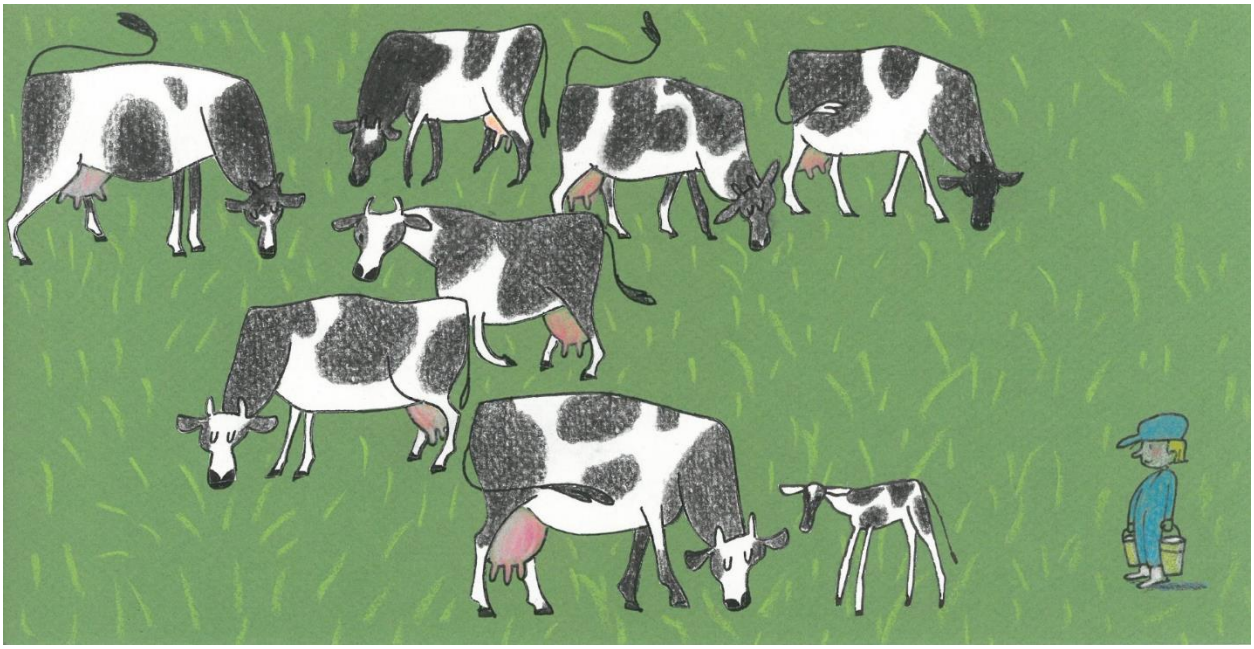
Appendices

Appendix A. Page 6 and 7 from the modified picture book *Boer Boris* [Farmer Boris]



Text: “Farmer Boris has a farm. It also involves pigs. They enjoy rooting on the ground or turning around in the mud.”



Text: “Farmer Boris has a farm. It also involves cows. They graze together in the meadow. There is also a sweet little calf.”

Appendix B. Critical differences between the experimental Picture task and the everyday picture book reading activity

Experimental Picture task	Everyday picture book reading activity
• Unfamiliar experimental setting, in which the experimenter sits in front of the child, without seeing the pictures. The child is instructed to help the experimenter by describing the pictures, because the experimenter cannot see the pictures.	• Familiar picture book reading setting, in which the experimenter sits next to the child on a chair or a pillow. The experimenter can see the pictures during the entire picture book reading activity. The child is invited to describe the pictures in the book, as they often do at home or in the classroom.
• Neutral behavior of the experimenter, who merely asks the child to describe the pictures, but does not further interact with the child.	• Less neutral behavior of the experimenter, who intervenes on each page by reading aloud the text, as a parent or teacher would do.
• 3 random picture trials, coming from the same series, but including unrelated contents.	• 11 picture trials, which all are part of a story line.

Footnotes

[1] In line with Batchelor et al. (2015), we used this dichotomous scoring, because (1) this way of scoring is more similar to the scoring of SFON in the action-based Imitation task, and (2) additional analyses associating the frequency of children's exact number word utterances in the Picture task with the frequency of their number-related utterances during typical picture book reading, yielded nearly the same results.

Figures

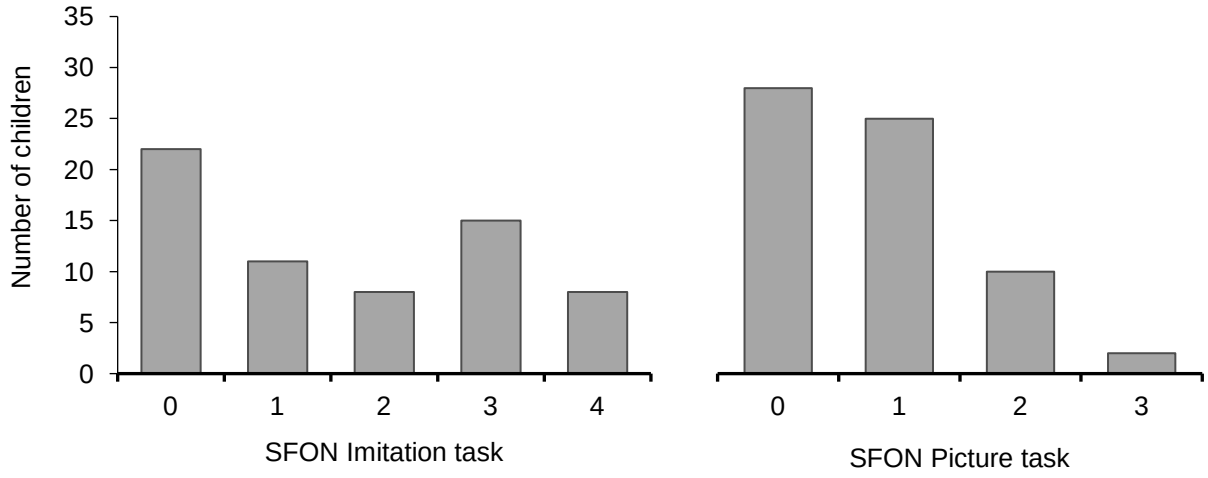


Figure 1. Number of children per total SFON score on the Imitation task ($N = 64$) and on the Picture task ($N = 65$).

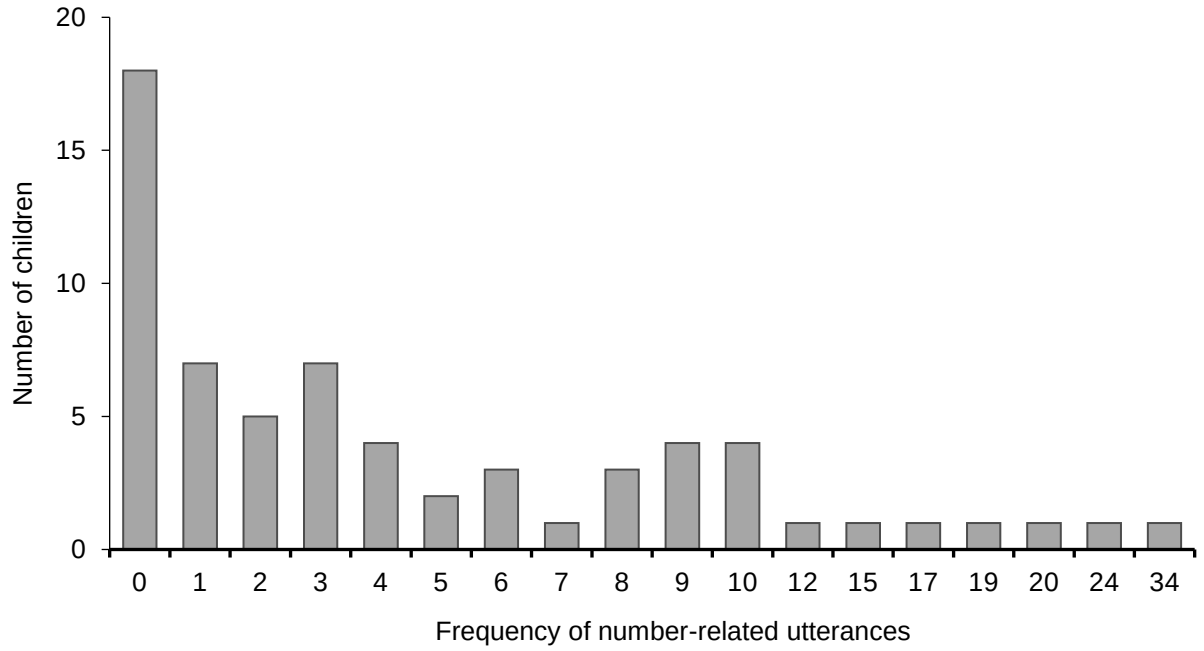


Figure 2. Number of children per frequency of number-related utterances.

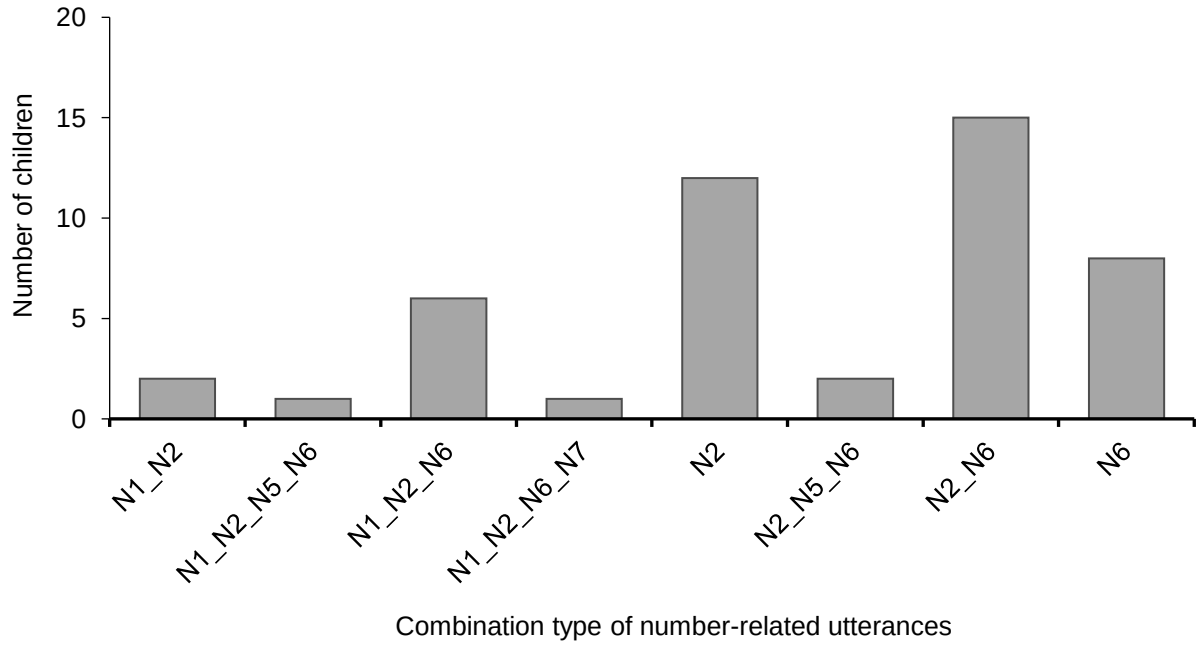


Figure 3. Number of children per combination type of number-related utterances. N1 = counting; N2 = determining numerosity; N5 = part-whole relationships; N6 = quantity concepts; N7 = ordinal numbers.

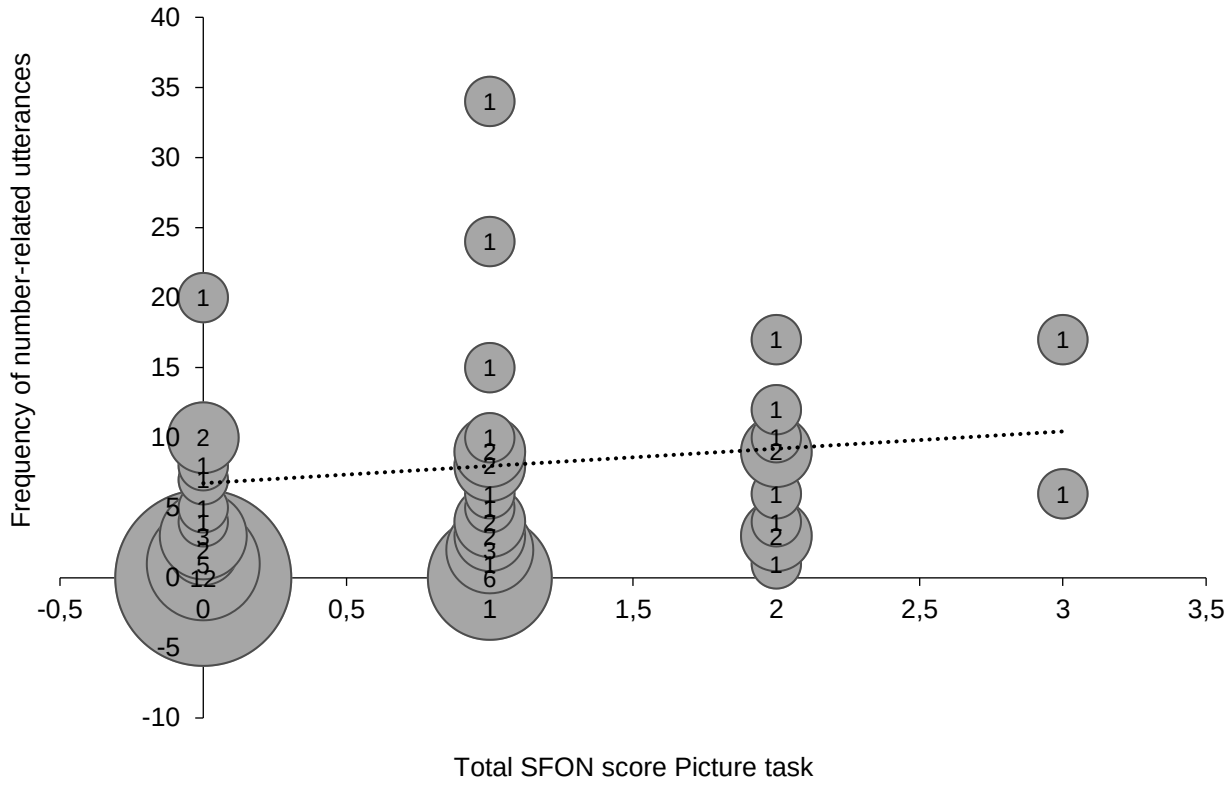


Figure 4. Bubble plot of the association between children's total SFON score in the Picture task and the frequency of their number-related utterances during the picture book reading activity, without accounting for word count. In each bubble the number of children for each combination of total SFON score in the Picture task and frequency of number-related utterances during the picture book reading activity is shown.