CHAPTER 6

KINDERGARTNERS' SPONTANEOUS FOCUS ON NUMBER DURING PICTURE BOOK READING

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Children's Spontaneous Focusing On Numerosity (SFON) predicts later mathematics performance. This association is assumed to rely on children's self-initiated practice in number recognition during everyday activities, which would enhance their further mathematical development. Consequently, SFON in the experimental tasks should be associated with SFON during everyday activities. The present contribution aims to enhance our understanding of this association by critically discussing the major results of two recently conducted studies on the association between SFON in experimental tasks and SFON during picture book reading. Study 1 revealed no association between children's SFON in the Imitation task and their number-related utterances during numerical picture book reading. Study 2, in which we contrasted two different SFON tasks and their association to picture book reading, revealed a positive association between children's SFON in the Picture task (but not in the Imitation task) and their number-related utterances during picture book reading. Theoretical, methodological, and educational implications are discussed.

Keywords: picture books; SFON; kindergartners; number

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1. Theoretical and Empirical Background

Many children develop and use a rich diversity of early mathematical abilities from a young age on (Torbeyns et al. 2015). During the past decade, a large number of studies have shown that these early mathematical abilities (e.g., counting or comparing numerical magnitudes) are highly predictive of later mathematics achievement in primary school (Aunio and Niemivirta 2010; Claessens et al. 2009; De Smedt et al. 2009; Nguyen et al. 2016; Vanbinst et al. 2015). Although a large body of research providing empirical evidence for the importance of these early mathematical *abilities* exists, recent research has revealed that children's mathematical *dispositions,* and in particular their tendency to spontaneously attend to and focus on numerosity (i.e., Spontaneous Focusing On Numerosity or SFON), is also important for explaining individual differences in early mathematical development (see Rathé et al. 2016a, for a review).

SFON is a recent construct developed by Hannula-Sormunen and colleagues, which refers to children's spontaneous (i.e., self-initiated, thus not prompted by others) focusing of attention on the aspect of exact number of a set of items or incidents and using this recognized numerosity in one's action (2010). SFON tendency indicates the amount of spontaneous practice in using exact number recognition across different task contexts and time (Hannula and Lehtinen 2005; Hannula et al. 2010). For example, some children spontaneously start to count the number of cars while playing with toy cars, while others do not explicitly focus on number, but instead pay attention to other, non-numerical aspects in the situation (e.g., colors or models of the cars).

So far, SFON has been measured primarily by using action-based Imitation tasks, in which children are required to imitate the experimenters' play behavior with toys (e.g., feeding berries into a toy parrot's beak; Hannula and Lehtinen 2005). More recently, SFON has also been measured with verbal description tasks, in which children are required to describe photos (Hannula et al. 2009) or the content of different cartoon pictures (Batchelor et al. 2015). Children score SFON in a trial when they spontaneously focus on the numerical aspect of the task: For instance, feeding the correct number of berries in the Imitation task, or mentioning at least once an exact numerosity (e.g., I see *three* houses) while describing the pictures in the Picture task. In all SFON tasks, it is important that (1) only novel and not explicitly mathematical tasks are used, (2) the experimenter does not provide any mathematical hints and has the full attention of the child on the task, (3) the task only includes a few trials as it aims to capture children's *spontaneous* attention on numerosity, and (4) the task includes numbers of items that are so small that all participating children should be able to recognize them (Hannula 2005).

Previous cross-sectional and longitudinal studies revealed that young children largely differ in their SFON tendency. Moreover, these individual differences in SFON were found to be associated with

early mathematical abilities, such as counting and subitizing-based enumeration (Hannula and Lehtinen 2005; Hannula et al. 2007), and they were uniquely predictive of later mathematics achievement in the beginning (Hannula et al. 2010) and at the end of primary school (Hannula-Sormunen et al. 2015). The latter findings suggest that SFON might play a foundational role in children's early mathematical development.

In particular, SFON tendency is assumed to promote children's amount of self-initiated practice in exact number recognition during everyday activities, which in turn would enhance their further mathematical development (Hannula et al., 2010). In other words, the predictive association between children's SFON as measured via experimental tasks and their later mathematics achievement can be explained hypothetically by the amount of children's SFON during everyday activities and play. Although some research on this topic has been carried out, previous studies that investigated the assumed association between SFON in experimental tasks and SFON during everyday activities have provided inconsistent results (Batchelor 2014, Study 3; Edens and Potter 2013; Hannula et al. 2005). Edens and Potter (2013), for instance, found no association between children's SFON as measured via various action-based Imitation tasks and their spontaneous activity choice (i.e., mathematics-related versus non mathematics-related activities) during free play in kindergarten. Their results suggest that higher SFON children do not per se choose more mathematics-related activities (e.g., block construction, jigzaw puzzles, and computer games) during free play in kindergarten in comparison to their peers with lower SFON scores. Children's SFON, however, is not limited to selecting mathematics-related activities, but can also occur during non-mathematics-related activities, such as picture book reading or making crafts. When testing the association between SFON in experimental tasks and SFON during everyday activities, it is important to consider children's concrete actions and/or numerical utterances when determining their SFON during everyday activities and play (Hannula 2005; Rathé et al. 2016b).

In this respect, the study of Batchelor (2014, Study 3) is highly relevant. In contrast to Edens and Potter (2013), Batchelor focused on children's and their parents' verbal expressions of SFON during everyday activities and play. Interestingly, results revealed a positive association between children's SFON as measured by the verbal Picture task and their verbal expressions of SFON as observed during a play session in which parents played different games (i.e., Hungry Hippos, Lego Duplo, and Picture Printing) with their children. Other researchers, who determined children's SFON on the basis of concrete actions (e.g., Imitation tasks), found evidence for an association between SFON in the posttest experimental tasks and SFON as observed by day-care professionals during everyday activities, but the same association was not found for SFON in the pretest experimental tasks (Hannula et al., 2005).

Taken together, previous research findings on the association between SFON in experimental tasks and SFON during everyday situations have been inconsistent and contradictory. Moreover, recent findings of Batchelor (2014) show that it is important to consider children's verbal expressions of SFON as observed during everyday activities when investigating the underlying mechanism of SFON. Therefore, future research is needed to further explore these inconsistencies by correlating children's SFON as measured by different experimental SFON tasks with their SFON during other meaningful everyday activities, such as picture book reading, of which the potential benefits for children's early mathematical development have been shown (Elia, van den Heuvel-Panhuizen, & Georgiou, 2010; van den Heuvel-Panhuizen & van den Boogaard, 2008).

Against this background, we set up two studies in which we aimed to investigate the association between children's SFON as measured by experimental tasks and their number-related utterances during everyday picture book reading. In Study 1 (Rathé et al. 2016b), we explored the association between children's SFON as measured by an action-based Imitation task and the frequency of their number-related utterances during numerical picture book reading. Based on the unexpected result obtained in this study, we conducted Study 2 (Rathé et al. 2017), in which we aimed to test whether the results of Study 1 might be explained by the way in which SFON was measured. More specifically, we contrasted two different experimental SFON tasks – an action-based Imitation task and a verbal Picture task – in their relation to everyday picture book reading. In the next sections, we summarize the method and the main findings of both studies and end with a discussion of some theoretical, methodological, and educational implications. For more details on the design and the results of the two studies, we refer the interested reader to the original research reports.

2. Study 1

The aim of Study 1 (Rathé et al. 2016b) was to address the assumed association between SFON in experimental tasks and SFON during everyday activities by investigating the association between children's SFON as measured by an action-based SFON Imitation task and their number-related utterances during numerical picture book reading. Based on Hannula and colleagues' hypothetical explanation (2010), we hypothesized that children with higher SFON scores in the experimental Imitation task would formulate more number-related utterances during numerical picture book reading.

Forty-eight kindergartners (28 boys, 20 girls, M = 4 years 6 months, SD = 4 months), coming from five different schools in Flanders (Belgium), participated in the study. All children individually completed an Elsi bird SFON Imitation task including four trials (Hannula and Lehtinen 2005) and - at least 10 days later - a numerical picture book reading activity, in which they individually were read

aloud the numerical picture book *Farmer Boris* [Boer Boris] (van Lieshout & Hopman, 2013). The picture book describes the story of Farmer Boris and his farm with the accompanying animals, fields, and machines, and is especially written for the purpose of learning the counting sequence from 1 up to 11. For an example page of the original numerical picture book, see Rathé et al. (2016b).

In the SFON Imitation task (see Figure 6.1), the experimenter put small numbers (ranging from 1 to 3) of colored berries into a toy parrot's beak and then instructed the child to "do exactly the same". Children were scored as focusing on numerosity in a trial when they gave the correct number of berries and/or if they were observed doing verbal and non-verbal quantifying acts, such as counting or showing numbers with fingers. As there were only 4 trials, the maximum score on the Imitation task was 4.

Figure 6.1. Materials in the Elsi bird Imitation task (Rathé et al. 2016b)

During the numerical picture book reading activity, children were invited to spontaneously comment on the pictures in the book. The experimenter did not provide any numerical hints. We registered the frequency and the type of children's number-related utterances expressed before, during, and after reading the text on the front cover, page 1 to 12, and the back cover of the book. Children's number-related utterances were classified into seven types of utterances that were largely based on the framework of Elia et al. (2010): (N1) counting (e.g., *1, 2, 3*) , (N2) determining the numerosity of a set of items (e.g., *There are six pigs*), (N3) recognizing a numerical symbol (e.g., *I see number 3*), (N4) comparing quantities (e.g., *There was 1 dog on the previous page, and now there is still 1 dog*), (N5) analyzing part-whole relationships (e.g., *There are 6 pigs, 5 pigs are walking around and 1 pig is playing in the mud*), (N6) using quantity concepts (e.g., *There are a lot of mice*), and (N7) using ordinal numbers (e.g., *The sixth pig plays in the mud*).

The results of Study 1 revealed large individual differences in kindergartners' SFON, and in the frequency and the type of their number-related utterances during numerical picture book reading. In the SFON Imitation task, about half of the children did not spontaneously focus on numerosity during

the solution of the task (52%), while the others (48%) spontaneously focused on numerosity in at least one of the trials, and received SFON scores ranging from 1 to 4 (see Figure 6.2).

During the numerical picture book reading activity, most children formulated at least one number-related utterance (87.5%). For the group of children who formulated at least one number-related utterance, we observed large individual differences in both the frequency and the type of their number-related utterances. The frequency of number-related utterances varied from 1 to 32 utterances (M = 8.96, SD = 8.21) and the type of number-related utterances varied from stating only one type of utterance (e.g., N6; 9.5%) to formulating different types of number-related utterances (e.g., N2_N6; 26%). Regarding the observed frequencies of the different types of number-related utterances, the kindergartners most frequently mentioned numerosities (N2; 45.6%) and quantity concepts (N6; 32%).

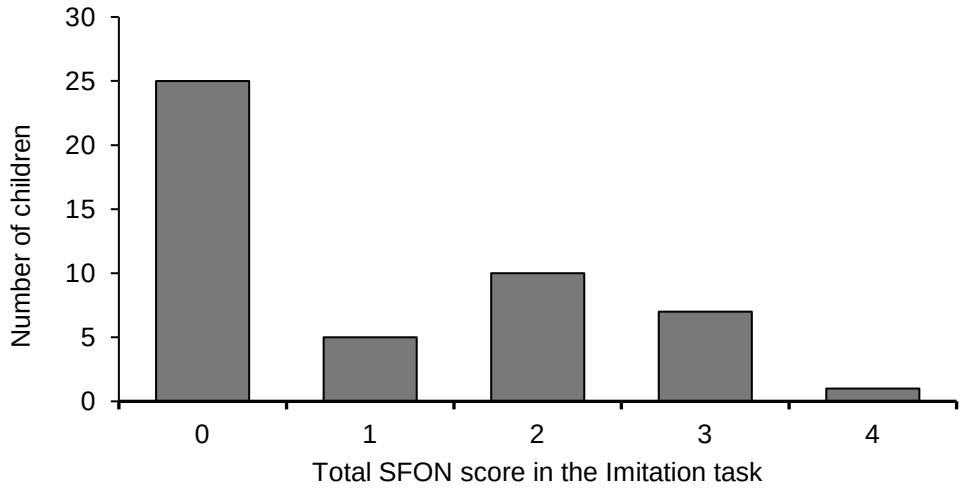

Figure 6.2. Number of children per total SFON score in the Imitation task (N = 48).

A Spearman correlation analysis did not reveal the expected association between children's SFON in the action-based Imitation task and the frequency of their number-related utterances during numerical picture book reading (r_s = -.14), also not after accounting for word count (i.e., the total number of words the children expressed during the picture book reading activity).

As discussed in Rathé et al. (2016b), there were different hypothetical explanations for this unexpected result. First, there was an important difference in response mode between the experimental SFON Imitation task and the numerical picture book reading activity. In the numerical picture book reading activity, children were required to *verbally* describe their mathematical thoughts and utterances (with attention for action-based numerical acts), while in the Imitation task children needed to use the information about numerosity in their *action*.

Second, the characteristics of the numerical picture book used in Study 1 might explain the absence of empirical support for an association between children's SFON and the frequency of their number-related utterances during numerical picture book reading. More specifically, the numerical picture book activity might not have captured children's *spontaneous*, but rather their *guided* focusing on numerosity (GFON), because the number words and number symbols on each page focused their attention toward numerosity. Finally, the absence of the expected association between children's SFON in the Imitation task and the frequency of their number-related utterances during numerical picture book reading might also be explained by the rather young age of the participating children (i.e., 4-5-year-olds) and their associated limited verbal skills.

3. Study 2

The aim of Study 2 (Rathé et al. 2017) was to investigate whether available inconsistent results on the association between SFON in experimental tasks and SFON in everyday activities (e.g., Batchelor 2014; Edens and Potter 2013; Hannula et al. 2005; Rathé et al. 2016b) could be explained by the way in which SFON is measured. Here we explicitly aimed to address and test the first hypothetical explanation as discussed in Study 1. We also took into account the second and third hypothetical explanation given in Study 1, but did not explicitly validate them.

With this aim in mind, we systematically contrasted children's SFON as measured by two different experimental tasks – an action-based Elsi bird Imitation task and a verbal Picture task – in relation to their number-related utterances during picture book reading, using a modified version of the picture book *Farmer Boris* without any number words and number symbols. Based on the reviewed literature above and the results of Study 1, we hypothesized that (1) children's SFON as measured by the verbal Picture task should be associated with the frequency of number-related utterances during everyday picture book reading, and (2) that children's SFON as measured by the action-based Imitation task should not be associated with the frequency of number-related utterances during everyday picture book reading.

In total, 65 kindergartners (31 boys, 34 girls, M = 5 years 5 months, SD = 7 months, range = 4 years 4 months to 6 years 4 months), coming from two different schools in Flanders (Belgium), participated in the study. All kindergartners were individually interviewed during two separate sessions, in which they first completed two experimental SFON tasks and a visuo-motor buffer task, and next were read aloud a modified version of the picture book *Farmer Boris*.

In the first session, all children individually completed an action-based Elsi bird SFON Imitation task including four trials (Hannula and Lehtinen 2005) and a verbal SFON Picture task including three trials (Batchelor et al., 2015). In the Imitation task, we used the same materials and procedure as in

Study 1. In the Picture task, children had to verbally describe as precisely as possible the content of a set of three pictures that included, among other things, items that can be counted (see Figure 6.3). To distract the children's attention from the numerical nature of the SFON tasks, they all completed a visuo-motor buffer task between both tasks.

In the second session, children were individually read aloud a modified version of the picture book *Farmer Boris* [Boer Boris] (van Lieshout and Hopman 2013). To identify children's *spontaneous* number-related utterances (and not their *guided* number-related utterances), we removed all the number symbols in the picture book pages. As an example, Figure 6.4 shows page 9 of the modified picture book, which displays Farmer Boris and his nine mice who are slinking secretly in the house of Farmer Boris. The picture book was read aloud according the same reading scenario as in Study 1.

Figure 6.3. First and second trial used in the SFON Picture task (Batchelor et al., 2015).

In line with Study 2, we scored children's action-based responses and their verbal and non-verbal quantifying acts during the solution of the SFON Imitation task. The maximum score in the Imitation task was 4. In the SFON Picture task, children were scored as focusing on numerosity in a trial when they explicitly mentioned at least once an exact number (e.g., I see *three* chickens) and/or showed non-verbal quantifying acts (e.g., counting acts). The maximum score in the Picture task was 3. Children's number-related utterances expressed during the picture book reading activity (e.g., There are *six pigs* walking around in the mud) were scored using the same classification scheme as in Study 1.

In line with the results of Study 1, we observed large individual differences in children's SFON scores in the action-based Imitation task and in the verbal Picture task (see Figure 6.5). Two thirds of the children (66%) spontaneously focused on numerosity in the Imitation task, whereas the other children (34%) did not show any evidence of SFON behavior during the solution of this task. During the administration of the Picture task, about half of the children (57%) spontaneously mentioned at least

once an exact numerosity and/or showed quantifying acts while describing the pictures, receiving SFON scores ranging from 1 to 3; the other children (43%) did not spontaneously focus on exact numerosity and/or did not show any quantifying acts while describing the pictures and received a SFON score of 0.

As in Study 1, we observed large variety in the frequency and the type of children's number-related utterances during picture book reading. Whereas 28% of the participating children did not formulate a number-related utterance during the picture book reading activity, the other children (72%) formulated at least one number-related utterance. Interestingly, the mean frequency of number-related utterances in Study 2 (M = 5.08 , SD = 6.56) was lower than in Study 1 and varied from 0 to 34. The combinations of types of number-related utterances differed from stating only one type of utterance (e.g., N6; 17%) to expressing different types of number-related utterances (e.g., N2_N6; 32%). With respect to the observed frequencies of the different types of number-related utterances, the children formulated altogether 329 number-related utterances during the picture book reading activity. As in Study 1, they most frequently focused on numerosities (N2; 62%) and quantity concepts (N6; 28.6%). As we expected, Spearman correlation analyses revealed a non-significant association between children's SFON as measured via the action-based Imitation task and the frequency of their number-related utterances during picture book reading (r_s = .02), and a positive significant association between children's SFON as assessed via the verbal Picture task and the frequency of their number-related utterances during picture book reading, r_s = .47, also after accounting for word count. In line with recent results of Batchelor et al. (2015), we found no significant association between children's total SFON score in the Imitation and in the Picture task (r_s = .06).

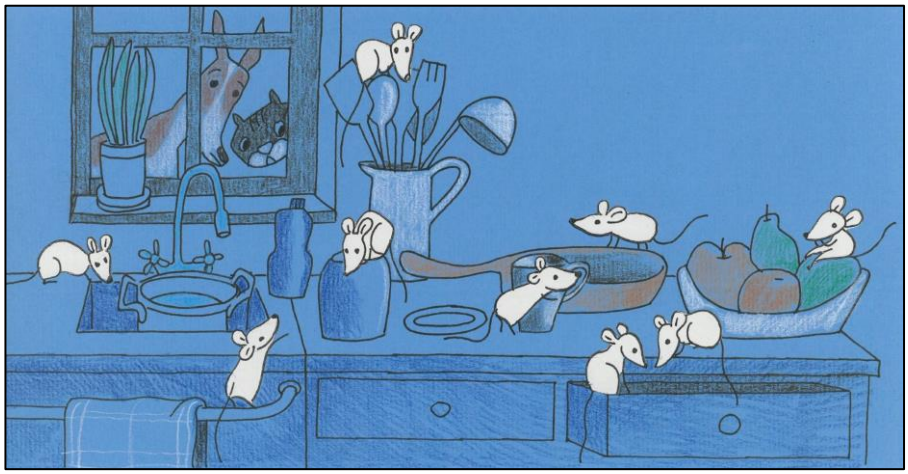

Figure 6.4. Page 9 from the modified picture book *Farmer Boris*. Accompanying text : "Farmer Boris has a farm. It also involves mice. Oh no, they do not belong there. They slink secretly in the house."

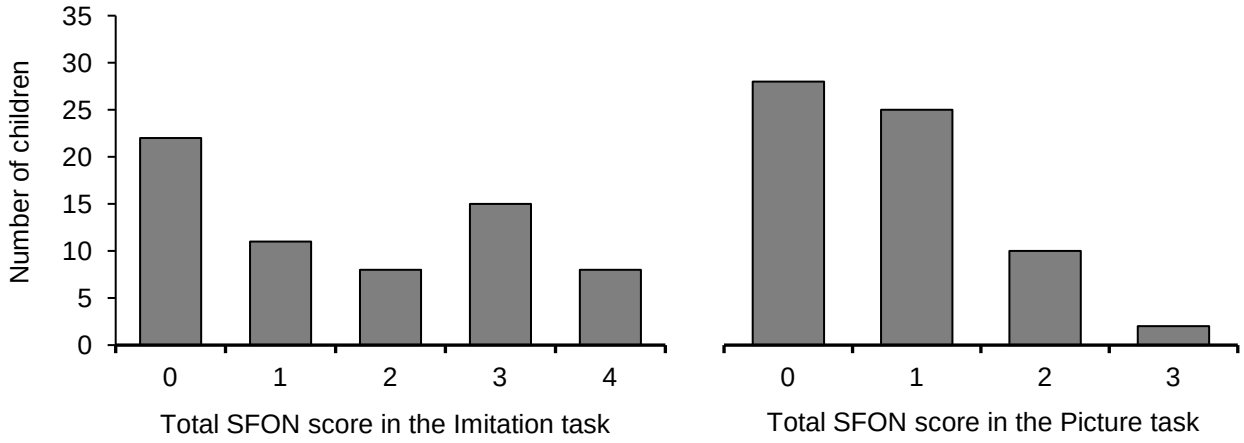

Figure 6.5. Number of children per total SFON score in the Imitation task (N = 64) and in the Picture task (N = 65).

4. Conclusion and Discussion

In recent years, young children's SFON tendency has been identified as a unique predictor of concurrent mathematical abilities and later mathematics achievement in primary school (Hannula-Sormunen et al. 2015; Hannula and Lehtinen 2005; Hannula et al. 2010). The main idea is that this SFON tendency promotes children's amount of self-initiated practice in number recognition during everyday activities and play, which consequently enhances their further mathematical development (Hannula et al. 2010). Thus far, results of studies that investigated the association between SFON in experimental tasks and SFON during everyday activities were inconclusive (Batchelor 2014, Study 3; Edens and Potter 2013; Hannula et al. 2005). These inconsistent results might be explained by the way in which SFON was measured during everyday activities and by the different types of experimental SFON tasks that were used.

To address these possible explanations, we conducted two closely related studies in which we examined the association between children's SFON in experimental tasks and their number-related utterances during picture book reading. More specifically, in Study 1 (Rathé et al. 2016b) we associated children's SFON as measured by an action-based Imitation task with their number-related utterances during numerical picture book reading. In Study 2 (Rathé et al. 2017), we explored the same association by contrasting two different experimental SFON tasks (i.e., an action-based Imitation task and a verbal Picture task) in relation to children's number-related utterances formulated during picture book reading, using a modified version of the picture book used in Study 1.

In line with previous research, both studies revealed large individual differences in kindergartners' SFON (e.g., Hannula et al. 2010; Hannula-Sormunen et al. 2015), and in the frequency and the type

of their number-related utterances during picture book reading (Elia et al. 2010; van den Heuvel-Panhuizen and van den Boogaard 2008). In Study 1, we found no empirical evidence for the assumed association between children's SFON in the action-based Imitation task and their number-related utterances during numerical picture book reading. Yet in Study 2, we observed a significant positive association between children's SFON in the verbal Picture task (but not in the Imitation task) and the frequency of their number-related utterances during picture book reading, providing evidence for the first hypothetical explanation given in Study 1.

Although our studies yielded new insights in the association between SFON in experimental tasks and SFON during everyday activities, it should be noted that Study 2 revealed only partial empirical evidence for this assumed association. In particular, we did not investigate the association between children's SFON in the Imitation task and children's SFON during an action-based everyday activity, such as motor play with blocks, and we did not take into account (the development of) children's mathematical skills. Therefore, future research is required to investigate children's SFON as measured by different experimental tasks in relation to their SFON as expressed during both verbal and action-based everyday activities, taking into account their (acquisition of) mathematical skills.

Related to our findings in Study 2 providing evidence for the first hypothetical explanation given in Study 1, SFON might be a multidimensional construct (including a verbal and an action-based aspect), which requires different experimental task contexts to measure these different aspects of SFON. However, as both verbal and action-based aspects of SFON have been shown to contribute to early mathematical development (Batchelor et al. 2015; Hannula-Sormunen et al. 2015), children's SFON as measured by the Imitation task and their SFON as measured by the Picture task, as well as their mutual relation, warrant further research.

In addition to these considerations, it could be argued that the positive association between children's SFON in the Picture task and their number-related utterances during picture book reading is not that surprising, given that the Picture task and the picture book reading activity are very similar. After all, both tasks assess children's number-related utterances when they are presented with pictures and are explicitly requested to comment on them. However, despite these similarities, there are some important differences between both tasks (see Table 6.1.), that clearly indicate why the Picture task should not be considered an experimental task instead of an everyday activity, and vice versa (Rathé et al. 2017).

Table 6.1: Differences between the experimental Picture task and the everyday picture book reading activity (Rathé et al. 2017).

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.

Finally, our studies may lead to some provisional implications for educational practice. More specifically, our findings suggest that, besides the acquisition of early mathematical abilities, children's mathematical dispositions, and in particular their SFON tendency, are also important for explaining individual differences in early mathematical development. Early childhood educators and parents could be informed about and helped in how to uncover and stimulate young children's tendency to attend to numerosities during not primarily mathematically focused everyday activities and play, including picture book reading. Interestingly, when comparing the results of both studies, we observed a lower frequency of children's number-related utterances during picture book reading in Study 2 than in Study 1, which suggests that the numerical characteristics (i.e., the number symbols in the text) of the picture book used in Study 1 might indeed have *guided* children's attention to number, instead of capturing their *spontaneous* attention to number. Moreover, this suggests that reading picture books with explicit numerical information included in the pictures and/or text, might be a promising tool to enhance children's SFON. Future observational and intervention studies, however, are needed to enhance our understanding on how to stimulate children's SFON during everyday activities and play. This might be an important first step in preventing later mathematical difficulties and stimulating positive attitudes toward mathematics in general.

References

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

Batchelor, S. (2014). *Dispositional factors affecting children's early numerical development*. Loughborough University, Leicestershire, United Kingdom. Retrieved from https://dspace.lboro.ac.uk/2134/

Batchelor, S., Inglis, M., & Gilmore, C. (2015). Spontaneous focusing on numerosity and the arithmetic advantage. *Learning and Instruction, 40*, 79–88. https://doi.org/10.1016/j.learninstruc.2015.09.005

Claessens, A., Duncan, G., & Engel, M. (2009). Kindergarten skills and fifth-grade achievement: Evidence from the ECLS-K. *Economics of Education Review, 28*, 415–427. https://doi.org/10.1016/j.econedurev.2008.09.003

De Smedt, B., Verschaffel, L., & Ghesquière, P. (2009). The predictive value of numerical magnitude comparison for individual differences in mathematics achievement. *Journal of Experimental Child Psychology, 103*, 469–479. https://doi.org/10.1016/j.jecp.2009.01.010

Edens, K. M., & Potter, E. F. (2013). An exploratory look at the relationships among math skills, motivational factors and activity choice. *Early Childhood Education Journal, 41*, 235–243. https://doi.org/10.1007/s10643-012-0540-y

Elia, I., van den Heuvel-Panhuizen, M., & Georgiou, A. (2010). The role of pictures in picture books on children's cognitive engagement with mathematics. *European Early Childhood Education Research Journal, 18*, 275–297. https://doi.org/10.1080/1350293X.2010.500054

Hannula-Sormunen, M. M., Lehtinen, E., & Räsänen, P. (2015). Preschool children's spontaneous focusing on numerosity, subitizing, and counting skills as predictors of their mathematical performance seven years later at school. *Mathematical Thinking and Learning, 17*, 155–177. https://doi.org/10.1080/10986065.2015.1016814

Hannula, M. M. (2005). *Spontaneous Focusing on Numerosity in the Development of Early Mathematical Skills*.

Hannula, M. M., & Lehtinen, E. (2005). Spontaneous focusing on numerosity and mathematical skills of young children. *Learning and Instruction, 15*, 237–256. https://doi.org/10.1016/j.learninstruc.2005.04.005

Hannula, M. M., Lepola, J., & Lehtinen, E. (2010). Spontaneous focusing on numerosity as a domain-specific predictor of arithmetical skills. *Journal of Experimental Child Psychology, 107*, 394–406. https://doi.org/10.1016/j.jecp.2010.06.004

Hannula, M. M., Mattinen, A., & Lehtinen, E. (2005). Does social interaction influence 3-year-old children's tendency to focus on numerosity? A quasi-experimental study in day care. In L. Verschaffel, E. De Corte, G. Kanselaar, & M. Valcke (Eds.), *Powerful environments for promoting deep conceptual and strategic learning.* (pp. 63–80). Leuven, Belgium: Leuven University Press.

Hannula, M. M., Räsänen, P., & Lehtinen, E. (2007). Development of counting skills: Role of spontaneous focusing on numerosity and subitizing-based enumeration. *Mathematical Thinking and Learning*, *9*, 51–57. https://doi.org/10.1080/10986060709336605

Mattinen, A. (2006). Abstract.

Nguyen, T., Watts, T. W., Duncan, G. J., Clements, D. H., Sarama, J. S., Wolfe, C., & Spitler, M. E. (2016). Which preschool mathematics competencies are most predictive of fifth grade achievement? *Early Childhood Research Quarterly*, *36*, 550–560. https://doi.org/10.1016/j.ecresq.2016.02.003

Rathé, S., Torbeyns, J., De Smedt, B., Hannula-Sormunen, M. M., & Verschaffel, L. (2017) Verbal and action-based measures of kindergartners' SFON and their associations with number-related utterances during picture book reading. *British Journal of Educational Psychology.*

Rathé, S., Torbeyns, J., Hannula-Sormunen, M. M., De Smedt, B., & Verschaffel, L. (2016a). Spontaneous focusing on numerosity: A review of recent research. *Mediterrean Journal for Research in Mathematics Education*, *15*, 1–25.

Rathé, S., Torbeyns, J., Hannula-Sormunen, M. M., & Verschaffel, L. (2016b). Kindergartners' spontaneous focusing on numerosity in relation to their number-related utterances during numerical picture book reading. *Mathematical Thinking and Learning*, *18*, 125–141. https://doi.org/10.1080/10986065.2016.1148531

Torbeyns, J., Gilmore, C., & Verschaffel, L. (2015). The acquisition of preschool mathematical abilities: Theoretical, methodological and educational considerations. *Mathematical Thinking and Learning*, *17*, 99–115. https://doi.org/10.1080/10986065.2015.1016810

van den Heuvel-Panhuizen, M., & van den Boogaard, S. (2008). Picture books as an impetus for kindergartners' mathematical thinking. *Mathematical Thinking and Learning*, *10*, 341–373. https://doi.org/10.1080/10986060802425539

van Lieshout, T., & Hopman, P. (2013). *Boer Boris*. Haarlem, The Netherlands: Gottmer.

Vanbinst, K., Ghesquière, P., & De Smedt, B. (2015). Does numerical processing uniquely predict first graders' future development of single-digit arithmetic? *Learning and Individual Differences*, *37*, 153–160. https://doi.org/10.1016/j.lindif.2014.12.004

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