Unique contribution of Ecuadorian kindergartners' spontaneous focusing on numerosity to
their early numerical abilities

Abstract

Recent evidence indicates that young children's spontaneous focusing on numerosity (SFON) uniquely contributes to their early numerical abilities. The present study complements previous findings by validating the relation between young children's SFON and their early numerical abilities in a developing country, namely Ecuador. We analysed 355 Ecuadorian 5-6-year-olds' SFON in relation to their early numerical abilities at the start of kindergarten, controlling for children's socio-demographic (socio-economic status, age) and general cognitive (working memory, intelligence) characteristics. Our results evidence the unique contribution of Ecuadorian kindergartners' SFON to their early numerical abilities, controlling for children's working memory, intelligence, socio-economic status, and age. Our findings support the validity of previous findings on the unique contribution of SFON to young children's early numerical abilities in developed countries for developing countries. Additionally, they raise timely questions for further theoretical and methodological studies on young children's numerical development worldwide, in developing and developed countries.

Introduction

Cumulative evidence points to the pivotal role of young children's numerical abilities at school entry for their later mathematical and academic achievement (Chu, vanMarle, & Geary, 2015; Claessens, Duncan, & Engel, 2009; Duncan et al., 2007; Geary & vanMarle, 2016; Martin, Cirino, Sharp, & Barnes, 2014; Nguyen et al., 2016; Schneider et al., 2016; Vanbinst, Ghesquière, & De Smedt, 2015). Recently, young children's spontaneous focus on the exact numerosity of a set of items in non-mathematically focused situations (= SFON) has been shown to uniquely contribute to their early numerical abilities (Batchelor, Inglis, & Gilmore, 2015; Gray & Reeve, 2016; Hannula, Lepola, & Lehtinen, 2010; Hannula-

Sormunen, Lehtinen, & Räsänen, 2015; see also the recent reviews of Hannula-Sormunen, 2015; Rathé, Torbeyns, Hannula-Sormunen, De Smedt, & Verschaffel, 2016a). Up to now, the unique contribution of young children's SFON to their early numerical abilities is only evidenced in developed countries. This focus on only developed countries makes the generality of previous findings on the relation between young children's SFON and their numerical development also for developing countries an open question, as they differ from developed countries in general societal and educational characteristics.

We aimed at addressing this important question by analysing the unique contribution of entering kindergartners' SFON to their early numerical abilities in a developing country, namely Ecuador. The cross-cultural validation of findings on the association between young children's SFON and their early numerical abilities is both theoretically and practically important. Current theoretical models on the relation between SFON and children's early numerical abilities rely on findings from developed countries, particularly Finland (cf. the models described in Hannula, Räsänen, & Lehtinen, 2007; Hannula-Sormunen et al., 2015). However, the acquisition of early numerical abilities is known to be influenced by young children's societal (e.g., Rodic et al., 2015) and educational (e.g., Cankaya & LeFevre, 2016; Kilday & Kinzie, 2009) context. Given the aforementioned differences in societal and educational characteristics of developed and developing countries, current theoretical models might require modifications in view of the specifics of developing countries. Moreover, the comparison of young children's early numerical abilities in relation to the contributing variables across cultures may help to optimize early mathematics education practices worldwide. A good understanding of young children's early numerical competencies across cultures makes it possible to design powerful learning environments optimally fitted to their differential early numerical needs.

Unique Contribution of Spontaneous Focusing on Numerosity

In 2005, Hannula and Lehtinen introduced young children's SFON as an important contributor to the acquisition of early numeracy. Different from early numerical abilities such as counting or magnitude processing skills, SFON is defined as an *attention* process. This attention process is assumed to occur *spontaneously*, i.e., in a self-initiated way, without explicit prompts or guidance by others. Importantly, attention is focused on *exact numerosity*: Children who demonstrate SFON pay attention to the exact number of items or incidents in the situation (e.g., 3 dolls or 2 chickens). According to the initiators of the SFON concept, SFON is needed to trigger exact number recognition processes and to use the recognized exact number in action (Hannula & Lehtinen, 2005; see also Hannula-Sormunen, 2015).

Building on the results of this first empirical investigation of SFON and its association with young children's early numerical abilities, a growing number of researchers - mainly from Europe but also, albeit to a limited extent, from US and Australia - aimed at unravelling the contribution of SFON to young children's early numerical development (Batchelor et al., 2015; Edens & Potter, 2013; Gray & Reeve, 2016; Hannula et al., 2010; Hannula-Sormunen et al., 2015; Rathé, Torbeyns, Hannula-Sormunen, & Verschaffel, 2016b; Sella, Berteletti, Lucangeli, & Zorzi, 2016). These researchers provided evidence for large inter-individual differences in young children's SFON. Importantly, these inter-individual differences in SFON were shown to be positively related to young children's concurrent early numerical abilities (Batchelor et al., 2015; Edens & Potter, 2013; Gray & Reeve, 2016; Sella et al., 2016) and their later mathematical performances up to the end of primary school (Hannula et al., 2010; Hannula-Sormunen et al., 2015). Moreover, the associations remained present after controlling for children's age and domain-general cognitive capacities including nonverbal intelligence, working memory, inhibition, general attention, and verbal skills. SFON was demonstrated to uniquely contribute to children's early numerical and later mathematical development.

The unique contribution of SFON to children's early numerical and later mathematical development is hypothetically explained by their self-initiated practice in daily life (Hannula et al., 2010; Hannula-Sormunen, 2015). The more children demonstrate SFON, the more they provide themselves with opportunities to practice their early numerical abilities such as counting sets of objects or comparing the magnitude of different sets of objects during daily life activities including play; and the more these children engage in such self-initiated practice of their early numerical abilities in daily life activities, the more fluent their early numerical and later mathematical development will occur. As the societal and educational context wherein children live and play differs between children from developed and developing countries, the assumed developmental mechanism might result in differences in the association between SFON and early numerical abilities between both groups of children. However, the proposed developmental mechanism underlying young children's early numerical development has received little systematic research attention so far (but see Rathé et al., 2016b, for an exception). Strong empirical support for the assumed mechanism explaining the frequently observed association in developed countries between SFON and early numerical abilities is currently missing (cf. Batchelor, 2014; Batchelor et al. 2015; Rathé et al., 2016a).

Present Study

With the exception of the recent study of Bojorque, Torbeyns, Hannula-Sormunen, Van Nijlen, and Verschaffel (2016), all previous studies on young children's SFON were conducted in developed countries, in particular Europe. This is problematic, as it seriously constraints current theoretical understanding of young children's early numerical development in developing countries, and as it limits the possibilities to establish research-informed early mathematics education practices in these countries.

We aimed at addressing this gap in the research literature by analysing the generality of previous findings on the unique contribution of SFON to young children's early numerical abilities in a developing country: Ecuador. As a developing country, Ecuador substantially differs from developed countries in terms of its general societal and educational characteristics. In Ecuador, about 36% of the inhabitants live in poverty (INEC, 2014) and only the minority of pre-schoolers attends preschool programs. Indeed, on the basis of the most recently available data, only 23% of the 3-4-year-olds attend preschool programs in Ecuador (Ministry of Education, 2013; UNESCO, 2015). With the majority of preschool children raised at home (in often weaker sociodemographic circumstances), Ecuadorian pre-schoolers have to acquire early numerical competencies in learning environments that clearly differ from the learning environments of their peers in developed countries.

Moreover, cumulative evidence indicates that young children's socio-economic status (SES) influences their early numerical development (Clements & Sarama, 2011; Jordan, Kaplan, Olah, & Locuniak, 2006; Klein, Starkey, Clements, Sarama, & Iyer, 2008; Starkey, Klein, & Wakeley, 2004). This variable was not explicitly taken into account in previous studies on the unique contribution of SFON to young children's early numerical abilities. We included children's SES as a control variable into our study, on top of their domain-general cognitive characteristics (intelligence, working memory) and age.

Method

Participants

The sample consisted of 355 Ecuadorian 5-6-year-olds (179 boys; $M_{age} = 5$ years 2 months [$SD = 3.7$ months]) from 18 different schools (6 schools per major school type in Ecuador, i.e., public urban, public rural, and private). Only children with parental consent participated to the study. All children were at the start of kindergarten entry. As described in more detail in Bojorque, Torbeyns, Moscoso, Van Nijlen, and Verschaffel

(2015), kindergarten corresponds to the first year of compulsory education in Ecuador and starts at the age of 5.

We constructed children's SES on the basis of the educational level of the mother: (1) no education, (2) pre-primary education, (3) primary education, (4) lower secondary education, (5) upper secondary education, (6) lowest level tertiary education, (7) lower-degree level tertiary education, (8) higher-degree level tertiary education, (9) doctorate level degree. Children's SES ranged from 1 to 8 (no doctoral level degree observed in the sample), $M = 4.86$ ($SD = 1.68$). The study was approved by the ethical committee of the KU Leuven.

Materials and Procedure

At the start (i.e., the first two months) of kindergarten, all children's SFON, early numerical abilities, non-verbal and verbal intelligence, and working memory were measured. All tasks were individually presented to the children, with the exception of some items from the early numerical abilities tests that were administered collectively by means of a paper-and-pencil test. All tasks were administered by well-trained research assistants (including the second author) and undergraduate students, all having Spanish as their mother tongue.

Spontaneous Focusing on Numerosity. We assessed children's SFON via the Spanish version of the Elsi Bird Imitation task (Hannula & Lehtinen, 2005; Bojorque et al., 2016).¹ This task addresses children's spontaneous attention for the experimenter's numerical behaviour in a non-mathematically focused situation. All children responded to the SFON task before they were offered the early numerical abilities tests, ensuring children's *spontaneous* attention for numbers in the SFON task.

The materials of the Imitation task consisted of a toy parrot and two cases with different-coloured berries, one placed on the left side of the parrot and one placed on the right side of the parrot. The interviewer started the task by pointing to the cases with coloured berries while saying "This is Bird Elsi, and there are [colour] berries here and [other colour] berries

here. Watch carefully what I do, and then you do just like I did.” In the first trial, the experimenter repeated “Watch carefully what I do” and then put two red berries and one blue berry with a large hand movement into the parrot’s beak one at a time; the berries dropped into the parrot’s stomach with a bumping sound. The child was next instructed to do exactly the same as the experimenter did: “Ready! Now you do exactly like I did.” For the second trial, three green berries and two yellow berries were used. The third and the fourth trial consisted of, respectively, two white and three brown berries, and one transparent and two light blue berries (Hannula et al., 2010).

In line with Hannula and Lehtinen (2005), children’s SFON was scored per trial on the basis of both their responses (i.e., the number of berries put into the parrot’s beak) and their verbal and non-verbal quantifying acts defined as (1) number word utterances referring to the number of berries, (2) use of fingers to express numbers of berries, (3) counting acts indicated by whispering number words or counting on fingers, (4) other comments referring to either the exact numbers of berries or counting of them, (5) interpretation of the goal of the task as being about exact numbers of berries. The child was scored as focusing on numerosity in a trial if (s)he gave the correct response (i.e., put into the parrot’s beak the correct number of differently-coloured and/or total number of berries) and/or if (s)he was observed doing at least one of the abovementioned quantifying acts (1-5) for that trial. All trials were scored dichotomously, resulting in a maximum test score of 4.

Early numerical abilities. Children’s early numerical abilities were measured using two different tests. All children solved the Test of Early Number and Arithmetic (TENA) (Bojorque et al., 2015), an Ecuadorian standards-based test for the domain of number and arithmetic, and the Spanish version of the Tools for Early Assessment in Math (TEAM) (Clements & Sarama, 2011), an internationally well-known standardized test for preschool up to second grade assessing core mathematical knowledge and skills.

The TENA is a reliable and valid test for Ecuadorian children's early numerical abilities (Bojorque et al., 2015), developed on the basis of the Ecuadorian national educational standards for kindergarten number and arithmetic. The TENA consists of 54 items divided over nine topics (with six items per topic), namely (1) quantifiers, (2) one-to-one correspondence, (3) order relations more than/less than, (4) counting, (5) quantity identification and association with numerals, (6) ordering, (7) reading and writing numerals, (8) addition, and (9) subtraction. The TENA has two parts: an individual part with 29 items that mainly require an oral response (12 tasks require the use of small blocks for children to manipulate or for the examiner to present the task), and a collective part with 25 paper and pencil items. Items are scored dichotomously, with a score of "0" for an incorrect response and a score of "1" for a correct response (maximum test score = 54).

The TEAM is an international reliable and valid test that evaluates children's mathematical knowledge and skills (Clements & Sarama, 2011). The TEAM is organized in two parts, number (Part A) and geometry (Part B). For the purpose of this study we administered the Spanish version of Part A. Part A consists of 93 items that measure (1) recognition of numbers and subitizing, (2) verbal and object counting, (3) number comparison and number sequencing, (4) number composition and decomposition, (5) adding and subtracting, (6) place value, and (7) multiplication and division. The TEAM uses an individual interview format and is ended after three consecutive incorrect answers. Most items (86 out of 93 items) are scored dichotomously, with a score of "0" for an incorrect answer and a score of "1" for a correct answer. Seven items consist of two tasks and are coded with a 2 score when both tasks are solved correctly. The maximum score on Part A of the TEAM is 100.

Intelligence. The Vocabulary and Block Design subtests from the Spanish edition of the Wechsler preschool and primary scale of intelligence - III (WPPSI-III; Wechsler, 2002;

Spanish Edition) were administered as indicators of children's verbal and non-verbal intelligence. The Vocabulary subtest involves defining words presented orally, in order of increasing complexity, and has a maximum score of 45. The Block Design subtest involves producing a block construction to match a pictorial model shown by the experimenter, using 1- or 2-color blocks and within a predetermined time limit, with a maximum score of 40.

Working memory. We used the Spanish version of the Odd One Out task from the Automated Working Memory Assessment Battery (AWMA; Alloway, 2007) to assess the visuospatial subsystem of children's central executive. This is a computerized task that requires children to indicate (on the screen of the computer) in a row of three shapes the shape that differs from the other shapes. At the end of each trial the shapes disappear and children need to recall and indicate the location of each different shape. More difficult levels include more sets of shapes (seven difficulty levels). This task has 42 items which are scored dichotomously: correct trials receive a score of 1, incorrect trials receive a score of 0.

Analyses

As children's performances on the TENA ($M = 25.32$, $SD = 8.60$, *range* 7-49) and the TEAM ($M = 15.67$, $SD = 8.74$, *range* 0-49) were highly correlated, $r = .81$, $p < .001$, we computed children's standardized score on both tests, calculated their mean per child as a general indicator of his/her early numerical abilities (ENA), and used this mean score per child in all our analyses. In other words, both children's scores on the TENA and their scores on the TEAM were included in our ENA indicator.

Given the nested structure of our data, we analysed the relation between SFON and early numerical abilities via multilevel analyses, with children nested within schools. All analyses were done in SPSS 23, using the Mixed Models technique (Hayes, 2006).

Results

Table 1 presents the means (and SDs and ranges) for the different variables and their correlations. As shown in Table 1, Ecuadorian kindergartners scored rather low not only on the ENA but also on the SFON tasks, with large inter-individual variability in their performances. Furthermore, children's ENA scores were positively correlated to their age, SES, verbal and non-verbal intelligence, working memory, and SFON.

Given these positive correlations, we constructed stepwise multilevel regression models, entering the different variables to the model on the basis of the correlation value: starting with the largest correlation, and ending with SFON in view of assessing its unique contribution to ENA. Table 2 includes the results of the final model, with ENA being predicted on the basis of, respectively, children's working memory, non-verbal intelligence, verbal intelligence, SES, age in months, and SFON. Table 2 reveals that SFON is a significant contributor to kindergartners' ENA at the beginning of the kindergarten year, after controlling for all these domain-general cognitive (working memory, non-verbal intelligence, verbal intelligence) and background (SES, age) characteristics.

Discussion

Against the background of previous findings on the unique contribution of SFON to young children's early numerical abilities in developed countries (Hannula-Sormunen, 2015; Rathé et al., 2016a), and the importance of these early numerical abilities for later mathematical performances and general academic achievement (Chu et al., 2015; Claessens et al., 2009; Duncan et al., 2007; Geary & vanMarle, 2016; Martin et al., 2014; Nguyen et al., 2016; Schneider et al., 2016; Vanbinst et al., 2015), the present study aimed at analysing the validity of previous findings on the association between SFON and early numerical abilities in a developing country, namely Ecuador. Our results extend current findings about the contribution of SFON to young children's early numerical abilities from both a theoretical and an educational viewpoint, but also point to timely questions for future research on the topic.

The present study evidences - for the first time - the unique contribution of young children's SFON to their early numerical abilities in a developing country. After controlling for the domain-general cognitive (verbal and non-verbal intelligence, working memory) and socio-demographic (age, SES) variables that are known to contribute to young children's early numerical development, SFON proved to be a meaningful contributor to Ecuadorian children's early numerical abilities at kindergarten entry. This main result of our study supports the validity of previous findings (coming from developed countries; see Hannula-Sormunen, 2015; Rathé et al., 2016a) on the association between young children's SFON and their early numerical abilities for developing countries as well.

Theoretical Implications

From a theoretical viewpoint, the results of the present study point to the universal nature of SFON as a unique contributor to children's early numerical abilities. Notwithstanding the different societal and educational context of young children in developed and developing countries, in both groups of children SFON is associated with early numerical abilities. This first evidence on the universal nature of the unique contribution of SFON to young children's early numerical abilities raises timely questions for further research.

A first question relates to the developmental mechanism underlying the relation between young children's SFON and their early numerical abilities. Hannula-Sormunen and colleagues (Hannula et al., 2010; Hannula-Sormunen, 2015; see also Rathé et al., 2016a, 2016b) hypothetically explain this association by pointing to the mediating role of young children's self-initiated practice in daily life activities. Concretely, they hypothesize that children demonstrating SFON will spontaneously attend to exact number during their daily life activities and, consequently, engage in activities that help them to practice their early number skills; this increased practice of early number skills during daily life activities is assumed to enhance children's early numerical development. Unfortunately, up to now, strong empirical

evidence for this hypothetical explanation is missing (Batchelor, 2014; Rathé et al., 2016a, 2016b). Whereas some scholars found empirical support for the relation between young children's SFON and their numerical activities in play situations (Batchelor, 2014), other research findings seriously question the assumed association between young children's SFON and their attention for number in daily life activities (Edens & Potter, 2013; Rathé et al., 2016b). It is important to deepen our theoretical understanding of the mechanisms underlying the development of SFON in relation to early numerical abilities via focused empirical investigations. The application of a cross-cultural design will help to disentangle the universal nature of the developmental mechanisms and, as such, refine current theoretical models of early numerical development.

A second question concerns the complex interplay between young children's SFON, educational context, and early numerical ability acquisition. Cumulative evidence indicates that young children's informal (Cankaya & LeFevre, 2016) and formal (Kilday & Kinsey, 2009) educational environment influences their early numerical ability acquisition. Up to now, the contribution of young children's informal and formal educational context to their SFON has hardly attracted any research attention (but see Batchelor, 2014, and Bojorque, Torbeyns, Hannula-Sormunen, Van Nijlen, & Verschaffel, in press, for two exceptions). In the present study, we collected data on young children's SES, which can be interpreted as a proxy for young children's informal educational environment (Klein, Starkey, Clements, Sarama, & Iyer, 2008; Starkey, Klein, & Wakeley, 2004). Our analyses did not empirically support an association between young children's SES and their SFON. However, as this is the first investigation that systematically included SES differences in relation to young children's SFON and as we only worked with a proxy for young children's informal educational environment, further studies in both developing and developed countries are required. In these future studies, data on young children's SES need to be complemented with instruments

assessing the characteristics of young children's home numeracy environment (LeFevre et al., 2009, 2010) to sharpen our insights into the complex interplay between children's SES, the numerical stimulation they receive at home, and their SFON development. It is assumed that children from higher SES backgrounds more frequently engage in quantitatively and qualitatively strong numerical activities in their home environment compared to children from lower SES backgrounds (e.g., Starkey et al., 2004). This differential engagement in numerically stimulating activities at home would result in differential developmental trajectories in the domain of early numeracy for children coming from higher versus lower SES backgrounds.

The study of Batchelor (2014) serves as a first step towards disentangling the relation between young children's SFON and their home numeracy environment. The author did not observe any association between English children's SFON and their parents' answers to a home numeracy environment questionnaire. But further investigations - again in both developed and developing countries and employing both questionnaire (e.g., LeFevre et al., 2009; Segers, Kleemans, & Verhoeven, 2015) and observation methods (e.g., Susperreguy & Davis-Kean, 2016) - are needed to deepen our understanding of the complex interplay between young children's home numeracy environment and their SFON. The findings from these studies will help to set the scene for further investigations on the contribution of young children's home numeracy environment to their early numeracy development as a whole, including both SFON and early numerical abilities. Again, the employment of a cross-cultural design can add to our understanding of the universal nature of the observed associations.

Educational Implications

From an educational viewpoint, our findings point to the need to develop educational interventions aiming at stimulating children's SFON and early numerical abilities in primarily their home and also their preschool environment. Compared to their peers from developed

countries, Ecuadorian 5-6-year-olds performed weak in general on both the SFON and the early numeracy tasks. For instance, with a mean score on average of 0.60 on a maximum of 4 for the SFON Imitation task, the kindergartners in our sample scored much weaker than their European peers on this task (for example, compared to Finnish 5-6-year-olds who scored on average 2.22/3 (Hannula et al., 2010) and English 5-6-year-olds who scored on average 2.02/3 (Batchelor et al., 2015)). These generally weak performances of Ecuadorian kindergartners are of serious concern, as both children's SFON and early numerical abilities are shown to contribute to their later mathematical performances in developed countries (Duncan et al., 2007; Hannula-Sormunen, 2015). The future studies on the complex interplay between young children's educational environment and their SFON and early numerical ability acquisition for which we pleaded above, should yield building blocks for the design of effective interventions in young children's educational environment in developing countries. Given the large number of preschool children raised at home in Ecuador, focused interventions in Ecuadorian children's home environment, aiming at enhancing young children's SFON and their early numerical abilities, may be of utmost importance. These intervention studies will help to optimize the numerical stimulation in young children's home environment and hopefully provide the necessary building blocks to address the mathematical difficulties of Ecuadorian elementary and secondary school children (INEVAL, 2014; UNESCO, 2015).

Methodological Implications

Notwithstanding its theoretical and educational contributions, our study has some methodological limitations that necessitate to treat its conclusions and implications with caution and that need to be addressed in future research.

First, the present study followed a cross-sectional design, with only correlational analysis of the associations between young children's early numerical abilities and their socio-demographic, domain-general, and domain-specific markers of early numeracy. As outlined

above, future studies following a longitudinal and intervention design are needed to deepen our understanding of young children's developmental trajectories in the domain of early numeracy in developing countries and of effective educational interventions. These studies can also help to pinpoint the causal associations between the different variables under study.

Second, we used maternal educational level as an indicator of children's SES. This rather narrow definition of SES on the basis of only the educational level of the mother was based on both practical reasons (i.e., the availability of information on only maternal educational level in the participating schools) and previous studies (e.g., Starkey et al., 2004). Although the educational level of the mother is a good indicator of young children's SES (with the mother as primary caregiver for young children), the use of composite measures relying on the educational level of both parents, parents' occupation, and/or family income (e.g., Jordan et al., 2006) can provide a more complete picture of children's SES in future studies.

Finally, we selected the - in previous research frequently used - SFON Imitation task to assess Ecuadorian children's spontaneous attention for exact number (Hannula-Sormunen, 2015; Rathé et al., 2016a). Although this task was originally developed to capture young children's verbal and action-based expressions of focusing attention on exact numerosity, its reliability and validity recently have been questioned in the international research literature (Batchelor et al., 2015; Baroody & Li, 2016; Chan & Mazzocco, 2017; Rathé et al., 2016a). Of specific concern are (1) the high working memory demands of the task, requiring children to remember the exact number of objects put into the recipient by the experimenter, (2) the primarily action-based nature of the task, with hardly any verbal indications of SFON in children's responses, (3) the saliency of the aspect of number in the experimenter's behaviour, making it difficult to focus on another aspect of the situation, and (4) the possibility to correctly respond to the task with non-numerical means, i.e., without attending to cardinal number (e.g., correctly feeding the parrot with 2 red berries and 1 blue berry by repeating the

red-red-blue sequence). On the basis of these concerns, various scholars started to develop alternative tasks aimed at a more reliable and valid assessment of children's spontaneous attention for exact number. For instance, Batchelor and colleagues (2015) recently developed a verbal Picture Description task, in which children are asked to verbally describe a clearly visible cartoon picture with both numerical and non-numerical information. Likewise, Chan and Mazzocco (2017) and Li and Baroody (2014) recently proposed primarily action-based (Picture) Matching tasks. In these tasks, children are requested to match visible sets (of pictures), including both numerical and non-numerical elements to focus on.

An important challenge for future studies on young children's SFON is to systematically analyse the psychometric characteristics of the different verbal and action-based tasks designed to capture young children's spontaneous attention for exact numerosity. These methodologically oriented studies will help to address the critical questions related to the need to triangulate different SFON tasks in view of a more reliable and valid assessment of SFON. These studies will also contribute to our conceptual understanding of SFON as a unitary or rather multidimensional construct (verbal SFON, action-based SFON), and, as such, challenge current theoretical models on the associations between SFON - as a unitary construct - and children's early numerical abilities. For instance, on the basis of the recent findings of Rathé et al. (2016b) and Sella et al. (2016), it might be assumed that young children's verbal SFON will mostly relate to their symbolic number skills whereas their action-based SFON may be primarily related to their non-symbolic number abilities. Focused longitudinal and intervention studies in both developed and developing countries and using different types of SFON and early number assessments will help to refine and optimize current theoretical models and inform early mathematics education practices worldwide.

Conclusion

The present study demonstrated - for the first time - that also in a developing country such as Ecuador young children's SFON uniquely contributes to their early numerical abilities. After control for domain-general cognitive and socio-demographic variables that are known to influence the development of early numerical competencies, Ecuadorian kindergartners' SFON was positively related to their early numerical abilities. This major finding points to the universal nature of the association between SFON and early numerical abilities that has been observed repeatedly in developed countries (Batchelor et al., 2015; Gray & Reeve, 2016; Hannula et al., 2010; Hannula-Sormunen et al., 2015; Rathé et al., 2016a). As the developmental mechanism underlying this association is currently ill-understood, it is a challenge for future research to scrutinize the complex interplay between young children's early numerical development, their domain-general cognitive competencies and their socio-demographic characteristics, particularly their home numeracy environment (LeFevre et al., 2009, 2010). A deepened understanding of these individual and contextual variables that contribute to young children's early numerical development will also be helpful to design effective interventions aiming at stimulating mathematical proficiency, in both developed and developing countries.

Footnote

¹ As described in Hannula-Sormunen (2015) and Rathé et al. (2016a), there are different types of SFON tasks. In addition to the Imitation task, researchers also apply (although to a far more limited extent) three other types of SFON tasks, namely (1) Model tasks, (2) Finding tasks, and (3) Picture Description tasks. We decided to use the Imitation task to assess children's SFON, as this is the most frequently used SFON task in developed countries and as this task was recently successfully applied in a previous study in Ecuadorian kindergartners (Bojorque et al., 2016).

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Table 1

Means (SDs, Ranges) and Correlations between the Variables

	<i>Mean</i>	<i>SD</i>	<i>Range</i>	1	2	3	4	5	6	7
1 - SFON	0.64	1.12	0-4	--						
2 - ENA	0*	1.18	-1.90-2.99	.38**	--					
3 - Age in months	62.41	3.74	54-72	.12**	.28**	--				
4 - SES	4.86	1.68	1-8	.09	.30**	.03	--			
5 - Non-verbal IQ	19.97	4.85	1-36	.18**	.40**	.20**	.15**	--		
6 - Verbal IQ	10.36	5.14	1-27	.05	.42**	.13**	.29**	.25**	--	
7 - WM	78.98	14.85	60-131	.23**	.47**	.15**	.18**	.24**	.25**	--

Note: IQ = intelligence, WM = working memory

* ENA was constructed as the mean of two standardized variables.

** $p < .01$

Table 2

Multilevel Model, with ENA Predicted on the basis of Children's Domain-General Cognitive and Background Characteristics and SFON

Predictor	<i>Beta</i>	<i>SE</i>	<i>Stand. beta</i>	<i>t</i>	<i>p</i>	<i>-2LL</i>
Intercept	-.39	.13		-2.98	<.01	959.33
Centred WM*	.02	<.01	.31	6.37	<.01	863.11
Centred Non-Verbal IQ*	.04	.01	.20	4.92	<.01	812.13
Centred Verbal IQ*	.04	.01	.22	5.29	<.01	781.67
SES	.05	.02	.09	2.19	.03	777.57
Centred Age*	.03	.01	.12	3.29	<.01	765.49
SFON	.19	.04	.22	5.51	<.01	736.50

Note: WM = working memory, IQ = intelligence

* These variables were centred using the grand mean centring method. As a consequence the intercept refers to the ENA score of someone with a mean value on these variables.