NUMERICAL ACUITY ENHANCEMENT IN KINDERGARTEN: HOW MUCH DOES MATERIAL PRESENTATION FORM MEAN?

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ABSTRACT

The current study aimed at exploring the impact of the modality in which numerical trainings proposed in kindergarten school. Participants were recruited from some Sardinian kindergarten schools and were then divided into three groups: a control group, which had to carry out the activities planned by the educational curriculum, and two experimental groups, which were proposed a psychoeducational mathematical enhancement training via either hard copies or multimedia software, respectively. Regardless of the format in which the training was proposed, results showed that the psychoeducational mathematical training lead to improved learning regardless of the format in which the training was proposed. Its positive effects in terms of performance improvement in both the experimental groups. Moreover, as evidenced by a follow-up assessment conducted six months after the end of the enhancement activities, the effect of the mathematical training was maintained over time. In conclusion, the implementation of specific psychoeducational programs aimed at improving numerical mathematical knowledge seems to be a crucial resource to promote learning in pre-schoolers.

KEYWORDS

Early numeracy learning; Psychoeducational Training; Kindergarten schools; Cognitive Empowerment; Educational technology

1. INTRODUCTION

In kindergarten schools, the promotion of specific activities aimed at enhancing the development of mathematics is frequently neglected. In fact, priority is often given to empower preparatory skills favoring the development of reading and writing expertise, such as methafonological awareness (Melhuish et al. 2008). Thus, this is not taking into account the fact that in children's everyday life numbers are crucial everywhere and, that daily life experiences should drive learning of preschoolers (Lucangeli et al. 2012) .

Mathematics is a subject that students often dislike and dread enough to get to real difficulties in learning. Overall, succeeding in mathematics is influenced by emotional, motivational and metacognitive factors (Caponi et al. 2012). In particular, the impact of the emotional dimension on math-related tests is supported by numerous studies that confirm the relationship between anxiety and success in mathematics, that is, the more students are anxious when tested on numerical cognition, the more they are prone to perform poorly (Newstead 1998; Rubinsten & Tannock 2010). Therefore, it is necessary that the first structured interaction with the numbers' world occurs in kindergarten school by means of specific playful activities. These activities have the goal to promote different aspects of numeracy learning, such as what a number is, how to represent its quantitative characteristics, how to express judgements about size (e.g., five cars are more than three cars), how to process calculation, in short, how to learn to process numerical information without any fear (Lucangeli et al. 2012).

There are several theoretical models explaining how to develop the ability to process an information related with numbers. According to several researchers, the notion of number/quantity is innate (e.g., Butterworth 1999), whereas authors such as Piaget and Inhelder (1958) state that developmental factors play a crucial role in promoting the development of the cognitive operations underlying number processing.

Among these operations, we find the ability to compare, classify and understand one-to-one correspondence and seriation, which, in turn, are crucial to learn cardinality and ordinality, which, in turn are essential to understand number word sequences.

Further empirical evidence based on the habituation procedure demonstrates that even infants are capable of identifying sets of different quantities, discriminating between collections of one to three discrete objects (Loosbroek & Smitsman 1990). Similarly, using the violation of expectation paradigm, Starkey, Spelke and Gelman (Starkey et al. 2004) documented that that six -to eight-month old children detect numerical correspondences between either two- or three-object arrays presented in audial and visual modalities, suggesting that infants as young as 6 months possess sensitivity to numerosity.

Krajewski and Schneider (2009) refer to early numeracy as the ability to operate with number word sequences and enumerate combined with mathematical–logical thinking skills, which is the core of mathematics development in preschoolers. Moreover, further studies highlighted the importance of visuospatial abilities (e.g., visuospatial working memory) in promoting different academic achievements such as numeracy in preschoolers and older children (Agus et al. 2015; Dehaene et al. 1993; Rinaldi & Girelli 2012). For instance, Agus et al. (2015) documented the positive effect of combined visuo-spatial and numerical trainings to empower numeracy learning in primary school. However, for what concerns the importance of the development of numerical skills in preschoolers many studies point out that early numerical skills predict successive arithmetic achievements in primary school (Booth & Siegler 2008; Cerda et al. 2015; Navarro et al. 2012). Espy et al. (2004) stated that skills in basic calculation are the best predictor of success in mathematics achievement at school, that is, students with underdeveloped numerical acuity are more likely to fail in mathematics and to develop low self-efficacy and self-esteem. For this reason, it is important to screen early mathematics achievement at preschool age, in order to implement specific psychoeducational interventions promoting successful scholastic performance and psychological well-being at school. In this regard, Aunio, Heiskari, Van Luit & Vuorio (2014) claim that differences in mathematical skills can be detected in kindergarten-age children before formal primary education. Moreover, the authors pointed out that without a specific intervention, preschoolers lacking relational skills in a numerical context and counting abilities cannot be corrected later in primary school. Thus, the risk is that these preschoolers will remain low-performers in mathematics and despite their effort; they cannot reach the performance level of their peers. Further empirical evidence confirms that children with low numerical knowledge in primary school can learn how to process numerical information slowly (Desoete et al. 2012; Missall et al. 2012), that is, they need longer time to develop mathematics skills and to learn the procedures driving number processing (Morgan et al. 2009).

In this perspective, Aubrey, Godfrey and Dahl (2006) point out the importance to implement early psychoeducational interventions aimed at enhancing numeracy learning in preschoolers at risk or with evident mathematical learning problems. In this regard, there is also ample (compelling) evidence of the benefits of the implementation of psychoeducational interventions in kindergarten school for children with and without atypical developmental characteristics (Magnuson et al. 2004; Sammons et al. 2004; Melhuish et al. 2008).

Distinguishing learning difficulties and specific learning disorders not easy (Tucci & Tressoldi, 2009). In order to discriminate a general difficulty due to a delay in terms of educational knowledge or to a real learning specific disorder, it is necessary identifying and separating the characteristics that can be traced back to a deficit and / or compromised profile from those which involve a simple and temporary slowdown in learning (Cornoldi 2007). Following the definition given by DSM V (American Psychiatric Association 2013) the diagnosis of a specific learning disorder requires the presence of persistent difficulties in reading, writing, arithmetic, or mathematical reasoning skills during formal years of schooling. Among symptoms are present in an inaccurate or slow way: effortful reading, poor written expression that lacks clarity, difficulties remembering number facts, or inaccurate mathematical reasoning. However, the diagnosis of specific learning disabilities such as dyscalculia can be conducted only in primary school age, after the end of the second grade. Nonetheless, as highlighted earlier, early interventions in kindergarten school are possible through specific and ad-hoc enhancements with the aim to strength crucial bases critical to the successive mathematics achievements.

Stressing the fact that the numeracy learning is a complex construct defined by different abilities, such as classification, comparisons among sets of stimuli to express quantity judgments, there is evidence that children benefit of different psychoeducational trainings aimed at empowering writing of numbers, calculation, representation of quantity, recognition of numbers (Molin et al. 2007; Wilson & Räsänen 2008;

Riccomini & Smith 2011). Such trainings may have specific connotations and effectiveness in terms of educational achievements and their efficacy depends on different factors related to the characteristics of the students involved (e.g., age, presence of deficit in academic achievement, learning style), the nature of the materials used, the form in which they are presented (e.g., computer-assisted versus pencil-and-paper) and social policy initiatives. Overall, according to Dehaene (2011) in order to be effective, a psychoeducational intervention aimed at enhancing numeracy learning must include activities promoting the sense of the number, which refers to the ability to quickly understand, estimate and manipulate numeric formats.; This is an essential feature of mathematical cognition and it is the crucial essence of several pre-school interventions (Malofeeva 2005).

With this background in mind, the aim of our study is to investigate the effect of presentation mode of a psychoeducational training for the development of numerical skills in kindergarten, proposing to children five years of activities presented in the paper - pencil mode, respectively, or by the use of computers. Specifically, we wanted to evaluate the effect of the above presentation of the training psychoeducational of numerical skills in relation to lexical area, pre-syntactic, semantic and counting, as well as in relation to intelligence fluid student.

The aim of our study is to test whether the implementation of psychoeducational training for the development of numerical skills in kindergarten provides an advantage for the pre-school students, who will possess more efficient numerical skills (not limited to math) that will be useful for the next steps in their education.

2. METHOD

2.1 Participants

Fifty-eight Italian children (mean age=64.5 months, ds=3.7), attending the last year of kindergarten in some small towns in the province of Nuoro and Cagliari (Sardinia), took part in the study after their parents had provided written informed consent for participation. The sample (f = 46.4 %) comprised typically developing children, showing no signs of cognitive or perceptual deficits. The research have a non-probability sampling and was conducted on the base of the ethical requests defined by the Italian Association for Psychology, thanks to the obtainment of the families' authorizations and consent forms. Children were divided into two experimental groups, who have made the same training to upgrade the numerical skills, one in paper - and - pencil mode (G1 n = 26), the other in the computerized version (G2 n = 19). Additional 13 participants in the research were included in the control group (G3). At the end of the project 50 participants out of 58 have completed all the surveys (pre training, post-training and follow-up).

2.2 Materials and Procedure

In order to have respectively a measure of fluid intelligence and of their numerical acuity, pre-schoolers were presented a standardized battery, constituted by the Raven's Colored Progressive Matrices (CPM, Raven 1958) and by the BIN (Numerical Intelligence Scale; Molin et al. 2007).

The CPM (Raven, 1958) can be used also for children in kindergarten (Italian adaptation, (Belacchi et al. 2008), tests, in their colored form, are easy to administer and easy to interpret in a clear way.

The BIN (Molin, Poli, & Lucangeli 2007) is composed of four subscales created in order to measure number and arithmetic knowledge. The four subscales are lexical, semantic, pre-syntactical and counting (Mascia et al. 2015), all these subscales have good psychometric characteristics with high test-retest reliability (Semantic subscale: r=.69; Lexical subscale r=.89; Pre-syntactic subscale: r=.79; Counting subscale: r=.74) (Sella et al. 2016).

The training program used was "L'intelligenza numerica I" (Lucangeli et al. 2003) and 'Sviluppare l'intelligenza numerica I" (Lucangeli et al. 2010) in pencil-and-paper format.

These programs are applied for typically developing children; the activities are presented like a game and range among many areas. They aim to improve the cognitive abilities related with numerical skills: counting, mental calculation, semantic processing, pre-syntactic processing, and lexical processing. The two programs present the same activities but in different format (pencil-and-paper and multimedial software). The programs contained many different modalities to support numerical achievement. For example, the promotion of counting from one to ten were supported with the use of a rhyme, moreover using the fingers and objects to help the achievements; similar activities are carried out by the software. Programs were created to allow to children to internalize calculation procedures in order to shift from physically to mentally actions in the numerical knowledge and its application. The trained educators administer both programs.

The children (n=26) were assigned to the first experimental group (G1) to perform activities in pencil-and-paper format; the other (n=19) composed the second experimental group who follow the same activities in the computerized format. Children in the control group (CG) carried out the regular curricular activities. Children were tested individually in two sessions (each sessions of twenty minutes) at pre-test (T1), post-test (T2) and follow up (T3). Each test was presented following the instructions contained in the original manuals (Belacchi et al., 2008; Molin, Poli, & Lucangeli, 2007). After the pre-test phase, children were randomly extracted from the original sample and matched for chronological age, after were presented the training activities in pencil-and-paper format (G1), in computerized format (G2) and in the control group (G3) that carried out the regular curricular activities proposed by their teachers. After 6 months from the post-test phase, a follow-up valuation was administered in the three groups (G1, G2 e G3).

3. RESULTS

In order to examine the development of skills in the course of the activities we were compared to the results achieved in the three time points (T1,T2 and T3) by calculating the linear correlation coefficient "r" of Pearson and later with the evaluation of differences between the averages with a Multivariate Mixed design Analysis of Covariance. Preliminary bivariate correlations (Table 1) were evaluated, these data confirm the presence of significant direct linear relationship between the size surveyed in the three time points, as shown in the literature (Molin et al. 2007; Mascia et al. 2015).

Table 1. Bivariate "r" Pearson Correlation

	Variable	1.	2.	3.	4.	5.	6.	7.	8.
1.	T1 LEXICAL AREA	1							
2.	T1 SEMANTIC	.506**	1						
3.	T1 COUNTING	.641**	.560**	1					
4.	T1 PRE-SYNCTACTICAL	.511**	.632**	.577**	1				
5.	T1 CPM	.200*	.335**	.248**	.360**	1			
6.	T2 LEXICAL AREA	.656**	.461**	.465**	.449**	.185*	1		
7.	T2 SEMANTIC	.453**	.559**	.474**	.597**	.349**	.607**	1	
8.	T2 COUNTING	.487**	.436**	.618**	.394**	.281**	.510**	.486**	1
9.	T2 PRE-SYNCTACTICAL	.517**	.570**	.503**	.718**	.367**	.579**	.734**	.506**
10.	T2 CPM	.356**	.372**	.332**	.417**	.495**	.335**	.424**	.338**
11.	T3 LEXICAL AREA	.498**	.382**	.450**	.391**	.221*	.565**	.450**	.373**
12.	T3 SEMANTIC	.419**	.412**	.438**	.433**	.291**	.484**	.569**	.474**
13.	T3 COUNTING	.549**	.349**	.609**	.412**	.230*	.616**	.507**	.706**
14.	T3 PRE-SYNCTACTICAL	.401**	.359**	.521**	.520**	.159	.408**	.527**	.490**
15.	T3 CPM	.299**	.271**	.197*	.379**	.427**	.189*	.296**	.211*
	Variable	**8.**	**9.**	**10.**	**11.**	**12.**	**13.**	**14.**	
9.	T2 PRE-SYNCTACTICAL	1							
10.	T2 CPM	.471**	1						
11.	T3 LEXICAL AREA	.525**	.342**	1					
12.	T3 SEMANTIC	.516**	.461**	.516**	1				
13.	T3 COUNTING	.554**	.386**	.605**	.591**	1			
14.	T3 PRE-SYNCTACTICAL	.587**	.384**	.427**	.490**	.566**	1		
15.	T3 CPM	.372**	.387**	.323**	.399**	.346**	.398*	1	

** p<.01; * p<.05

It was subsequently applied an Analysis of Multivariate Covariance in order to verify that the groups did not differ in the pre -training survey (T1) in relation to the investigated dimensions. This analysis confirmed the absence of statistically significant differences between groups [Wilks' Lambda =. 799; $F_{(10;102)}$=1.210; p=.293].

In order to assess any changes in participants' skills during the implementation of the upgrading course, it was applied the Multivariate Analysis of Covariance with mixed design, in which as a factor among subjects is considered the group (G1, G2 , G3) and as within-subjects factor the time of the valuation (T1 , T2, T3). The covariate is the age of participants in the pre - test in months, as dependent variables repeated measures relating to the scales of the BIN and CPM. These analyzes showed a significant interaction effect between *group*valuation time* [Wilks' Lambda =. 374; $F_{(4;43)}$=17.986; p=.0001; $p\eta^2$ = .626]. Statistically significant differences in relation to the dimensions have been highlighted with the Post hoc comparisons (Fisher's Least Significant Difference); they are briefly indicated in Tab. 2.

Table 2. Principal results obtained with Analysis of Covariance with mixed design (Post Hoc Comparison LSD)

Group	Dimension	Relevation		Relevation	Mean differences (Standard error)
Training in pencil and paper format	LEXICAL AREA	T2	>	T1	12.796 (4.303)**
	COUNTING	T2	>	T1	20.174 (5.050)**
	COUNTING	T3	>	T1	20.653 (5.858)**
	PRE-SYNTACTICAL	T2	>	T1	22.817 (3.948)**
	PRE-SYNTACTICAL	T3	>	T1	18.618 (5.655)**
	CPM	T3	>	T1	17.895 (6.318)**
Training in computerized form	LEXICAL AREA	T2	>	T1	10.795 (5.025)*
	SEMANTIC	T3	>	T1	18.180 (6.905)**
	SEMANTIC	T2	>	T1	12.678 (5.275)*
	COUNTING	T3	>	T2	17.477 (5.817)**
	PRE-SYNTACTICAL	T2	>	T1	20.969 (4.611)**
	PRE-SYNTACTICAL	T3	>	T1	24.941 (6.604)**
	CPM	T3	>	T1	20.488 (7.378)**
Control group	SEMANTIC	T2	>	T1	16.018 (6.778)*
	PRE-SYNTACTICAL	T3	>	T1	20.878 (8.486)*
	PRE-SYNTACTICAL	T3	>	T2	17.504 (7.804)*

Table 2 highlights the significance of the differences between the average size of the investigated specifically in relation to the presented training both in print mode and in CD mode room, in relation to the three time points (T1, T2 and T3). Specifically, the area of the Pre syntax appears significantly greater at T3 in all experimental groups , but in specific the G1 appeared to have better performance specifically in the area of the Count , while the G2 specifically in semantics .

In any case, both modes of the training presentation appear to be effective in enhancing the numerical skills of pre-school age, which also maintain the follow-up survey.

4. DISCUSSION AND CONCLUSIONS

A wide literature stresses the importance of the effects and the effectiveness of psychoeducational trainings developed to improve working memory and early numeracy in kindergarteners (Kroesbergen et al. 2014). There is also evidence suggesting that trainings efficacy depends also upon the modality in which they are presented (Slavin 2013). However, a few studies are focused on the investigation of the long-term effects of the psychoeducational interventions promoting the development of the numeracy in preschoolers, as well as not so many training programs are addressed to children with typical and atypical development trajectories.

The current study was mainly aimed at exploring the impact of the presentation modality of a psychoeducational training promoting the empowerment of mathematics skills in children attending the kindergarten school. Furthermore, we were interested in investigating the possible long-term effect of the intervention.

Overall, compared with previous studies (Afshari et al. 2009; Jordan et al. 2007; Krajewski & Schneider 2009; Lefevre et al. 2010; Hasselhorn 2013), current findings seem to be very interesting.

As it was already documented in literature (Krajewski & Schneider 2009), the development of working memory capacity and the speed of access to long-term memory are precursors of a successful improvement of mathematics achievements in primary school too. In agreement with this trend of research and consistently with the study conducted by Mascia et al. (2015), current findings suggest that the positive impact of the proposed numeracy training is maintained even a few months after its conclusion, that is, when both control and experimental groups were only involved in the conduction of the curricular activities. Specifically, at follow-up step (i.e., T3) pre syntactical numeracy skills (i.e., appraising the ability to link numbers to their number representation and to order several quantities) were significantly greater in both the experimental groups (G1 e G2) than in the control one. This also suggests that in agreement with previous studies (Penna et al. 2002; Agus et al. 2015; Mascia et al. 2016). Overall, the variation of training presentation form (i.e., pencil-and-paper versus computer-assisted modality) did not impact the development of numeracy skills in preschoolers. Nonetheless, two exceptions deserve to be pointed out. First, at follow-up, compared to the other experimental and control groups, children who attended the pencil and paper training (G1) exhibited better counting performance (i.e., the ability to recite the number–words sequence forward and backward, as well as the knowledge of the order of Arabic digits from 1 to 5). Second, at follow-up, the experimental group exposed to the computer-assisted training showed better semantic knowledge about number (i.e., the ability to associate numerical sizes, dots and Arabic digits). This last finding suggests us to point out that if from the one hand technology tools allow to present a set of activities in an interactive way promoting the motivation in the pupils, that in turn learn, explore and then process new stimuli in a very active and joyful way (Vanderlinde et al. 2014); from the other hand the attainment benefits of technology-based interventions are currently limited and contradictory (Sandford et al. 2006).

Although National Council of Teachers of Mathematics of the USA some years ago stated that technology is essential in teaching and learning mathematics (Moeller et al. 2015), to our knowledge, so far a few studies have evaluated the use of technology-based numeracy trainings in supporting mathematics development in early childhood (Nutta 2013), but some literature shows that trainings based on technology supports have a great importance in the development of many different kinds of learning abilities (Meneses et al. 2012). As regards the empowerment of numerical and mathematical abilities using technology, a research showed that students who resolved the problems in the context of a computer story treatment had a considerable higher achievement than students who solved the problems in the context of a paper story and isolated word problems treatments (Gunbas 2015). Thus, the development of computer-based interventions seems to represent an excellent choice to promote the enrichment of specific cognitive skills underpinning scholastic achievements (e.g., counting, reading) in a playful fashion, where children learn while they interact with some avatars presented on the computer screen.

Most literature focuses the attention on the number line trainings, starting from the beneficial effect of paper–pencil tools on children's numerical development and their mathematics achievement (Klein et al. 2013; Moeller et al. 2015).

However, according to Pitchford (2015) technology can effectively promote the empowerment of mathematical skills in preschoolers if the software is carefully designed to actively engage the child in the learning processes and if the presented contents are developed consistently with the curriculum activities, which, in turn, must take in account the cognitive developmental stage reached by the user.

This fact sometimes can be due to limitations in its design and content (Yelland & Kilderry 2010) we can state, the in this case both modalities used as complementary to the curricular teacher activities are shown good results in numerical acuity enhancement in kindergarten.

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