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Comparing the effects of combined numerical and visuo-spatial psychoeducational trainings conducted by curricular teachers and external trainers. Preliminary evidence across kindergarteners.

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Abstract. The aim of this study was to verify the efficacy of two pencil-and-paper trainings empowering numerical and visuo-spatial abilities in Italian five-year-old kindergarteners. Specifically, the trainings were respectively carried out by the curricular teacher or by an external trainer. The former received a specific training in order to use the psychoeducational programmes with her pupils, whereas the latter received a specific education about the role of numerical and visuo-spatial abilities for school achievement and she was also trained to use psychoeducational trainings in kindergarten schools. At pre-test and post-test nonverbal functions and numeracy knowledge were assessed through a battery of standardized tests. The results show that both the numerical psychoeducational programme and the visuo-spatial one are useful tools to enhance mathematical achievements in kindergarteners. However, when the trainings were proposed by the external trainer, the efficacy of the psychoeducational programmes was more significant. These outcomes seem to be related both to the expertise and the novelty effect of the external trainer on the classroom.

1. Introduction

The measurement is a complex activity in which the researcher try to acquire specific and detailed information on the world, in order to describe the nature of the relationships among concepts and proprieties [1]. In the educational and psychological fields, the application of measurement presents a series of difficulties, related to different dimensions, such as the nature of the attributes, the theoretical and abstracted features of the cognitive processes underlying human behaviour in life span [2]. Indeed, the measurement of knowledge, skills and abilities (KSAs) [2] in human cognition is related to a social construction of the inquired concepts, which can be assessed indirectly [3]. Therefore, the evaluation of the KSAs is related to the measurement of “soft” systems [1,4], that is, a complex set of domains in human cognition directly involved in different aspects of behaviour [5]. Thus, from a theoretical perspective, in order to support the measurement, it is useful to assess each construct using many indicators, considering the multi-faceted dimensions of each behaviour and applying appropriate and validated instruments [6]. It follows that the measurement needs to be characterised by *objectivity* and *intersubjectivity* [7], in order to support the application of a functional concept of the Measurement



System [8]. Embracing this approach, objectivity is crucial in order to meaningfully discriminate conceptual entities that eventually share some properties through the application of universal procedures measuring a particular variable [9]. Moreover, intersubjectivity implies that within each measurement system, all the measurements about some psychosocial aspect “are comparable with each other” [10, p. 3773]. Overall, the abovementioned aspects tied to the measurement system require an agreement among the scientists in relation to the psychological concepts measured [2]. Therefore, the application of validated instruments of measurement allow us to acquire a specific knowledge about the world through the experience (i.e., Empiricist approach to measurement [2,11]), the demonstration that useful theories are linked with practice (i.e., Pragmatic approach to measurement [2,12]) and finally thought the intuition that scientific research is devoted “to gain knowledge about a natural world” (i.e., Realism to the measurement [e.g. 2, p.8]).

Applying the abovementioned theoretical assumptions in the psychoeducational field, the current study points out how complex the measurement of several aspects of numerical knowledge in pre-schoolers can be. That is, embracing a *representational viewpoint* [7,14], the measurement of numeracy learning in kindergarteners can be thought like an homomorphism between the “empirical relational structures” [7] and a “symbolic relational structure” [7, p.71].

There is evidence that mathematics learning is made up of a number of components, such as basic knowledge of numbers, memory for arithmetical facts, understanding of mathematical concepts, and the ability to follow procedures [15]. Concerning this, several studies show that math performance has high stability and the development of numeracy skills among children is predicted by counting ability [16]. A further body of psychological research has identified the cognitive processes (e.g., counting ability, visual attention, metacognitive knowledge, and listening comprehension) underpinning the development of numerical knowledge in early childhood [17]. Specifically, there is evidence of a strong relationship between mathematical achievements and the development of visuo-spatial working memory abilities in life span [18,19], that is, since early childhood children learn to represent and manipulate visual (e.g., shapes) and spatial (i.e., locations) information in order to perform geometry and math (e.g., comparing quantities) tasks [20]. Overall, this suggests that the conduction of specific trainings empowering non-verbal mnestic processes since early childhood [21] can play a fundamental role in order to promote the empowerment of numeracy skills. Indeed, a body of studies carried out in educational settings underlines the importance to train visuo-spatial working memory processes through targeted interventions and specific teaching strategies, in order to support the development of numerical abilities both in typically and atypically developing children [22]. In this regard, a long research tradition concerning the measurement of mathematics learning in pre-schoolers [23,24] as a function of the measurement of psychoeducational trainings efficacy suggests that the effect size of the trainings enhancing numerical skills since the early childhood highlights the practical significance of the outcomes in terms of improvements of specific aspects of mathematics achievements (e.g., mental calculation, counting sequences, quantity comparisons) [25]. Concerning this, there is evidence that the effectiveness of the psychoeducational intervention in primary school depends also upon the expertise and competences showed by the teacher [26], such as her/his knowledge about the curriculum contents, the strategies selected to promote numeracy learning and therefore the way in which educational goals are presented to the pupils [27].

Some experimental evidence suggests that since the age of three the adoption of the investigative approach seems to facilitate math achievement. Besides, a further crucial factor impacting school achievements is the level of novelty of the stimuli to be learned, because the originality of the material can drive and then enhance motivation, attention and attainment of the students both when the curricular activities and specific psychoeducational programs are conducted in the classroom [28–30].

However, to our knowledge, no studies have been conducted in order to investigate whether a specific expertise of the trainer about the relationship between visuo-spatial abilities and the development of numeracy can influence mathematical learning in preschoolers.

2. Aims and method

This work was aimed at exploring: 1) the effect of a combined visuo-spatial and numerical psychoeducational training on the development of math skills in pre-schoolers; 2) whether the expertise of the trainer about the contribute of visuo-spatial skills in promoting numeracy development can impact the empowerment of math skills in kindergarten children.

Therefore, for the aims of the study, the curricular teacher received a specific training about the administration of the mathematical psychoeducational program, but she was not specifically trained about the role of visuo-spatial functions for the development of numeracy skills. In contrast, an external trainer received a specific education on the relationship between mathematics and non-verbal abilities for math achievements in pre-schoolers as well as she was trained to use a psychoeducational programme empowering numeracy in preschool children.

Thus, it was hypothesised that: 1) children trained with a combined numerical and visuo-spatial programme would have outperformed children carrying out only the curricular activities (i.e., control group); 2) after a number of training sessions (i.e., post-test), children trained by the external trainer would have shown better math skills than children trained by their curricular teacher [27,31,32].

Before the training (i.e., at pre-test) and after that (i.e., at post-test), pre-schoolers were collectively administrated a battery of tests assessing their numerical and visuo-spatial abilities.

2.1. Participants, tools and procedure

After the parents provided written consent, seventy-two 5-year-old children were recruited in two kindergarten schools located in Sardinia (Italy). The participants (56.9% male) were divided into two experimental groups, which were trained by a combined mathematical and visuo-spatial programme by the curricular teacher (G1, $n=27$) or by an external trainer (G2, $n=23$). Moreover, there was a further group (G3, $n=22$) that carried out only the curricular activities. Both the trainers and children took voluntarily part in the study (i.e., non-probabilistic sampling).

At pre and post-test, the participants individually completed a battery of standardised tests. The Battery for Numerical Intelligence (BIN) [33] measuring different facets of mathematical abilities in children, related to cognitive and metacognitive aspects. Specifically, this tool assesses four dimensions of numerical skills: the lexical numeric knowledge (i.e., evaluating the skill to read and write Arabic numbers); the semantic numeric knowledge (i.e., appraising the ability to associate numerical sizes, dots and Arabic digits); the pre-syntactical numeric knowledge (i.e., considering the competency to link numbers to their number representation); counting skill (i.e., assessing the ability to recite the number-words sequence forward and backward). Each subscale revealed worthy psychometric characteristics, showing high test-retest reliability (lexical: $r=.89$; semantic: $r=.69$; pre-syntactic: $r=.79$; counting: $r=.74$). The evaluation of these multiple scales, related to different aspects of numerical abilities, supports a deeper measurement of the potential differences among the groups. The Coloured Progressive Matrices (CPM) [34] evaluated the fluid intelligence and the visuo-spatial abilities, which are strongly related to the development of numerical abilities. The child is asked to point out across a series of alternatives, the item necessary to complete 36 visuo-spatial patterns, that is, he/she has to relies on his/her imagery abilities in order to solve each visuo-spatial problem. The battery of tests was selected because of the specific homomorphism between the presented problems and the numeracy and visuo-spatial skills. Each individual session lasted about 40 minutes.

After pre-test, both the experimental groups were collectively presented the pencil-and-paper numerical training “L'intelligenza numerica I” developed by Lucangeli et al. [35] and the visuo-spatial

psycho-educational training “Conosco le forme” by Lucangeli et al. [36], for 10 weekly sessions lasting thirty minutes each. Both the psychoeducational programmes were developed in order to enrich counting, semantic, lexical, and syntactic numeracy skills and non-verbal functions, respectively. Moreover, the abovementioned training were developed to enrich the metacognitive processes underpinning the math and nonverbal tasks [27].

3. Results

The descriptive statistics for the scales of BIN and CPM [33,34] were observed. Then the linear correlation (Pearson's r) was computed between the dimensions investigated before and after the training. As expected, at pre-test and post-test positive linear correlations between visuo-spatial and mathematical abilities were detected. A Manova with mixed design on the scores of the BIN and CPM with the ‘*training group*’ as the between factor, the ‘*scale*’ and the ‘*time*’ as within factors. The multivariate tests were significant for the ‘*time*’ (Wilks’ lambda $_{[1;54]} = .651$, $p=.0001$), for the ‘*scales*’ (Wilks’ lambda $_{[4; 51]} = .487$, $p=.0001$), for the interaction between ‘*time*’ * ‘*training group*’ (Wilks’ lambda $_{[2; 54]} = .686$, $p=.0001$), between ‘*scale*’ * ‘*training group*’ (Wilks’ lambda $_{[8; 102]} = .700$, $p=.017$) was applied. Then by the application of the Bonferroni Post Hoc Procedure, significant differences between the groups at the post-test were detected (Table 1 summarises these main results).

Table 1. Main results of the Bonferroni Post Hoc Procedure

group		group	Dependent variable
G1	>	G3	General mean at post-test
G1	>	G3	Counting scale at post-test
G2	>	G3	General mean at post-test
G2	>	G3	Lexical scale at post-test
			Semantic scale at post-test
			Counting scale at post-test
			Pre syntax scale at post test
G2	>	G1	CPM at post test
G2	>	G3	CPM at post test

Legend : G1 combined training administered by the curricular teacher; G2 combined training administered by the external trainer; G3 control group

4. Discussion

Applying the concepts of *objectivity* and *intersubjectivity* in the measurement [7], this study attempted to overcome the disagreement among scientists about the measurement methods, typical of the *soft systems* [5,14]. The selected instruments referred to accurate explanatory theories shared among scientists [14,33,37], on which there is the agreement in the educational field [19]. The combination of all these aspects support us in the challenge to apply a “theoretical control over the reproduction of the measured construct” [19, p.54].

Considering the above-mentioned aspects, we believe that the current investigation highlights at least two very relevant outcomes. First, the use of psychoeducational trainings developed by Lucangeli and coll. [35,36,38,39] are effective to enrich mathematical and non-verbal skills promoting the development of numeracy in pre-schoolers. Indeed, compared to the control groups, at post-test both the experimental groups showed better numeracy and visuo-spatial skills, as well as a greater metacognitive competence in carrying out math and non-verbal tasks. Therefore, overall these outcomes support the hypothesis concerning the role played by visuo-spatial processes for the development of numeracy in

pre-schoolers [19,40]. Second, the expertise of the trainer seems to play a crucial role in favouring mathematic learning in kindergartners. That is, children trained by an external trainer showing a specific knowledge about the role played by visuo-spatial abilities in promoting math learning outperformed pre-schoolers trained by their curricular teacher [28,41]. Although current findings highlight the relevance of adequate educational materials and the competence of the trainer for the promotion of numeracy learning in kindergarten children, future research has to clarify the long-term effects of the interventions aimed at promoting the development of math skills in pre-schoolers, through measurements conducted at follow-ups.

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