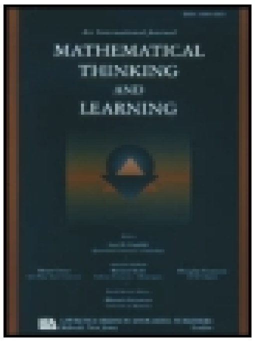

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Promoting spontaneous focusing on numerosity and cardinality-related skills at day care with one, two, how many and count, how many programs

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ABSTRACT

In this study we investigated the effects of two naturalistic 2- to 4-year-old children's intervention programs aimed at promoting children's Spontaneous Focusing On Numerosity (SFON) and early numerical skills. The study consisted of a quasi-experimental, pretest-posttest design with a delayed posttest and an active control group participating in the Let's Read and Talk program. All conditions had 6 weeks of intensive training followed by a 4-month rehearsal phase, when intervention activities were integrated into normal day care. The results of both numerical interventions in the whole group level show positive, small- to medium-sized long-term effects on cardinality-related skills from pretest to delayed posttest. The SFON tendency increased more from pretest to posttest in both studies but the group differences vanished in the delayed posttest. The children in the Count, how many programs developed more in SFON tendency from pretest to posttest, while the better development of SFON from pretest to posttest was significant only for the low group in the One, two, how many programs. There were no group differences in vocabulary or story comprehension skills. Educational implications suggest that combining SFON and cardinality-related skill training at day care results in developmentally effective activities for early educators and children.

KEYWORDS

Spontaneous focusing on numerosity; intervention; cardinality; day care; preschool; children; early numeracy

Child pointed to her sock and said to her early educator: Look, I have one cat on my sock!

Early educator: Yes, you are right; there is one cat on your sock. Do you have more cats?

Child pointed twice at her sock: A cat and a cat.

Early educator: How many cats?

Child: One, two.

Early educator lifted her two fingers up: Really, there are two cats!

In this example from a day care center, a child spontaneously focused on numerosity (SFON) and recognized the exact number of one item while the early educator started scaffolding the child's thinking further toward noticing there were two cats on the sock. The concept of SFON refers to the process in which a person focuses her or his attention on the exact number of a set of items or incidents, makes use of this information in her or his actions (Hannula & Lehtinen, 2005), and does so spontaneously, not prompted by others or by task instructions. SFON tendency is a more generalized tendency across different contexts and it indicates the amount of practice acquired in using one's exact

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number recognition skills (Hannula et al., 2010). This example illustrates a teacher's mathematical pedagogical awareness (Björklund & Barendregt, 2016) in noticing a child's spontaneous focusing on numerosity, giving supportive feedback, and challenging and supporting the child to the higher level to seek more items to focus on (Mattinen, 2006). The kindergarten teacher also gave explicit information on the number two by representing it in multiple ways (Wiese, 2003). However, Björklund and Barendregt (2016) showed that even though preschool teachers engage children in communication about mathematical phenomena, they do not systematically use the physical environment as a point of departure for directing children's attention to specific mathematical concepts or principles. A great number of opportunities to support children's mathematical development are missed due to teachers' lack of awareness of these opportunities (Mattinen, 2006).

The aim of our research was to develop and study the impact of two naturalistic intervention programs for children learning cardinality (i.e., number of elements of the set) recognition and counting skills, which are at the core of the early number concept. One, two, how many – program is focused on supporting c.a. 2-to 3- year-old children's numerical development when they are learning to recognize their first cardinal numbers without counting, whereas Count, how many – program is aimed at enhancing slightly older (c.a. 3 – 4 – year-old) children's counting skills and thus more advanced numerical skills. The intervention programs were based on the idea proposed by Hannula and Lehtinen (2005), according to whom the use of number skills, such as exact number recognition in natural surroundings, is not an automatic act that would be equally often triggered by different contexts and persons. This leads to substantial inter-individual differences in how often persons use their exact number recognition skills. As a result, the amount of practice young children acquire in using their early number skills may differ substantially according to how frequently they focus on the exact number of items in their surroundings (Hannula, 2005; Hannula & Lehtinen, 2005). The resulting individual differences in the amount of self-initiated practice children acquire in using their numerical skills may help explain developmental differences in numeracy from early childhood to the end of primary school. Even more importantly, supporting children's SFON tendency at day care or in preschool contexts could support their numerical development and prevent later difficulties in mathematics learning.

One important aspect of previous SFON studies was recognized by Mattinen (2006), in which it was demonstrated how easily adults go along with the children who spontaneously focus on numerosity and provide those children with increasing numbers of numerical activities, while the children who do not spontaneously focus on numerosity are easily left without guidance toward numerical activities. To counteract this, the SFON research findings describing the behaviors of the children whose SFON tendency is strong can be used to model the desired numerical behaviors for the children with lower SFON tendency. More generally, in addition, kindergarten teachers should be challenged to ask questions that stimulate further mathematical thinking among children (Saebbe & Mosvold, 2015) as part of everyday activities with the children (Hannula et al., 2005; Mattinen, 2006).

Early mathematical programs designed for the prekindergarten environment are more effective than interventions implemented later in kindergarten or in school (Nelson, 2017; Wang et al., 2016). Based on a systematic review of studies in which early childhood mathematical programs were evaluated, both Frye et al. (2013) and Clements and Sarama (2011) pointed out the importance of changing the perspective from practicing young children's mathematical skills through separate exercises to guiding them to view the world mathematically. Drilling individual skills does not appear to produce transfer effects or sustainable learning outcomes (e.g., Räsänen et al., 2009).

Early interventions with the approach of mathematizing everyday activities, such as activities in the Building Blocks program developed by Clements and Sarama (2007) or SFON enhancement by Hannula et al. (2005) seem to trigger children's deliberate practice in early numeracy and thus produce transfer effects to other early mathematical skills (Bojorque et al., 2018; Hannula-Sormunen, 2015). This not only supports the development of early mathematical skills but also literacy skills (Sarama et al., 2012); this is of benefit especially for minority students and it shortens the time for children to approach their eventual skill level in elementary school (Dumas et al., 2019).

Spontaneous focusing on numerosity (SFON)

The example of a child with cats on their sock demonstrates how young children can use and practice their early number skills alone and together with others, even in settings that are clearly not mathematical in the first place. The aim of the assessments of SFON has been to acquire a reliable indicator for children's self-initiated practice of using their exact number recognition skills (Hannula & Lehtinen, 2005). This is done by using non-mathematical tasks contexts and activities that allow for multiple focusing aspects. All SFON tasks are within the children's enumeration and cognitive skill range so that individual differences in the tasks are due to focusing differences. For example, Hannula and Lehtinen (2005) developed an imitation task in which the child is asked to do the same as the experimenter while the experimenter feeds a toy parrot a small number of berries. The authors of recent reviews indicate these kinds of tasks allow for capturing large, inter-individual differences among young children's spontaneous focusing on numerosity (Hannula-Sormunen, 2015; Rathé et al., 2016).

Hannula and Lehtinen (2005) showed that individual differences in children's SFON are not explained by their lack of enumeration skills or other cognitive skills needed for SFON tasks. Focusing on other aspects, such as spatial locations, is a separate process that does not negate the correlation between SFON and counting skills (Hannula et al., 2010). Nanu et al. (2018) demonstrated that SFON measures are not enumeration accuracy measures, but instead the individual differences in the tasks are due to focusing differences. SFON tendency has been shown to be a rather stable component of early mathematical skills (Bojorque et al., 2017; Hannula & Lehtinen, 2005) that is not explained by motivational factors (Edens & Potter, 2013; Lepola & Hannula-Sormunen, 2019; Nanu et al., 2018), general attentional skills, non-verbal IQ, comprehension of instructions (Hannula & Lehtinen, 2005; Hannula et al., 2010), or inhibition (Nanu et al., 2018). Yet, the contextual and task differences exist, particularly between action and measures of SFON that are verbally based and relatively novel (Batchelor et al., 2015; see a recent review, Rathé et al., 2016).

Previous studies show that SFON is positively related to the development of cardinality recognition, subitizing-based enumeration, object counting, and number sequence skills before school age (Edens & Potter, 2013; Hannula, 2005, 2005; Hannula & Lehtinen, 2001; Hannula et al., 2007; Potter, 2009) and from preschool age up to 7 years later (Hannula-Sormunen et al., 2015; Hannula et al., 2010; Nanu et al., 2018). Thus, it is important to investigate how early education may support children's learning to focus on numerical aspects during preschool years.

In our SFON-based intervention study investigated whether it is possible to enhance the SFON tendency among 3-year-old children in day care (Hannula et al., 2005; Mattinen, 2006). In this intervention, SFON was trained only by using small, exact numbers (one, two, and three). During the 4-week training period, day care professionals were purposefully guiding children's attention to small, exact numbers both in everyday interactions and with structured numerical games. Guided focusing on numerosities involved talking, showing, and manipulating small numbers of toys, snacks, socks, and other things during everyday interactions. Structured games involved deliberate variations with the number of objects as part of the game (Marton & Booth, 1997). For instance, a picture of an aquarium with one to three disappearing and reappearing paper goldfish was used as a target of shared attention. The adults varied the numbers of fish in secret so that children, by themselves, could notice how the numbers altered. Another example of the structural material used was a matching game with one to three figures (for instance, different numbers of ice cream balls and matching cones). Children who participated in the SFON enhancement program outperformed the "business-as-usual" control group in the SFON tendency and cardinality skills in the delayed posttest, which was conducted half a year after the pretest (Hannula et al., 2005; Mattinen, 2006). In addition, those children in SFON enhancement who had some initial SFON tendency in the beginning developed significantly in their mathematical skills from pretest/posttest to delayed posttest (Hannula et al., 2005). During the training period, the early educators observed and kept a record of incidents when children spontaneously focused their attention on numerosity. The analyses between children's SFON scores in a set of three experimental SFON tasks and their SFON tendency, observed by the personnel in the day care settings, showed a positive correlation (r = 0.55).

Recently Braham et al. (2018) showed that a 5-min parent–child activity with numerical focus resulted in an increase in children's SFON measured directly after the activity. This was conducted in a children's museum, and the comparison group of parents and children had a non-numerical task to complete. Here, in the current set of studies, the aim was to increase children's long-term SFON tendency and cardinality related skills.

Development of cardinality recognition skills

Recognition of the exact numbers of items can be done based on two separate skills, subitizing, and verbal counting (Sathian et al., 1999), and they can be distinguished from approximate number recognition (Lemer et al., 2003). Subitizing-based enumeration is accurate, fast, parallel apprehending of items up to around three or four (e.g., Jevons, 1871; Trick et al., 1996). Children's subitizing-based enumeration skills develop during childhood (Chi & Klahr, 1975; Starkey & Cooper, 1995; Trick et al., 1996) but the main aspect of numeracy development deals with counting and its subskills (Fuson, 1988), including how the cardinal meanings of number words are learned (Sarnecka & Gelman, 2004). Focusing attention on the exact number of objects or incidents in one's surroundings, i.e., the attentional process enabling the utilization of the preattentional subitizing mechanism for quantification, is an essential skill to be learned before a child can utilize his or her innate mechanisms efficiently for utilizing quantification in his or her actions (Hannula et al., 2007).

Children recognize the number of small items without counting before they are able to determine the exact numerosity of large sets and prior to acquisition of the cardinal word principle (e.g., Bermejo et al., 2004; Mix et al., 2012; Wynn, 1990, 1992). They learn the cardinal meanings of the first few numbers before they learn to count them. They recognize exact small numbers of items and are able to use them in their actions; for example, this may be observed when picking up accurate numbers of socks to caterpillars (Hannula & Lehtinen, 2001) or when giving a requested small number of objects (Wynn, 1990). The prolonged, separate development of subskills of counting and cardinality recognition without counting is followed by the integration of these skills when the child typically progresses to the recognition of three or four items and eventually understands how cardinality of a set can be determined by counting (Fuson, 1988; Gelman & Gallistel, 1978; Wynn, 1992). Thus, children understand the cardinal principle by which the last word of the counting list defines the cardinality of the set. Better small number recognition skills result in a better understanding of the purpose of counting procedures and more success with learning to count (Mix et al., 2012; Wynn, 1992). Furthermore, better enumeration skills can, in turn, also enhance a child's interest in utilizing his or her quantitative skills and thus strengthen his or her subsequent SFON tendency at preschool age (Hannula & Lehtinen, 2005). The reciprocal nature of the skills may also suggest that training of these skills together is worth investigating.

Results from recent longitudinal studies on children with mathematical learning disabilities have underlined the importance of cardinality understanding by showing that delayed understanding of the cardinal value of number words in preschool years was associated with substantive deficits in arithmetic skills in the first grade (Chu et al., 2019). Likewise, Geary et al. (2018) showed that early cardinality understanding predicts number system knowledge measured by simple addition retrieval, complex addition decomposition, number line accuracy, and creation of number sets in the beginning of school. Due to the important role of cardinal skills on children's early mathematical development they were targeted in our intervention program.

Verbal counting skills are building blocks for the natural number concept and later numeracy skills (Fuson, 1988; Gelman & Gallistel, 1978). Gelman and Gallistel described five counting principles. These deal with rules of how and what to count, as well as understanding features of the other four principles. Thus, young children's learning goals for object counting skills are related to mastering five principles that define accurate counting: one to one, stable-order, cardinal, abstraction, and order-irrelevance principles.

In addition to these principles, Hannula (2005) suggested that SFON would be not only a developmentally relevant disposition or numeracy-producing practice of number recognition skills, but also a relevant sub-process of any counting act. Before a set of items can be enumerated, attention needs to be focused on the aspect of exact numerosity in the set of items. The focusing of attention on the aspect of numerosity is thus needed for exact number recognition. It does not happen automatically (Trick & Pylyshyn, 1994). This is particularly important in children's natural surroundings, where the sets of items are not readily defined and where there are no hints with regard to exact numerosity as a relevant aspect. This is also why it is important to train children's small recognition and counting skills in isolation of learning to focus on numerosity, first as guided activity, and then subsequently leading to a generalized tendency to the spontaneous using of exact number recognition skills in the children's own activities. The period beginning around the age of 3 years might be the time when children's spontaneous practice in small number recognition could be triggered (Hannula, 2005). Correspondingly, for the counting skills, on average, slightly older children could optimally benefit from counting intervention.

The recitation of number words, even during enumeration tasks, does not necessarily indicate that children know their cardinal values (Geary & vanMarle, 2018). Nevertheless, a child's first attempts to use counting for the determination of cardinality of a set offer visible signs of developing number concepts and skills (Goldin-Meadow et al., 1993) and they often trigger a caregiver's enhanced support in the learning of counting skills (Mattinen, 2006).

Sociocultural aspects of early numerical development

The studies on SFON can be described as attempts to determine and describe how early, low-level, quantitative capacities become integrated with cultural practices of numeracy, as well as how children learn to focus on exact numerosity and other mathematically relevant aspects of their surroundings and use their existing mathematical skills in their own actions (Hannula-Sormunen & Lehtinen, in press). Hannula and Lehtinen (2005) argued that the sociocultural mediation of numerical cognition develops a child's skills to focus on the aspect of numerosity and to utilize their innate and cultural tools for enumeration. This is similar to Sophian's (1998) theory about the developmental processes of the conceptual knowledge of numbers and goal-directed numerical activities. Children's conceptual knowledge about numbers is dynamically related to their goal-based numerical activities: conceptual advances facilitate new goals and corresponding activities, which in turn provide the input for further advances (Sophian, 1998). According to Saxe et al. (1987) and Sophian (1998), counting development is reciprocal in such a way that socially structured goals of quantification change along with the development of skills, directing children's attention to different aspects of numbers and the ways they are used. In the present study, the interactive processes in the sociocultural mediation of numerical cognition were deliberately varied and its effects on the development of cardinality-related skills were investigated.

Aims of the study

We developed two SFON-based early numeracy intervention programs suitable for a day care context in Finland; we tested their effects on children's learning of cardinality-related and linguistic skills. The research questions of the study were: (1) Does the development of SFON and cardinality-related skills differ in the 2.5- to 3-year-old children participating in the One, two, how many programs or the Let's read and talk program?; and (2) Does the children's development of SFON and cardinality-related skills differ in the 3- to 4-year-old children in the Count, how many programs or the Let's read and talk program? By including active control groups training linguistic skills, we studied domain-specificity of the intervention effects. Furthermore, in both sub-studies, we investigated whether children grouped in the low and high groups based on their pretest SFON tendency and cardinality-related skills differed in their responses to the interventions.

The aims of the SFON-based intervention programs

SFON-based interventions were aimed at promoting children's focusing on numerosity, recognizing, and using of exact number recognition and counting skills in structured games, and engaging in meaningful play in various contexts and across different everyday situations. As a result, focusing on numerosity and the recognition of small numbers of items and/or the counting of objects was constantly present in all the activities of the day care, providing all the children opportunities to practice their number recognition skills in a fun and playful way. This way, children's guided focusing on numerosity would generalize from guided situations to the children's own, spontaneous focusing on numerosity in novel situations. The structure of the activities was similar in the experimental and control groups. Children in all groups participated in the small group activities. They had daily, whole group activities, and the content of the programs was connected to daily routines and activities. A great importance in all programs was placed on the early educators' sensitivity toward the zone of proximal development, initiatives, questions, and discoveries of the child. Specifically, children's levels of numerical skills in the numerical programs and early literacy skills in literacy programs was taken into account in the activities. The One, two, how many programs targeted small number recognition skills, not counting, while the Count, how many programs was aimed at enhancing not only small number recognition skills but also counting skills. The Let's read and talk program was aimed at supporting children's vocabulary and story comprehension skills.

Methods

Participants

Participants of Study 1 were 59 native Finnish-speaking children (23 girls) with no developmental delays from 12-day care centers located in middle-SES areas in a medium-sized city in southwest Finland. The children were from 2 years, 5 months to 3 years, 6 months (on average 3 years old; SD = 3.0 months) at the time of pretest. Approximately half the children (n = 32) participated in an SFON enhancement program, whereas the active control group (n = 27) participated in the Let's read and talk program.

Participants of Study 2 were 78 native Finnish-speaking children (38 girls) with no developmental delays from 5 day care centers located in middle-SES areas in a medium-sized city in southwest Finland. The children were from 2 years, 11 months to 4 years, 3 months (on average 3.6 years old; SD = 9.0 months) at the time of pretest. Approximately half the children (n = 43) participated in the Count, how many programs, whereas the active control group (n = 35) participated in the Let's read and talk program.

Participation in the studies was voluntary and the day care groups of similar, middle-SES socio-economic backgrounds were divided into experimental and control groups according to the location of day care centers so that possibility of contamination of the intervention programs was minimized. Informed consent was obtained from participants' parents and early educators before the study began. The ethical guidelines of the University of Turku were followed and both the ethical committee of the University of Turku and day care administration gave permission for conducting the study.

In Study 1, early educators (n = 23) from 7-day care centers and 7 child groups were trained to implement the One, two, how many program; the early educators of the active control group (n = 17) from 5-day care centers and 6 child groups were trained to implement the Let's read and talk program. Correspondingly, in Study 2, there were 3 day care centers and 3 child groups with 10 early educators running the Let's count how many program, and 2-day care centers and 2 child groups with 6 early educators running the Let's read and talk program.

Design and schedule of the studies

The experimental intervention programs differed slightly in their length of intensive phase (see Figure 1). The One, two, how many intervention group started with a 4-week intensive phase including three weekly, small-group (2 to 3 children) sessions lasting 15 to 30 minutes, while the Count, how many intervention group started with a 6-week intensive phase in which every second week children participated in a small group activity (3 to 7 children, 15 to 30 min, three times a week). Every second week, the focus was on applying the skills practiced in the small groups to everyday situations at the day care. The intensive phase in the autumn was followed by a spring rehearsal phase. During this 20-week period, focusing on numerosity and enumeration practice was applied in the context of daily day care routines. Every fifth week of the rehearsal phase, the small-group activities practiced in the intensive phase were repeated as rehearsal activities and the early educators especially emphasized the noticing of numbers and the using of number recognition. The purpose of this was to remind adults and children about the intervention activities and aid numerical focusing and enumeration training in becoming a regular, everyday behavior of all children in the longer term. Throughout the interventions, the active control group had a similar

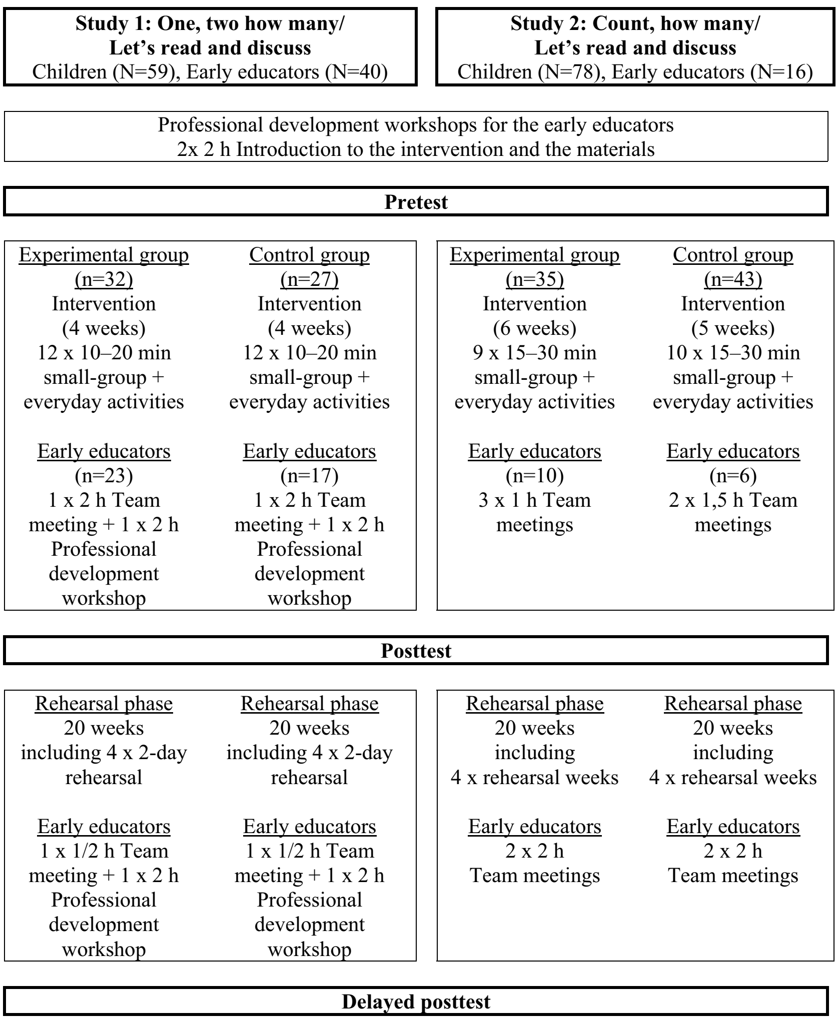

Figure 1. Timetable of Data Collection, Professional Development Support and Intervention Phases in Studies 1 and 2.

frequency and overall structure of intervention activities as its corresponding experimental intervention.

Professional development support of the early educators

Before and during intervention, the early educators participated either in the training of pedagogical and early math content knowledge concerning the enhancement of SFON and cardinality recognition skills, or in the training of pedagogical content knowledge about supporting verbal comprehension and vocabulary development so that they could implement the interventions they were participating in. The training in all educators of both studies consisted of two, 2-h workshops, introduction of designed materials for activities, and 3 1.5-h small-group professional development discussions during the intensive and rehearsal phases. In addition, in Study 2, the last small-group activity of each structured activity week was video recorded. In the 4 1.5-h team meetings of the following week after the recorded session, at each day care center, the educators and researchers watched these videos and reflected especially on the well-guided numerical episodes chosen by the researchers. In addition, the educators' questions about the activities and numerical guidance were addressed and discussed.

Structured activities

Small group sessions included activities that were planned to enhance children's numeracy skills. All the small group activities (see Figure 2) were carried out with the whole day care group.

1. The *how many box* is a light drawer cabinet with eight boxes with doors. Behind every door, there is a different picture of objects (or real objects) in differing numbers, which allows for playing the hide and seek game together while focusing on numbers. Children's attention is guided toward the exact number of objects before and after opening the door. The how many box (Study 1) had only one to three items behind the doors. The objects can be picked up one-by-one from the box on the table and enumerated or counted as well as compared, increased, and decreased easily. Later, each child gets their own counting box for their own play, during which they can play garage, or they can play the baking or hiding game, in which one always cares about how many toys go inside and come out of the box.

2. The *how many board* (Study 1) has one to three ladybirds with one or two leaves. The *Count, how many board* is a large photo of either a table or a sandbox. The children's attention on the number of photographic silhouettes of similar everyday items was captured by asking how many items there were

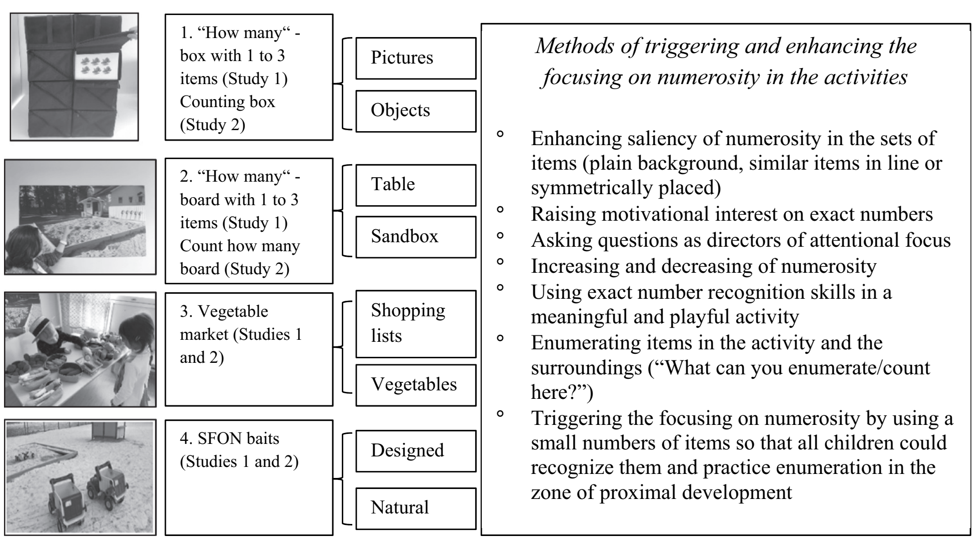

Figure 2. Structured, Adult-Guided Activities in One, Two, How Many and Count, How Many Intervention Programs.

in addition to increasing and decreasing the number of items together with children. In addition, the children were asked to find out how many of similar and different items there were in the actual day care environment.

3. *Vegetable market* is a structured, adult-guided role-play in which children act as customers, salespersons, drivers, and warehouse workers. The customer has a shopping list with a picture of one to three (Study 1) or one to seven (Study 2) similar vegetables. The child is asked to find out how many vegetables they need to buy and then go asking for the same number of vegetables from the salesperson at the market. Next, they take the shopping "home" and use the shopping list to ensure that the correct number of items was brought. Educators guided children in the game to especially focus on and recognize exact numbers of items as a natural part of their role in the play.

4. During the whole intensive phase and every now and then during the rehearsal phase in both studies, *SFON baits* were placed around the day care center by the early educators to prompt the children to notice small numbers of items in their surroundings. A designated SFON bait was made of similar toys or everyday materials arranged in a symmetric manner that separated the set of toys from other things in their surroundings and made the numerosity more salient, with focusing as the target. The idea was that the arrangement of similar toys, side by side, in a row, on a plain background might aid the set of items to pop out and increase the likelihood of exact number recognition and/or counting behavior. If the child did not focus on the numerosity of the items in the SFON bait, the early educators explicitly guided the child's attention by asking how many items there were, or by taking away or adding items. Children were encouraged to notice and share their findings of natural SFON baits that were in their surroundings (for example, 2 lamps in the ceiling).

Everyday situations

In utilizing everyday situations, the early educators were instructed to be especially sensitive to children's enumeration initiatives, to notice numerosities everywhere, and to encourage enumeration and counting in all day care routines (outdoor activities, eating, getting dressed, crafting, etc.). The early educators were encouraged to cherish these counting moments and to make these little moments of counting a typical routine in a day care day.

Let's read and talk intervention program

The control group participated in the intervention called "Let's read and talk", aimed at supporting children's vocabulary and story comprehension. The program included reading the picture book by dialogic reading (Whitehurst et al., 1988) and listening to Bunny Stories in the comprehension program (Mattinen et al., 2014). Four stories of Onni-boy (Pelliccioni, 2015) were read and discussed with the children in the groups of 2 to 3 children in Study 1. In the groups of 3 to 7 children in Study 2, they read one story per week. The story was read in three parts, both in small groups and as a whole group activity. Each story entailed everyday situations that were bridged to children's own experiences. Children were prompted to discuss and ask questions and early educators were guided to embrace verbal initiatives of the children. The contents of the story were concretized and dealt with daily activities and play. The early educators were guided to mark down each time when children spontaneously had questions or gave comments on the story. The early educators were prompted to use the dialogic reading method in other book reading situations and to read Onni-boy stories again during the rehearsal phase.

Testing procedure and measurements

In the test situations, the children participated one by one in the experiment that was administered in a quiet, familiar room at the child's day care center. The experimenter ensured that the testing was free from any numerical displays that might have prompted the children to focus on numbers. Neither the parents nor the nursery personnel were informed about the explicit content of the tasks. The test situation that lasted on average 20 minutes included six test tasks in both of the studies and two short breaks, respectively: SFON imitation task (disappearing objects), vocabulary task, short break activity, SFON selection task, story comprehension task, short break activity, SFON imitation task (visible objects) and "give-a-number" task. The breaks included joyful exercises (for example, "let's jump like frogs") and the purpose was to ensure the spontaneity of the next SFON assessment in the test situation. The test situations were video recorded and all scoring was done based on video recordings. There were two testers collecting the data from the children, counterbalanced between pretest and posttest in order to keep the test situation as novel as possible. The same person tested the child in the pretest and delayed posttest. There were no tester effects according to t-tests.

The tasks were presented in the same order for every child. Parallel versions of SFON tasks were administered in pretest, posttest, and delayed posttest. After each task, each child received general praise, but no specific feedback.

Children's responses were scored from the videos by two observers. The inter-rater reliability of all SFON tasks varied from 0.96 to 1.0, indicating very high reliability. In the "give-a-number" task the reliability was 1.0 in each measurement point. The inter-rater reliability of the story task varied from 0.98 to 1.0 and for the vocabulary task it varied from 0.91 to 0.98, indicating high reliability.

SFON tasks

In the SFON tasks, the participants were not directed to focus on numerical aspects of the tasks and the experimenter avoided the use of any phrases or other contextual hints that could have suggested to the child that the task was mathematical or quantitative (Hannula & Lehtinen, 2005). Further, the experimenter did not give any feedback about the child's performance during the test situation. Only very small numerosities (1 and 2) were involved so that at least most of the children would have sufficient enumeration skills to recognize the numbers in the tasks.

SFON tendency was measured by scoring the child's responses as either 0 or 1 for each trial of SFON tasks depending on whether the child spontaneously focused on numerosity. The response was scored 1 if the child put the same number of items as the experimenter or if he or she presented any of the following verbal or nonverbal quantifying acts: (a) utterances, including number words related to the task objects (berries/envelopes) during the task; (b) the use of fingers to express the amount of objects; (c) counting acts related to task objects; and (d) numerical goal comments. The maximum SFON tendency score was 9 since there were three trials in each of the three SFON tasks. In Study 1, the average measures of intra-class correlation for all three SFON tasks were.577 in the pretest; .763 in the posttest; and .796 in the delayed posttest. In Study 2, average measure intra-class correlation for the all three SFON tasks were .691 in the pretest, .820 in the posttest and .839 in delayed posttest. There were no tester effects and the interrater reliabilities ranged from 0.98 to 1.00.

The *imitation task* with disappearing objects (Hannula & Lehtinen, 2005) was conducted as follows: The experimenter placed a toy parrot (in the pretest), a toy post-box (in the posttest), and a toy puppy (in the delayed posttest) on the table in front of the child. Then, the experimenter said to the child, "Look (child's name), this is Vaakku bird (in the pretest), a post-box (in the posttest), or a Haukku puppy (in the delayed posttest) and here are berries for Vaakku/envelopes/biscuits for Haukku. Watch carefully what I'm doing and then you do exactly as I did. Look, I'm doing it now." The experimenter put two berries/envelopes/biscuits into the parrot's mouth/the post-box/the puppy's mouth, one at a time from a plate or pile of 8 items on the table. Then, the child was told, "Now you do exactly like I did." The number of berries/envelopes/biscuits across the separate items was 2, 1, and 2.

The selection task (Hannula et al., 2005) was presented with a brown paper creature with either one or two legs (in the pretest), a red paper house with one or two windows (in the posttest), and a green paper caterpillar with either one or two legs (in the delayed posttest). The experimenter started the task by lifting the object from the bag and saying, "Look (child's name), here is a creature/house/caterpillar, but it feels cold/the wind blows inside the house/there is water around. Here are shoeboxes/boxes of windows/boxes of socks under the cloth." The experimenter revealed all four boxes and presented each of them, one at a time, by pointing to it with her hand and saying, "Here is this kind of shoebox/window box/sock box, here is this kind of shoebox/window box/sock box, etc. For this creature, give it its very own box of shoes/for this house its very own box of windows/for this caterpillar its very own box of socks." There were 4 boxes with 3, 1, 2, or 4 target items glued on each box, on the table in a row from left to right. The number of legs/windows/legs across the separate items was 2, 1, and 2.

The *imitation tasks with visible items* (Hannula et al., 2005) included a truck and a box with gravel (in the pretest), a toy hen together with a spoon, a plate and a box full of grains (in the posttest), and a tractor and shovel with a trailer (in the delayed posttest). The experimenter started the task by introducing the materials and then said, "Look, I'll now put gravel to the truck's loading platform/grain to the hen's plate/seed onto the trailer." The experimenter loaded two handfuls of gravel/two spoons full of grains/two shovels of seeds and said, "Now you put gravel to the loading platform/grains to the plate/seeds onto the trailer." The number of handfuls/spoonfuls/shovels across the separate items was 2, 1, and 2.

"Give-a-number" task

Children's cardinality-related skills were tested with a "give-a-number" task, applied from Wynn (1990). In this task the child was advised to place onto a table a certain amount of small, wooden objects by saying, for example, "Take two strawberries from the box and put them onto the table. How many strawberries will you put onto the table?" If the child answered with a wrong number, did not answer at all, or only showed the number with their fingers, he or she was advised, "You were supposed to take two. How many will you take onto the table?" When the child repeated the correct number, he or she was allowed to take the objects from the box and put them onto the table. The numbers were 2, 3, 4, 5, 7, and 9 for Study 1 and additionally 13, 19, 23, and 32 in Study 2. There were always 10 extra items in each case, after the correct number of items was taken. The task was discontinued after two consecutive mistakes and repeated similarly in all measurement points.

Cardinality skills based on the "give-a-number" task were scored based on the amount of correct responses with the maximum score being 6 in Study 1 and 10 in Study 2. Cronbach alphas for the give-a-number task were .748 and .83 in the pretest; .570 and .87 in the posttest; and .780 and .88 in the delayed posttest in Studies 1 and 2, respectively.

Linguistic tasks

Participants' linguistic skills were assessed with two standardized verbal tasks.

In the *vocabulary task* (WPPSI-III, Wechsler, 2009), the child was asked to name objects presented in pictures (five rather familiar objects) and explain the general meaning of 10 to 35 concepts, depending on the success of the participant. Three consecutive questions resulting in 0 points ended the task. The task was repeated similarly in all measurement points. The maximum was 61.

In the *story comprehension task* from NEPSY II (Korkman et al., 2008), the experimenter showed a picture and read a short story related to the picture (parallel versions for each measurement point were used). After that, there was a free recall task in which the child was encouraged to tell as many aspects about the story as he or she remembered. If the child could not begin telling anything about the story, he or she was encouraged with two hint questions. After the free recall, guided questions were posed about the aspects that remained unmentioned in the free recall phase. The maximum score provided by accurate responses in the task was 24.

Data analysis

The data were analyzed statistically with IBM SPSS Statistics 22 using covariance analysis and repeated measure ANOVAs.

Results

Table 1 presents the descriptive statistics of demographic information and the main variables for both studies. Independent sample t-tests in pretest measures between the experimental and the control group in Study 1 showed no differences in SFON tendency, cardinality skills, or story comprehension. Children from the One, two, how many programs had higher vocabulary scores compared to children from the Let's read and talk program: $t(56) = 2.37$; $p = .021$. In Study 2, the experimental and control groups did not differ in SFON tendency or cardinality skills but the experimental group was better in vocabulary [$t(76) = 2.07$; $p = .042$] and story comprehension skills [$t(76) = 3.10$; $p = .003$] in the pretest.

Intervention effects from pretests to posttests in studies 1 and 2

One-way ANCOVAs with the pretest measure as a covariate and the posttest measure as a dependent variable were run for each skill (Table 2) to investigate intervention effects. In Study 1, no significant group difference was found in the posttest measures. In Study 2, significant group effects were identified for SFON tendency and cardinality skills. Children who participated in the Count, how

Table 1. Descriptive statistics of all measures per experimental condition.

	Experimental			Control		
	n	M (SD)	[Min, Max]	n	M (SD)	[Min, Max]
Study 1: One, two, how many program						
Gender (proportion female)		53.1%			22.2%	
Age in months at pretest	32	35.68 (3.25)	[29.7, 41.76]	27	36.02 (2.84)	[32.72, 43.63]
SFON						
Pretest	31	3.13 (2.22)	[0, 8]	27	2.69 (1.69)	[0, 5]
Posttest	32	3.53 (2.65)	[0, 9]	26	2.52 (1.93)	[0, 8]
Delayed posttest	32	4.03 (2.67)	[0, 9]	27	3.50 (2.27)	[0, 9]
Cardinality skills						
Pretest	32	1.28 (1.37)	[0, 5]	26	0.88 (1.14)	[0, 4]
Posttest	32	1.22 (1.01)	[0, 3]	27	1.00 (1.07)	[0, 3]
Delayed posttest	32	2.81 (1.79)	[0, 6]	26	1.54 (1.53)	[0, 5]
Vocabulary						
Pretest	32	7.03 (3.35)	[0, 15]	26	5.23 (2.16)	[1, 11]
Posttest	32	7.81 (4.04)	[2, 21]	27	7.04 (2.98)	[2, 13]
Delayed posttest	32	11.72 (5.87)	[5, 25]	26	9.62 (5.61)	[4, 25]
Story comprehension						
Pretest	32	2.34 (1.95)	[0, 8]	26	1.85 (2.22)	[0, 7]
Posttest	32	3.34 (3.22)	[0, 11]	27	2.37 (2.45)	[0, 11]
Delayed posttest	32	3.87 (3.50)	[0, 15]	26	2.77 (2.79)	[0, 8]
Study 2: Count how many – program						
Gender (proportion female)		48.8%			48.6%	
Age in months at pretest	43	54.08 (9.26)	[35.75, 68.80]	35	50.18 (8.48)	[34.96, 68.01]
SFON						
Pretest	43	3.53 (2.06)	[0, 8]	35	3.46 (1.84)	[0, 8]
Posttest	43	4.37 (2.27)	[1, 9]	35	3.43 (1.84)	[0, 9]
Delayed posttest	43	4.28 (2.41)	[0, 9]	35	4.14 (2.39)	[1, 9]
Cardinality skills						
Pretest	43	4.00 (3.09)	[0, 9]	35	3.54 (1.92)	[0, 7]
Posttest	43	5.23 (2.82)	[0, 10]	35	3.77 (2.21)	[0, 8]
Delayed posttest	43	6.14 (2.43)	[0, 10]	35	4.40 (2.44)	[0, 9]
Vocabulary						
Pretest	43	17.67 (10.71)	[4, 48]	35	13.11 (8.22)	[4, 38]
Posttest	32	7.81 (4.04)	[2, 21]	35	7.04 (2.98)	[2.13]
Delayed posttest	43	19.93 (9.35)	[4, 41]	35	17.00 (8.63)	[5, 40]
Story comprehension						
Pretest	43	7.47 (5.46)	[0, 19]	35	4.23 (3.73)	[0, 15]
Posttest	42	8.76 (5.19)	[0, 19]	35	6.54 (3.88)	[0, 13]
Delayed posttest	43	9.42 (5.72)	[0, 21]	35	6.46 (4.46)	[0, 20]

Table 2. Summary of ANCOVA results using posttest measures as output and pretest measures as covariate in the comparisons of experimental and control groups in studies 1 and 2.

	Study 1 (n = 57)				Study 2 (n = 78)			
Predictor	*df*	*F*	*p*	partial η2	*df*	*F*	*p*	partial η2
SFON tendency								
pretest	1	21.91	.000	.32	1	38.63	.000	.34
group	1	1.82	.183	.03	1	5.31	.024	.07
Cardinality skills								
pretest	1	49.78	.000	.46	1	48.90	.000	.40
group	1	0.04	.836	.00	1	6.62	.012	.08
Vocabulary								
pretest	1	60.69	.000	.53	1	115.47	.000	.61
group	1	1.97	.166	.04	1	0.17	.68	.00
Story								
pretest	1	48.86	.000	.47	1	51.53	.000	.41
group	1	0.51	.479	.01	1	0.04	.846	.00

many programs outperformed the children from the Let's read and talk 2 program in SFON tendency and cardinality skills.

Next, in order to investigate, if the children of low and high initial SFON and cardinality recognition skills developed differently as a function of intervention programs, we formed low and high groups. These groups were formed by using the median split on average of proportion correct scores in the pretest SFON tendency and cardinality skills. Thus the sample was divided exactly half according to the average of the sum scores in the pretest SFON and Give a number tasks. Similar ANCOVAs for the whole group were run for each measure. Results of Study 1 showed a positive intervention effect of the One, two, how many programs in the low group in the SFON tendency: F (1, 26) = 4.94; p = .035; η^2 = .16. Planned contrasts showed that children who participated in the One, two, how many intervention programs had significantly higher SFON tendency scores compared to children who participated in the Let's read and talk program [$t(76) = 4.28$; $p < .001$; $r = 0.48$] in the posttest when the pretest was controlled for. In Study 2, there were no significant differences between experimental conditions divided in the low and high groups.

Intervention effects from pretest to posttest and delayed posttests in studies 1 and 2

Repeated measures 3 × 2 ANOVA with time represented by pretest, posttest, and delayed SFON and cardinality measures as within subject factors, experimental condition as between subject factors were run to investigate if the experimental and control groups differed from pretest to posttest and delayed posttest in their SFON, cardinality recognition, vocabulary, and story comprehension as a function of a participation in the One, two, how many programs and in the Count how many program (Table 3, Figure 3 and Figure 4). Results showed a significant interaction effect between time and experimental condition for cardinality skills. In Study 1, planned contrasts showed that children who participated in the One, two, how many intervention programs developed more in cardinality skills as compared to children who participated in the Let's read and talk program. Their cardinality skills were better in the delayed posttest [$t(56) = 2.88$; $p = .006$; $r = 0.36$], while scores were similar in the posttest [$t(57) = 0.81$; $p = .424$; $r = 0.11$]. In study 2, the children who participated in the Count, how many programs had significantly higher scores for cardinality skills, in both the posttest [$t(76) = 2.57$; $p = .012$; $r = 0.28$] and delayed posttest [$t(76) = 3.14$; $p = .002$; $r = 0.34$] compared to children who participated in Let's read and talk program. There were no other significant group differences.

Similar analyzes were run in the low and high groups to investigate whether children developed differently as a function of a participation in the One, two, how many programs and in the Count how many programs across the three measurement points. In both studies there were significant

Table 3. Summary of repeated-measures ANOVA results on the effect of intervention program over the three measurement points for SFON, cardinality skills, number sequence production, vocabulary, and story comprehension.

	Study 1 (n = 58)				Study 2 (n = 78)			
Predictor	*df*	*F*	*p*	partial η2	*df*	*F*	*p*	partial η2
SFON								
time	2	4.49	.013	.08	2	4.96	.008	.06
group	1	1.15	.289	.02	1	0.86	.356	.01
time X group	2	0.69	.505	.01	2	2.26	.108	.03
Cardinality skills								
time	2	25.77	.000	.32	2	17.07	.000	.18
group	1	3.58	.064	.06	1	5.99	.017	.07
time X group	2	5.30	.006	.09	2	3.46	.034	.04
Vocabulary								
time	2	42.16	.000	.43	2	9.79	.000	.11
group	1	2.64	.110	.05	1	3.05	.085	.04
time X group	2	0.72	.402	.01	2	0.73	.478	.01
Story comprehension								
time	2	5.30	.006	.09	2	11.31	.000	.13
group	1	1.89	.175	.03	1	8.58	.004	.10
time X group	2	0.22	.807	.00	2	0.69	.494	.01

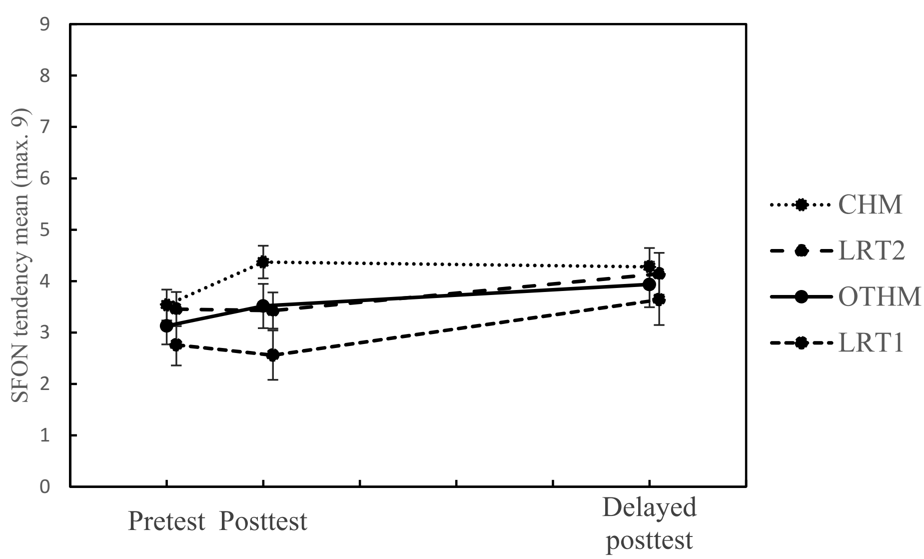

Figure 3. Development of SFON tendency in the children of Study 1 participating in either One, two, how many (OTHM) or Let's read and talk 1 (LRT1) program and in the children of Study 2 participating in either Count, how many (CHM) or Let's read and talk 2 (LRT2) programs (means and standard errors).

interaction effects between time and experimental conditions in cardinality skills in the low groups [Study 1: F (2, 52) = 5.43; p = .007; η^2 = .17; Study 2: F (2, 62) = 5.51; p = .006; η^2 = .15] while the interaction was nonsignificant in the high groups. Planned contrasts showed that children from the low group who participated in the Study 1 One, two, how many program [t (26) = 2.29; p = .030; r = 0.41] and in the Study 2 Count how many program [t(31) = 2.49; p = .018; r = 0.41] had significantly higher scores for cardinality skills in the delayed posttest compared to children who participated in the Let's read and talk program. No significant differences were found in the posttest.

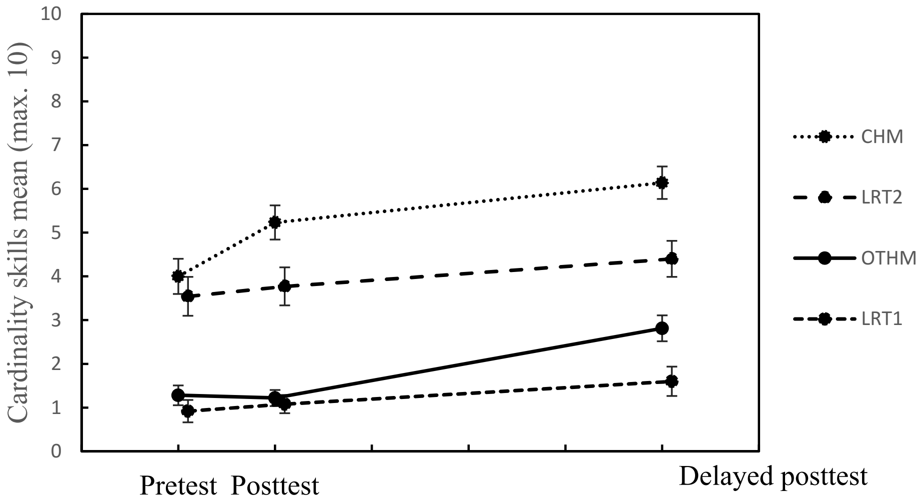

Figure 4. Development of cardinality skills in the children of Study 1 participating in either One, two, how many (OTHM) or Let's read and talk 1 (LRT1) program and in the children of Study 2 participating in either Count how many (CHM) or Let's read and talk 2 (LRT2) programs (means and standard errors).

Discussion

The main objective of our study was to evaluate the effectiveness of two novel early mathematical intervention programs aimed at enhancing young children's SFON tendency and cardinality-related skills in day care. The One, two, how many programs was aimed at enhancing 2- to 3-year-old children's SFON tendency and small number recognition skills, while the Count, how many programs were aimed at promoting approximately 3- to 4-year-old children's SFON tendency and counting skills. Both numerical intervention groups' performances were compared with active control groups who participated in the Let's read and talk intervention aimed at enhancing children's vocabulary and listening comprehension skills. Both numerical interventions included a set of structured play activities in small group and whole group settings, in which focusing on numerosity and cardinality recognition skills could be used and practiced in a playful way. In addition, everyday situations were used to enhance skills targeted. We tested domain-specific intervention effects on SFON tendency and cardinality-related skills and domain-general intervention effects on vocabulary and story comprehension by comparing experimental groups with active control groups participating in a listening comprehension intervention. The results of both numerical interventions at the whole group level showed positive, small- to medium-sized long-term effects on cardinality-related skills from pretest to delayed posttest, which is in line with previous results of Hannula et al. (2005). More specifically, it was the low group that improved with a large effect size in the cardinality skills in both studies. Consistent with previous studies (Bojorque et al., 2018; Braham et al., 2018), results from Study 2 showed that children in the Count, how many programs developed more in SFON tendency from pretest to posttest, while the better development of SFON from pretest to posttest was significant only for the low group in Study 1. There were no significant differences in children's development of vocabulary and story comprehension skills in either study, which indicates that all intervention programs supported linguistic development equally.

The design of the studies does not allow interpretations about the causality between SFON and cardinality-related skills. That was not the purpose of these studies; instead, we aimed at developing early mathematical intervention programs integrating guided focusing on numerosity with cardinality recognition training in an adequate numerical range of cardinality recognition skills. The idea of the interventions was to introduce activities that would be easily embedded in the day care centers' daily practices so that the effects of the intervention would not last solely for weeks, but continue and strengthen after that. Overall results indicate larger effects for the Count, how many programs than for the One, two, how many programs. There are a few possible reasons for this.

First, as this was a naturalistic, design-study type of project, we developed our professional development support substantially from Study 1. Instead of lectures and discussions as the main training methods for early educators, in Study 2, we had regular small-group reflection and feedback sessions with the early educators in each day care center. In these sessions, selected parts of video recordings of early educators' own small group structured activities were watched and reflected on together. This may have helped better tailor our professional development support for the needs of individual educators than more general lectures and discussions in Study 1. These notions are supported by (Norman, Golian & Hooker, 2005), showing that teachers' joint reflections and the constructive support from external critical "friends" is paramount for a teacher's professional development. Teachers who reflect on their practice transfer the skills and habits of inquiry beyond the specific project they engage in; they use their new skills more often in other classroom situations; and they "become more focused on the needs and thinking of their pupils" (Randi & Zeichner, 2004, p. 213).

We cannot differentiate which activity or aspect of program produced the intervention effects. Specific effects related to specific activities remain an open question for future experimental studies. Our aim was to develop a program that would be useful for a day care or preschool context, having a rather wide age and skill range of children. Based on our limited information on the fidelity of implementation, it seems plausible that early educators had differences in their implementation of the program, particularly in Study 1. Based on this notion, professional development support in Study 2 was provided in more individualized way in each day care center along the intensive and rehearsal phases, and we used video-recordings of early educator's own small-group activities in guiding them.

Conclusions

Individual differences in children's mathematical knowledge are already evident among 2- to 3-year-old children. Social interaction in everyday situations with adults plays a critical role in the development of children's mathematical understanding. This should have implications, for example, in early educators' pre-service and in-service education. In line with Mattinen (2006), learning to recognize and support young children's first initiatives of exact number recognition and counting are of educational value. Further, fostering understanding of early numeracy skills among daycare and preschool educators is an important step toward developing early learning contexts that support children in developing mathematical thinking (Björklund & Barendregt, 2016).

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Appendix

Early childhood education in Finland

Formal schooling starts when children turn 7 in Finland. The year before, children are enrolled in compulsory preschool with 700 hours of preschool education. Before that, public and private daycare including early education is available for children, and typically children from close to 3 to 5 years of age are in the same groups, while younger and older ones are in their own groups.

An ECEC teacher in Finland must hold a degree from a university or a university of applied sciences, and ECEC childcarer must have at least an upper secondary level qualification in social welfare and healthcare (Education Finland, 2018). All daycare centers in Finland follow their local curricula, which is based on the normative national core curriculum. The purpose of the national steering of ECEC is to create equal preconditions for the holistic growth, development and learning of the participating children.

ECEC is an entity consisting of education, instruction and care with an emphasis on pedagogy. ECEC is not only care, but also goal-oriented and systematic activities that support children's development and learning and are evaluated and developed on a regular basis. In ECEC, children are engaged in the planning, implementation and evaluation of the activities (Finnish National Agency for Education, 2020). ECEC lays the foundation for the children's transversal competences.

Early childhood education and care in Finland is strongly play-based, and it includes free discovery and collaboration (Education Finland, 2018.) An integrative approach and play-based pedagogy have strong emphasis in the national curriculum. Early educators have lots of pedagogical freedom and autonomy for planning their activities, but observation-based pedagogical evaluations are mandatory for daycare and preschool and they are used for developing individual learning plans for all children.