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A SYSTEMATIC REVIEW OF THE CONTRIBUTION OF SPONTANEOUS FOCUSING ON NUMEROSITY TO ENHANCE CHILDREN'S MATHEMATICAL DEVELOPMENT

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ABSTRACT

There is solid evidence that high score of spontaneous focusing on numerosity (SFON) have substantial contribution on children's mathematics development. Based on the literatures, around 2005 until 2010 most of the studies conducted about SFON in Finland. However a growing literature shows that the six years past the studies about SFON began to spread outside Finland, such as United State, Belgium, United Kingdom, Germany, China and Australia. This article aims at reviewing about implications of SFON within 12 years past with a twofold objective: (i) to describe how SFON related to children's mathematics skills; and (ii) to explain that SFON predict later mathematics achievement. The studies were identified through systematic search of electronic databases and analyzed accordingly. SFON as well as other early maths skills in the earliest years play a role in children's mathematics successes. Five database has been selected to conduct the search for target articles; (i) the Science Direct database offering access to social science, education and SFON journal articles; (ii) the Web of Science (WoS) service, indexing cross-disciplinary research in sciences, social sciences, arts and humanities; (iii) the Taylor and Francis Online with extraordinary information in SFON and numerosity; and (iv) the Springer LINK database covering education and language, mathematics and social science journals. Literature was collected from 46 articles of alleged journal from 2005 until 2019. Theme analysis was adopted to analysis the data. Based on 14 articles that has been reviewed, SFON skill greatly contribute to children mathematics skill and predict children later mathematics achievement. These results truly proving that SFON is a very important skill in early childhood math learning. In conclusion, SFON significantly effects and contribute to children learning in mathematics skill. In other words, children who want to be good in mathematics they should be expert in SFON. Therefore, all the preschool teachers in this country should pay more attention on learning SFON during the early education of young children.

Keywords: spontaneous focusing on numerosity (SFON), early mathematics, skills, children, later achievement, contribution

INTRODUCTION

When it comes to issues related to spontaneous focusing on numerosity (SFON), there may be relatively less common to hear. Understandingly, for those who are not in the field of mathematics education, this is something new for them. Any how it is not something that awkward when people from mathematics itself do not familiar about SFON. Although the study of SFON is not new and was started 12 years ago, but studies conducted against SFON is still somewhat lacking. This senario probably happen because they do not realize or know this SFON will impact on the development of mathematical skills. We often hear, people discussed about factors that influence mathematics skill development such as school space environment factor (Močinić, & Feresin, 2017), computer-assisted intervention in learning (Pramudya et al., 2019) and so on. However when it comes to SFON not everyone know detail about how this factors can be related to mathematics development. Therefore, this article discusses in detail about the contribution of SFON toward mathematics skill among young children.

Fisrt of all, understand what is SFON is one of important part in this article. SFON refers to a process of spontaneously (i.e., in a self-initiated way not prompted by others) focusing attention on the exact number of a set of items or incidents. According to Hannula and Lehtinen (2005), this attentional process is needed for triggering exact number recognition and using the recognized exact number in action because exact number recognition is not a totally automatic process that would take place every time a person faces something to enumerate (Trick & Pylyshyn, 1994). SFON tendency is considered an indicator of the amount of spontaneous practice in using exact enumeration a child gets in her or his natural surroundings (Hannula & Lehtinen, 2005).

Interestingly, the SFON has been hailed as one of the most important skills in early mathematics (Hannula-Somunen et al., 2015). Taking into account the previous studies, a large number of researchers have started to investigate SFON. Around the year 2005 until 2010, most of the studies on SFON carried out in Finland (Hannula, 2005; Hannula & Lehtinen, 2005; Hannula et al., 2005; Hannula et al., 2007). However, in the past three years, many studies about SFON conducted outside of Finland, including the UK (Batchelor, 2014; Batchelor et al., 2015), Ecuador (Bojorque et al., 2016), Belgium (Rathé et al., 2016), Germany (Poltz et al., 2014), China (Tian & Booth, 2015), USA (Edens & Potter, 2013; Tian & Siegler, 2016), Switzerland and Germany (Kucian et al., 2012), Australia (Gray & Reeve, 2016), Italy (Sella et al., 2015), and have thereby addressed several research themes. This is a very significant development that occurred in reseach about SFON. Research on SFON began to spread to the countries of the world.

If we look detail in each study, each researcher has different objectives and focuses. Some studies looked into additional theoretical questions on the development of SFON by examining spontaneous non-verbal counting in toddlers (Sella et al., 2015), the role of cognitive factors, such as symbolic fluency (Batchelor et al., 2015), or by focusing on the role of environmental factors, such as spontaneous activity choice during kindergarten play (Edens & Potter, 2013), the quality of early mathematics education (Bojorque et al., 2016), home numeracy experiences (Batchelor, 2014, Study 3), number-related utterances during numerical picture book reading

(Rathé et al., 2016), and cross-cultural influences (Tian & Booth, 2015). Strictly speaking, much progress has been made in the diversity of topics being investigated that make connection between SFON and mathematics.

Other studies addressed methodological issues by investigating the psychometric properties of the current SFON tasks and developing and testing new SFON tasks (Batchelor, 2014, Study 1; Batchelor et al., 2015). A final series of studies focused on the relation between SFON and mathematical difficulties, such as Developmental Dyscalculia (DD) (Kucian et al., 2012) and (low) math profiles (Gray & Reeve, 2016).

Most importantly, the rapid development studies regarding SFON has largely contributed to the development of early mathematics skills. Hence, the objective of this study is to discuss the contribution of SFON to math skills, SFON as predictors of later mathematics achievement and correlation between SFON and mathematics difficulties. More interesting, this study provides added value in math skills. in other words, SFON is a very important early skills in mastering mathematics.

METHODOLOGY

The most important keyword in the scope of this paper is "SFON". In this study the limits were set. SFON discussed only on the basis of its implications for the development of children's mathematical. Other matters related to the font will not be raised at all in this discussion.

Information Sources

Four database has been selected to conduct the search for target articles; (i) the Science Direct database offering access to social science, education and SFON journal articles; (ii) the Web of Science (WoS) service, indexing cross-disciplinary research in sciences, social sciences, arts and humanities; (iii) the Taylor and Francis Online with extraordinary information in SFON and numerosity; and (iv) the Springer LINK database covering education and language, mathematics and social science journals. The rationale behind this selection is to cover both SFON and mathematics literature, and provide a broader view of researchers' efforts in a wide, but relevant, range of disciplines.

Study Selections

In the selections of study two authors who performed the screening and then reviewed by one other authors. The process of study selection consisted of searching the literature sources, followed by two iterations of screening and filtering. The first iteration excluded the duplicates and irrelevant articles by scanning the titles and abstracts, while the second iteration filtered the articles after a thorough full- text reading of the screened articles from the first step.

Search

The search was initiated at the start of January 2019, in Science Direct, WoS, Taylor & Francis and Springer LINK databases via their search boxes. We used a mix of keywords that contained "SFON", "numerosity", "mathematics" and "early childhood" in different variations, combined by the "AND" operator. The exact query text is shown at the top of Figure 1. The article sought is the article published from 2005 until June 2019 only.

Data Collection Process

In order to simplify further steps, a full list of all included papers, with their corresponding initial categories was com- piled from the various sources into a single EXCEL® file. Several full-text readings were performed by two authors, and resulted in a large collection of highlights and comments on the surveyed works. All comments were saved on the body of the texts (depending on each author's preferred style, either on hard or soft copy versions).

This was followed by the process of summarization, tabulation and description of the main findings. Sets of relevant information were saved in WORD® and EXCEL® files, including the full list of articles, their respective source databases, summary and description tables, categorization tables based on medical specialties, purposes, review sources, target platforms and audiences, as well as various related figures.

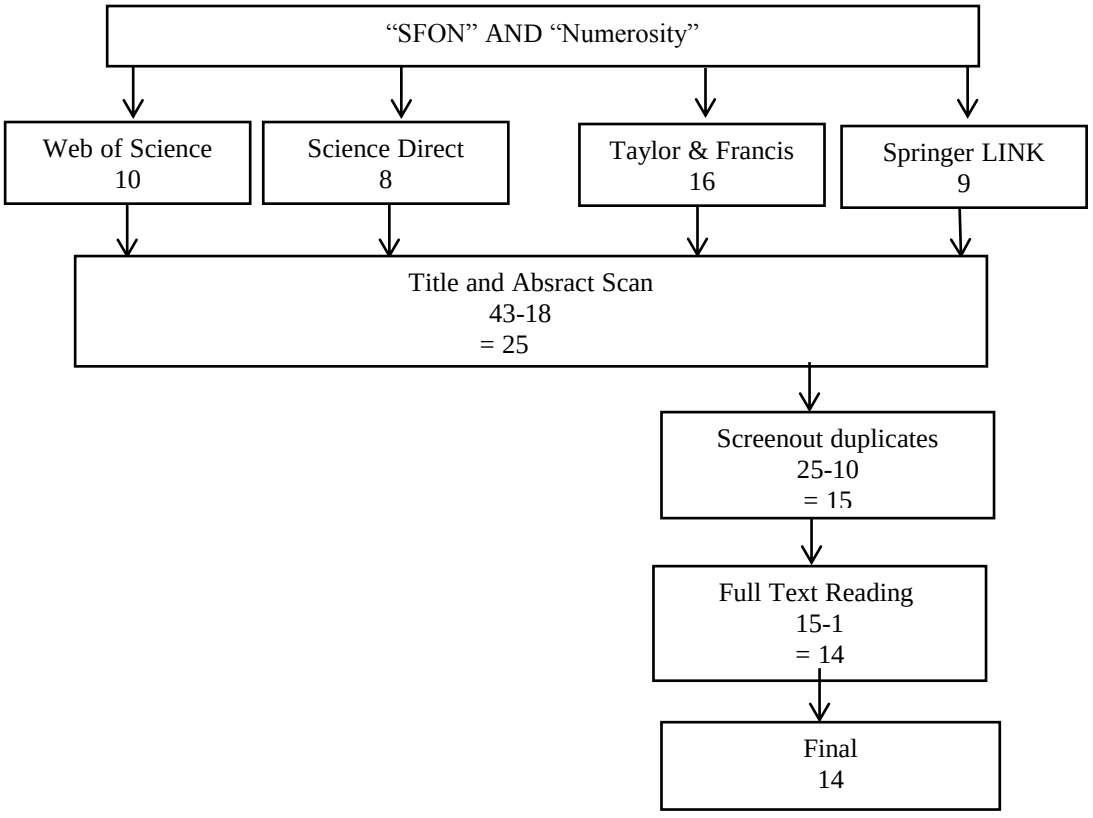

Figure 1. Flowchart of study selection, including the search query.

RESULTS AND DISCUSSIONS

The initial query search resulted in 43 articles: 8 from Science Direct database, 10 articles from WoS, 16 articles from Taylor and Francis, and 9 articles from Springer LINK over the span form 2005 to 2019. After scanning the titles and abstracts, 18 articles were excluded, resulting in 25 corresponding articles. Then, 10 articles were duplicates among the four library databases. Full-text reading excluded 1 article, leaving 14 articles in the final included set. Those papers were read thoroughly in the main purpose of finding out a general map for the conducted research on this emerging topic. Based on 14 articles has been read by two researchers, contribution of SFON can be viewed from two major aspects.

SFON Related To Children's Mathematics Skills

Six of the article revealed the unique contribution of SFON to the development of early mathematical skills (Hannula & Lehtinen, 2005; Hannula et al., 2007; Bactherlor et al., 2015; Edens & Potter, 2013; Bojorque et al., 2016; McMullen et al., 2019). These early mathematical skills involve counting skills, arithmetic, number sequence, subitizing-based enumeration and symbolic number processing skills. Using Pearson's correlation coefficien analysis, Hannula and Lehtinen (2005) have found that children's SFON tendency was positively associated with their mathematical skills, with number sequence elaboration, $r=0.42$, with counting of objects, $r=0.35$, and with basic arithmetic skills, $r=0.49$ (values of $p<0.01$). Whether this association was explained by non-verbal IQ or verbal comprehension was studied by partial correlations. Controlling non-verbal IQ, or comprehension of verbal instructions affected the association between SFON and mathematical skills only slightly. When the effects of non-verbal IQ and comprehension of verbal instructions were controlled, the partial correlations of SFON to object counting was $pr=0.26$, to number sequence elaboration $pr=0.27$, and to basic arithmetic skills $pr=0.37$ (values of $p<0.001$). Beside that, children with a strong, general, long-term tendency to focus on numerosity tended to enumerate by subitizing larger numbers of items, and had better counting skills at the age of 5 years. The result of mediation analyses showed that SFON was indirectly related to object counting skill through its association with subitizing-based enumeration.

On the contrary, the association between SFON and number sequence production was direct, and not affected by subitizing-based enumeration. These exploratory results further expand the earlier studies of Hannula and Lehtinen (2005) by suggesting that the size of the relations between SFON and different enumeration skills may depend on the extent to which the skills are dependent on understanding cardinal meanings of number words and the purpose of counting routines.

Beside that children who spontaneously focus on numerosity are advanced in their counting skills. Edens and Potter (2013) disclose that a correlation between SFON and counting skills very significant with $r = 0.71$ ($p<0.01$). Moreover, this study corroborating findings from Finland (Hannula & Lehtinen 2005). Contribution of SFON to early mathematics skills can also be seen in the symbolic skill. Children aged 4-5 years (N ¼ 130) completed a battery of tasks designed to assess SFON and a range of mathematical skills.

Results showed that SFON was positively associated with children's symbolic numerical processing skills and their performance on a standardized test of arithmetic. Hierarchical regression analyses demonstrated that the relationship between SFON and symbolic mathematics achievement can be explained, in part, by individual differences in children's non symbolic numerical processing skills and their ability to map between nonsymbolic and symbolic representations of number (Batchelor et al., 2015). Not only-but also, SFON tendency is positively related to the development of cardinality recognition, subitizing-based enumeration, object counting, and number sequence skills before school age (Batchelor et., 2015; Bojorque et al., 2016; Hannula et al., 2007).

Consequently, children's and students' tendencies to focus on number and quantitative relations–spontaneous or otherwise are key components of mathematical development and education (McMullen et al., 2019). In these studies McMullen et al. (2019) highly suggest a causal link between SFON tendency and early numerical skills, with SFON tendency having a positive impact on the development of early counting and enumeration skills.

SFON Predict Later Mathematics Achievement

Second major aspect of SFON's contribution is SFON as a predictor of later children's mathematic achievement. Similarly to SFON and mathematics skills, there also eight articles that associated with SFON and later mathematics achievement (Bojorque et al., 2016: Bojorque et al., 2018; Hannula et al., 2010; Hannula et al., 2015; Hannula-Sormunen, 2015; Hannula-Sormunen et al., 2015; McMullen et al., 2015; Nanu et al., 2018). The 2 year longitudinal study to children's individual differences in SFON in kindergarten show results that SFON tendency in kindergarten is a significant domain-specific predictor of arithmetical skills, but not reading skills, assessed at the end of Grade 2 (Hannula, et. al, 2010). It is strongly supported by the findings of Hannula-Sormunen et al. (2015). In the seven-year longitudinal study examined how children's SFON, subitizing based enumeration, and counting skills assessed at five or six years predict their school mathematics achievement at 12 years, Hannula-Sormunen and colleagues demonstrate that SFON and verbal counting skills before school age predict mathematical performance on a standardized test for typical school mathematics in Finnish children Grade 5. After controlling for nonverbal IQ, only SFON predict school mathematics. Moreover, they reported a reciprocal developmental relation between SFON and early numerical bilities, since SFON at the age of 4 predicted numerical abilities at the age of 6, and numerical abilities at the age of 3.5 years predicted SFON at 6 years (Hannula & Lehtinen, 2005).

In addition, McMullen et al. (2015) provided empirical support for the contribution of children's SFON to later mathematical achievement, as it was found that children's SFON tendency before school age is a strong predictor of later rational numbers conceptual knowledge, even after con- trolling for preschool number sequence skills. Even children's SFON was positively related to the development of numerical competencies up to the end of primary school (Hannula-Sormunen, 2015).

Furthermore, findings by Bojorque et al. (2016) that children's SFON development throughout the kindergarten year was positively related to their mastery

of early numerical abilities at the start of that year. When they conducted the other research (Bojorque et al., 2018) the result as close to the previous study findings. Even though results demonstrated limited SFON development during the kindergarten year, with large individual differences in and highly consistent SFON performances, children's SFON development during the kindergarten still predicted by their SFON tendency and early numerical abilities at the start. Equally important, the development of SFON children from the beginning of the year to the end of the school year is continuous and consistent. In line with previous studies in Finnish children (Hannula et al., 2010; Hannula–Sormunen, 2015; Hannula–Sormunen et al., 2015), we found that Ecuadorian children's SFON development at the end of the kindergarten year was predicted by their early numerical abilities at the start of the year.

In the same way, Nanu et al. (2018) in their study involving 74 5-year-olds participated in a 7 year follow-up study, in which they explored whether SFON measured with very small numerosities at 5 years of age predicts mathematical skills and knowledge, math motivation, and reading in fifth grade at 11 years of age. Results show that preschool SFON is a unique predictor of arithmetic fluency and number line estimation but not of rational number knowledge, mathematical achievement, math motivation, or reading. These results hold even after taking into account age, IQ, working memory, digit naming, and cardinality skills. Previous findings indicate that SFON measured across subitizing and counting ranges is a domain specific predictor of mathematical skills (Hannula-Sormunen et al., 2015). The current study extends these findings by determining that SFON measured solely with very small numbers predicts formal mathematical skills 7 years later, even after controlling for age, early counting skills, IQ, and verbal working memory. These results underline the importance of children's early mathematical experiences for the development of mathematical skills and support the conclusions of the domain specificity of the relation between SFON tendency and mathematical skills.

Outstandingly, the contribution of children's early numerical abilities to SFON development was stronger than the contribution of their initial SFON tendency. These results present additional support for the bidirectional relations between SFON and early numerical abilities (Hannula & Lehtinen 2005). The present findings generally replicate Hannula and colleagues' findings (Hannula & Lehtinen, 2005; Hannula et al., 2010; Hannula–Sormunen, 2015; Hannula–Sormunen et al., 2015) and provide the first empirical evidence on the mutual relation between the acquisition of SFON and early numerical abilities in Ecuadorian children.

CONCLUSIONS

In the past years, numerous international studies have related children's mathematical achievement to specific aspects of their early numerical competencies (e.g., De Smedt et al., 2009; Geary, 2011; Hannula et al., 2010; Hannula et al., 2007; Hannula–Sormunen, 2015; Hannula–Sormunen et al., 2015; Jordan et al., 2009; Mazzocco et al., 2011). Interestingly, SFON was demonstrated to contribute to both the development of children's early numerical abilities and their later school mathematical achievement (as briefly discussed above). As has been stated, six articles in this paper clearly shows that the SFON are related to children's mathematics skills and development. In this part, we highlight two important issues coming out from these study as an important

conclusion.

Firstly, SFON act as predictor in mathematics performance in future. Several empirical studies have shown that children who have a high score on SFON were predicted getting higher performance in mathematics. In other words, SFON and skills contribute to children's mathematics skill and achievement in the future. However, until 2016 there is no significant results shows that children who get low score on SFON their achievement in mathematics also lower. In other words children score lower in mathematics would have difficulties in mathematics later. Conversely, there is one research quiet related with this issue but in that research they used student with developmental dyscalculia (DD) as a sample (Kucian et al., 2012). Even some researchers believe that children with problem in learning such as dyscalculia the same as the term mathematics difficulties, but in this study it is two different things.

Secondly, child everyday situation or daily routine influence how children's self-initiated practice with mathematics skills. In this case we can say that enhancement of SFON can be carried out with a positive impact on the environment of children in kindergartens or nurseries.

As a conclusion SFON is one of the important skills that everyone have to master before that learn the formal mathematics in schools. Children as young as possible should be given a positive environment of the numbers so that they better in SFON. All these research has shed light on SFON as a key factor for explaining young children's early mathematical competencies. Besides, these skills in SFON were predictively related to mathematical performance during the first years of formal schooling and at the end of primary school.

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