



# The contribution of attentional processes to calculation skills in second and third grade in a typically developing sample

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## Abstract

Attention is an important, multifaceted cognitive domain that includes many key cognitive processes involved in learning. This study aimed to identify the predictive links between different components of attentional skills and core calculation skills development, using two standardized measures assessing calculation (AC-MT 6–11) and attention skills (CAS) in a sample of 143 typically developing children of age range from 7.6 years to 9.4 years. The results showed that in 2nd grade, selective visuo-spatial attention emerged as an important predictor in the written calculation task, while the ability to inhibit distracting information seemed to better predict accuracy in oral calculation. In 3rd grade, visuo-spatial components of attention emerged as no longer predictive, whereas planning and active visuo-spatial attention abilities emerged as predictive of accuracy in the oral calculation task. These results confirm previous findings about the contribution that attentional skills may have in calculation skills development, supporting evidence for progressive automation attentional components over time.

**Keywords** Attention · Cognitive processes · Calculation skills development · Primary school

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## Introduction

Attention is an important, multifaceted cognitive domain that includes many key cognitive processes involved in learning (Jaekel et al. 2013). Indeed, a number of studies that investigated the influence of attention on academic achievement outlined how being efficient in controlling and sustaining attention may be predictive of better academic achievement and with being proficiently engaged in learning activities later on in development (Alexander et al. 1994; Duncan et al. 2007; Scerif 2010). In particular, with reference to the acquisition of basic learning skills such as calculation, studies have confirmed the role of attention (Commodari and Di Blasi 2014), and as a counterpart, impairments in attention in young children have been associated with difficulties in consolidating learning skills (Mayes and Calhoun 2006; Vellutino et al. 2004). Attentional skills and the ability to master them have long-lasting development from infancy to adolescence (Wetzel 2014). Attentional efficiency improves throughout a continuum (e.g., Suades-González et al. 2017), and different attentional components emerge from the first years of primary school to about 9 years of age when they reach a more stable factorial structure (Best and Miller 2010). Such a developmental trajectory has also been documented in children with attentional disorders (Polderman et al. 2007). Nevertheless, a large part of the existing literature in this domain is mostly focused on non-typical populations (Barkley et al. 1990; Fergusson et al. 1997) and learning disabilities (Commodari 2012; Johnson et al. 1999). This specific focus of the literature also extends to studies that investigate the existing relationship between attention and learning how to calculate, which are again mostly focused on non-typical populations (Berninger et al. 2017; Re and Cornoldi 2010), while only a few studies examine these process developmental interrelations in a more typical sample (e.g., Commodari and Di Blasi 2014).

### Attention skills related processes

Attention is a complex function strongly implied in supporting learning processes. Attention processes are, in fact, greatly involved in controlling and regulating cognitive resources and efforts in a daily life context particularly stimulating, such as school (e.g., Checa and Rueda 2011). Attentional skills and the ability to master them have prolonged development from infancy to adolescence (Wetzel 2014). Attentional efficiency, as mentioned, improves over time, throughout a continuum (e.g., Suades-González et al. 2017), and the same developmental trajectory has been documented in children with attentional disorders (Polderman et al. 2007). In this perspective, a number of studies have investigated the role of attention in the acquisition of basic scholastic skills, in primary school children (LaBerge 1990; Muter et al. 2004; Vellutino et al. 2004). In this regard, there is a general agreement that attention is a multi-component function consisting of different processes, distinguishable at the functional and anatomical levels (Mirsky et al. 1991; Posner and Fan 2008). Naglieri and Das (1997) describe attention as “a mental process by which the individual selectively focuses on particular stimuli while inhibiting responses to competing stimuli presented over time” (p. 3). This definition is outlining the role of focused, selective, sustained, and effortful attentional components. According to Naglieri’s model (Naglieri 1999), focused attention refers to concentrate directly on a specific activity/stimulus; selective attention requires inhibiting responses to distracting stimuli and the management of interferences; sustained attention refers to the maintenance of concentration over time. Among these three main components, selective attention is the process that determines what we see and act upon; it has been considered the result of the

interaction between an observer's current selection of goals and the salience of objects present in the environment. Coherently with this perspective, Naglieri and Das (1997, 2005), theorize the PASS (planning, attention, simultaneous, and successive) theory according to which selective attention and the ability to shift the focus of attention are interconnected with more controlled processes, such as planning and inhibition with which they work as interconnected systems. In general, all main models of attentional control have described selective attention as the result of the interaction between bottom-up and top-down processes (Corbetta and Shulman 2002; Itti and Koch 2001; Theeuwes 2010). Top-down control processes can be described as the cognitive subcomponents of a single supervisory attentional mechanism and include inhibition and the ability to update the information maintained in working memory (WM; Miyake et al. 2000). Inhibition comprehends abilities that include: (1) selectively maintain the focus on a specific stimulus while suppressing attention to other stimuli (selective attention), (2) remain on the task and completing it over time (sustained attention), and (3) inhibit prepotent responses (response inhibition). WM entwines with attentional processes and particularly with selective attention involving mnemonic aspects of attention (see Eriksson et al. 2015). In particular, the ability to actively update WM refers to the ability to keep relevant information, both new and already stored, in short-term memory, mentally manipulate such information, and act on account of it. The cognitive processes needed to strengthen this ability include the executive/attentional control of short-term memory, which allows the integration, the processing, the disposal/retrieval of information, and, coherently, the executive core of the "WM/active attention system" reflects the ability to control attention and maintain a limited amount of information active, particularly when interference is present (Kane and Engle 2002). In this perspective, it is important to take into consideration the complex interrelations that characterize attention, memory, and executive function (EF), as "Metaphorically, memory, attention, and executive functions may be interrelated as past, present, and future are interrelated" (Eslinger 1996, p. 392).

### The elements of calculation

Calculation and mathematical performance rely on a number of components, such as basic knowledge of numbers, retrieval of arithmetical facts, understanding of mathematical concepts, and the ability to follow procedures (Dowker, 1998; Gersten et al., 2005; Tobia et al., 2016). Early numerical abilities emerge and manifest very early on in development, already in the first months of life in humans, and this evidence is confirmed in populations from various cultural backgrounds (e.g., Gordon 2004; Wynn 1992; Xu et al. 2005). This early sense of numerical magnitudes includes the ability to efficiently understand, approximate, and manipulate numerical quantities (Dehaene 1997) and is hypothesized to be part of an innate non-symbolic system of numerical representation. Through education, this non-symbolic system is gradually supported by a culturally determined linguistic and symbolic (Piazza et al. 2013). This component is involved in all mathematical tasks that require the retrieval of arithmetic facts and exact calculations (Dehaene et al. 1999; Levine et al. 1992). McCloskey et al. (1985) differentiated the ability to understand and produce numbers from the ability to calculate. In particular, the ability to perform operations and calculus evolve over time throughout primary school, and being a complex task, it requires the activation of several cognitive skills. According to McCloskey et al.'s model, the number processing system involves distinct mechanisms for number comprehension and number production. Within the comprehension and production subsystems, the components for processing Arabic numbers are separate from

the components for processing verbal numbers. The calculation system includes three major components in addition to number processing mechanisms: processing of operational symbols or words that identify the operation, retrieval of basic arithmetic facts, and execution of the calculation procedure. These components are diversely involved in mental and written calculations. Furthermore, any calculation task requires some sort of number production and/or comprehension abilities. Research that has been performed to understand how children develop these specific abilities suggests that before schooling, children possess an elementary understanding of arithmetic concepts (Canobi et al., 2002). Cornoldi and Lucangeli (2004), on the basis of this model, identified three main dimensions of calculation competence: numerical knowledge, calculation accuracy, and calculation speed. Numerical knowledge is described as the combination of expertise and skills that enable a child to understand numerical quantities and their transformations (Dehaene et al. 1990), whereas calculation accuracy and speed would define and determine a child's capacity to solve rapidly and accurately arithmetic calculations (Cornoldi and Lucangeli 2004; Jordan and Montani 1997).

Primary education is structured to develop this early conceptual knowledge, in order to allow children to select the adequate mathematical procedures to transfer understanding to new mathematical situations (Rittle-Johnson and Siegler 1998), for this reason, the first years of elementary school are crucial to understanding the evolution of this components also in relation to other important cognitive domains.

### **Attention and calculation: which contribution?**

The ability to perform arithmetical operations, as mentioned above, evolves throughout a prolonged developmental period and requires the activation of several cognitive and attentional skills. Attention, in this perspective, acts as a filter to select and maintain relevant information while suppressing irrelevant distracters, improving the efficiency with which information arriving from the environment is acquired and processed and then memorized and learned (Posner and Rothbart 2005). In this regard, the existing literature concerning calculation and mathematical learning, stresses how different features of attention, and related controlled processes, such as planning and inhibition, are crucial for decision making, supporting the ability to perform written operations, particularly in maths problem solving, performance monitoring, in recalling and applying specific maths facts, and in evaluating one's answer (Das et al., 1994; Naglieri and Das 1997b). Literature, in fact, documents how attention fosters number processing, e.g., in the case of subitizing which has been documented to be attention-dependent (Anobile et al., 2012a, b; Burr et al., 2010), and specifically, active attention has been implicated in the early acquisition of arithmetic, supporting the conceptions of how numbers map onto space develop, during school years (Booth & Siegler, 2006; Siegler & Booth, 2004).

In particular, a more recent study by Commodari and Di Blasi (2014), aimed to investigate the contribution of the main components of attention on calculation skills development, showed how specific attentive components such as immediate span of attention and rapidity in shifting attentive focus play a pivotal role in the acquisition of the set of skills and knowledge that enable a child to understand the numerical quantities and their transformations, during the first year of the formal learning of arithmetic. Whereas in the successive grades of primary school, when children's basic arithmetic abilities are established, attention skills influence more extensively the calculation competence. The authors, in fact, point out how, in 3rd grade, of primary school, rapidity in the selection and recognition of visual or auditory

targets influenced specifically numerical knowledge, calculation accuracy, and calculation speed. The role of visuo-spatial components of attention and memory is documented to persist to maintain an important role also in older children (Anobile et al., 2013; Hubbard et al., 2005). Indeed, abilities such as number inversions and reversal, alignment/ misalignment of digits, and difficulties such as ignoring signs, and acquiring concepts of borrowing/carrying over, are strongly linked to visuo-spatial abilities (Bull et al., 2008). The visual-spatial system also supports as well a number of aspects of non-verbal numerical processing such as number magnitude, estimation, and representing information in a spatial form (e.g., in the case of the mental number line; Dehaene, 1997; Dehaene et al. 1999; Zorzi et al. 2002). With regard to calculation, a specific role of phonological WM seems to be played in both in terms of integration of direct retrieval of arithmetic facts from long-term memory and more complex procedural knowledge (Baroody & Wilkins, 1999; Dowker, 2003; Geary et al., 2000) as the one implied in more elaborate operation such as multiplication (Imbo and Vandierendonck 2007). The role of mnemonic components of active attention has also been supported in studies that investigate the cognitive characteristics of children that show difficulties in mathematics (Bull & Scerif; 2001). In accordance with this hypothesis, Cragg and Gilmore (2014), in their review, suggested that executive function co-related skills, which include active attention, inhibition, and flexible thinking, might be pivotal for mathematics competence development; in particular, they address the fact that the role of these processes in arithmetic performance may vary along time. This specific result is also coherent with other studies performed in childhood. Szucs et al. (2013) examining developmental dyscalculia in 9- and 10-year-old primary school children outlined how impairments in inhibition resulted as connected to the disruption of active attention functions, leading to hypothesize how difficulties in visuo-spatial processing and attentional may rely on short-term memory/working memory and inhibition impairments. These results provided by different studies, accounting for different components of attention and related processes, which consider also different populations, contribute on one hand to outline the complexity of the existing relationship between attention and related cognitive processes, and specific calculation skills development, while on the other hand outline the importance to add knowledge on this topic and to understand more clearly this existing link also in the typical development.

## The present study

The main aim of this study is to identify the contribution of different components of attention-related skills over calculation skills development between 2nd and 4th grade of elementary school. Coherently with this aim, we chose not to include in this study children attending 1st grade, as the first year of elementary school is dedicated to teaching basic math skills, such as number system knowledge, the ability to relate a quantity to the numerical symbol that represents it, and to manipulate quantities which are pivotal abilities to learn how to calculate, while in 2nd grade these skills are already acquired. Attentional skills and the ability to master them, as mentioned above, have a prolonged development over time (Wetzel 2014). Attentional efficiency, in fact, improves throughout a continuum (e.g., Suades-González et al. 2017), and different attentional components emerge from the beginning of primary school to about 9 years of age (Best & Miller 2010). Due to the beginning of formal learning, in correspondence with a time of developmental changes, in a bi-directional relationship with environmental stimulation (Rinaldi and Karmiloff-Smith 2017), we expect that specific attentive components, namely, selective attention, focused attention, shifting focus, planning, inhibition,

and visuo-spatial WM, may be particularly elicited in the early years of learning. Moreover, due to the evolution of important cognitive features that support attentional skills, such as WM and inhibition, between 6 and 9 years of age (Cowan, 2016; Pureza et al., 2013), and given the documented role of primary education in developing children's early conceptual numerical knowledge, allowing children to select the adequate mathematical procedures which enable them to transfer understanding to new mathematical situations (Rittle-Johnson and Siegler, 1998), we expect that the contribution of selective attention, focused attention, shifting focus, planning, inhibition, and visuo-spatial WM to accuracy in computation, in particular written calculation, numerical knowledge, accuracy, and speed in calculation (Cornoldi & Lucangeli, 2004), would change across this time lapse, with a more prominent role early on. Even if, as mentioned, only few investigations have been performed about this topic (Commodari & Di Blasi, 2014) considering a typical population, to the best of our knowledge, a study that investigated the contribution of attentional skills over the ability to calculate between 2nd and 4th grade using a non-computerized battery, more similar to the tasks that children tend to perform in school and more comparable, ecologically, is still missing.

In order to test these hypotheses, the aim of the present study is two-folded:

- 1 To investigate the predictive role of attention, specifically selective attention, focused attention, shifting focus, planning, inhibition, and visuo-spatial WM, on specific calculation skills development, in particular written calculation, numerical knowledge, accuracy in calculation, and speed, in 2nd and 3rd grade
- 2 To investigate the predictive role of 2nd and 3rd graders' attention and WM skills on calculation skills development 1 year later. In particular, investigating the predictive role of attention and WM measured in 2nd grade over calculation skills development measured in 3rd grade, and the role of attention and WM measured in 3rd grade over calculation skills development measured in 4th grade

## Method

### Participants

A total of 143 (66 males) of age range from 7.6 years to 9.4 years participated in the study. The participants were excluded from the analysis if they did not speak Italian as their first language or had been diagnosed with any disability (e.g., learning disabilities) or that received a diagnosis for any developmental disorders from the national public or private health system. Nineteen participants were excluded as they did not speak Italian as their first language, and twelve participants were excluded due to a pre-existing diagnosis from the national health system. The sample, at time 1, during the first data collection, included 59 TD children (28 males) attending 2nd grade and 53 children (24 males) attending 3rd grade.

At  $T_2$  during the 2nd evaluation, it was not possible to collect data from nineteen children that had participated in the study in the previous year. For this reason, the final sample, at time 2, included a total of 93 participants: 59 children (28 males) attending 3rd grade and 34 children (17 males) attending 4th grade. None of the children that participated in the study skipped/anticipated years, and all of them were on time with respect to the school program.

The children all attended the same school, located in the suburbs of a large city in the center of Italy of a predominantly middle-class area. The assessments were administered in accordance with privacy requirements and the informed consent policy required by Italian law (Legislative Decree DL-196/2003). Ethical standards for research were guaranteed by referring to the latest version of the Declaration of Helsinki by the World Medical Association in building up the research. The study was also approved by the Ethics Committee of the University of Florence.

## Materials and procedures

The families were previously informed about the aims of the study and about the activities in which the participants were involved. A written informed consent form was completed by the parents, and the children were also informed of the purposes of the research before testing began. Trained experts in Psychology of Education carried out data collection in two sessions: a group one that lasted 1 h, and a second 40-min individual one.

Testing was performed between May and June of each year. The data illustrated in this paper are part of a larger study investigating attention processes and learning in early development (Bigozzi et al. 2016; Bigozzi et al. 2018): Children were tested at time 1 while they were attending 2nd grade and 3rd grade, and the same children were tested at time 2 when they were attending 3rd grade and 4th grade, respectively, in a longitudinal cross-sectional design. The Cognitive assessment system (CAS) subtests (matching numbers, planned codes, expressive attention, number detection, and receptive attention) plus two BVS-Corsi Battery subtests, Path and Corsi's backward digit span, were administered at time 1 ( $T_1$ ), during the first data collection, and the same tasks except for Path and Corsi's backward digit span, were administered at time 2 ( $T_2$ ) during the second data collection 1 year later. At  $T_2$ , in fact, the school asked us to reduce the children's time schedule, and, for this reason, it was not possible to administer the last two tasks.

## General cognitive functioning measures

The similarities and block design tasks from the Wechsler Intelligence Scale (WISC-III; Wechsler 2003; Orsini and Picone 2006) were used as control variables. The assessment of IQ, as a control factor, is considered a reasonable strategy in research studies where intellectual functioning is not the main focus of the assessment (Sattler and Dumont 2004) but it may be important to control for the level of function in order to avoid misinterpreting the results in case of a lower level of functioning that may impact on learning.

**Calculation tasks** AC MT 6–11 (Cornoldi et al. 2002) This standardized battery is meant to assess different components of calculation abilities, and provides four scores, respectively: *written calculation*, *numerical knowledge*, *calculation accuracy*, and *calculation speed*, that together determine the global calculation efficiency. The administration procedure provides tasks to be administered both in class (or group) and individually. The written calculation task score determines the ability to perform written operations, and it comprehends the global number of correct responses (class or group administration). The numerical knowledge dimension exerts the set of abilities that are crucial to allow the child to understand the concept of numerical quantity, the "size" of a number, and its changes. The score is the number of correct responses obtained in the size discrimination, word-number transcoding, and number ordering tasks respectively.

The accuracy score is obtained by considering the child's ability to correctly process information during a calculation task, in this case considering performance in an individual session only that comprehends both written and mental calculation tasks. In this case, the dependent variable is the score obtained from the total number of errors committed. Errors committed in the written calculation task were scored 3, while errors committed in all other tasks in this session were scored 1.

Speed score is obtained accounting for children's response times in performing calculation tasks. This calculation speed measure is considered a measure of the automation of the calculation process. This score is obtained summing up response times in the written calculation, mental calculation, and enumeration tasks.

Cronbach's alpha for our sample was .74 for competence in calculation and .55 for numerical knowledge.

## Attention tasks

**Cognitive assessment system (CAS) (Naglieri and Das 1997, Italian version by Taddei and Naglieri 2005)** CAS is a multidimensional measure of cognitive processing based on the PASS (planning, attention, simultaneous, and successive) theory of intelligence adapted for children from 5 to 17 years of age. For the purpose of this study, we used the tasks of the planning and attention scales. The internal reliability coefficients are high: .88 for planning and .88 for attention, respectively.

### *Planning subtests*

#### *Matching numbers task* (planning, selective attention)

The task requires the identification, as quickly as possible, of identical pairs of numbers on a worksheet, where numbers are arranged in an ordered matrix in which also distracters are present. Children need to remember the target numbers. The child is asked to find the two numbers in each row that are the same and use an appropriate strategy to distinguish them from the distracters. The time needed to complete the task and the number of correct responses are recorded.

#### *Planned codes task* (planning, inhibition)

The task requires children to copy sequences of symbols (e.g., OX XX OO) arranged in a matrix of seven rows and eight columns. Each child has to complete the cells left empty with the correct code based on the example provided. On each item, a code associates Xs and Os with A, B, C, or D; for example, OX is associated with A on item 1. The child is asked to write the correct two-letter code for each letter. For each item, the sequence changes so that the child is also required to shift from item to item inhibiting interferences as well. Accuracy and speed are recorded for each item.

### *Attention subtests*

#### *Expressive attention task* (inhibition of automatic responses, interference control)

This is a Stroop task (Stroop 1935). For ages up to 7 years, the child has to inhibit the dimension of the figures and identify the real size of the corresponding animal from 8 years old; the child has to inhibit the word's meaning and say the color of each word's ink. The



words are in fact names of colors that are printed in different colors (e.g., the word red might be printed in blue ink). Stimuli are arranged in an ordered matrix style sheet. Accuracy and speed are recorded for each matrix.

*Number detection task* (selective attention, shifting focus)

Children are instructed to find and underline the target numbers (as reported in the example) among several distractors. Stimuli are always arranged in columns and rows in matrix style sheets, and target numbers change among sheets.

*Receptive attention task* (focused attention)

The child is instructed to find, among distracting stimuli, pairs of items matching on the basis of the graphic similarity or, subsequently, on the basis of the category (name). Stimuli are arranged in matrix style sheets. For children from 5 to 7 years of age, each item consists of ten rows of five pairs of drawings. For test-takers who are 8 or older, the stimuli are letters. The test measures the ability to switch the attentional focus.

For all CAS subtests, final scores combine speed and accuracy measures.

**Visuo-spatial working memory tasks** Visuo-spatial WM abilities were assessed with the Paths and Corsi's backward digit span from the BVS-Corsi Battery (Mammarella et al. 2008).

*Paths* (sequential-spatial working memory)

This task requires the child to follow verbal instructions and indicate, by imaging the corresponding path without any iconic support, the arrival on a grid. Level complexity increases from  $2 \times 2$  to  $6 \times 6$  grids. Accuracy is measured as the highest level a child performs. Test reliability is .85.

*Corsi's backward digit span* (visuo-spatial working memory)

The child must recall backward a clustered sequence of positions indicated by the psychologist on a nine-block board. The span, that is, the longest sequence a child recalls correctly, is measured. The internal reliability coefficient is .74.

More details on these procedures and materials are provided in Section 1 of the Supplementary Material (SM).

## Data analysis

Descriptive statistics of all the metric variables (mean, standard deviation, skewness and kurtosis coefficients, minimum and maximum values) were carried out distinctively for each grade of primary school. The normality assumptions were verified for all variables, and in those cases in which the distribution was not normal, the appropriate monotone increasing transformations were applied (Fox, 2015). Pearson's correlation coefficients were carried out to check the statistical association among written calculation, numerical knowledge, accuracy (errors), speed, attention, and visuo-spatial working memory measures, both in 2nd and in 3rd

grades. In line with the aims of the study, in order to determine which attention and visuo-spatial working memory variables could predict calculation skills for each group considered (2nd to 3rd-grade group and 3rd to 4th-grade group), a series of linear multiple regression analyses were performed. For each analysis implemented, the different attention and visuo-spatial working memory variables were inserted as independent variables, whereas calculation tasks scores were inserted as dependent variables (stepwise method).

Each analysis was implemented respectively first, investigating the contribution of attentional skills measured at  $T_1$  over calculation task score measured at  $T_1$ , then crossing variables and investigating whether performance at the attentional tasks at  $T_1$  could predict an increased performance in calculation tasks at  $T_2$ , and then re-test if any change in the pattern occurred at  $T_2$  testing the contribution of attentional skill over calculation skills at  $T_2$ .

Before the implementation of the multiple linear regression analyses, the variance inflation factor (VIF) coefficient was calculated for all the independent variables to exclude the possible presence of multi-collinearity (Field 2005). For each independent variable included in the regression models, the effect size coefficient partial eta-squared ( $\eta^2$ ) was also calculated.

## Results

The descriptive statistics about all the calculation, attention, and visuo-spatial working memory variables, in 2nd, 3rd, and 4th grade, are reported in Tables 1 and 2, respectively. Skewness and kurtosis values refer to the original scale of measure of the variables. The asterisks in the brackets indicate those variables that were successively normalized by increasing monotonic transformations.

The analysis of correlations (see Table 3) showed a stronger and more consistent pattern of association among AC MT 6–11 scores and attention and visuo-spatial working memory variables in 3rd grade with respect to the pattern that emerged in 2nd grade.

In 2nd grade, written operations resulted significantly associated with selective attention, shifting focus, and sequential-spatial working memory while accuracy in calculation emerged as associated with selective attention, shifting focus and inhibition of automatic response/interference control. Whereas in 3rd grade a stronger and more consistent pattern of correlations emerged, among attention, visuo-spatial working memory task scores and AC MT 6–11 scores. Notably, numerical knowledge emerged as significantly related only to inhibition on automatic response/interference control, and written operations emerged as associated with focused attention and planning/selective attention. Accuracy in calculation emerged as significantly associated with inhibition of automatic responses/interference control and sequential-spatial working memory; speed in calculation emerged as associated with focused attention, inhibition on automatic response/interference control, and planning selective attention. Tests to investigate whether the data met the assumption of collinearity indicated that multi-collinearity was not a concern as tolerance and VIF values' ranges were .54–.97 and 1.21–1.85 respectively.

The results of the linear regression analyses are reported in Tables 4, 5, 6, and 7. In 2nd grade, written operations was positively predicted by selective attention processes exerted in number detection task (measuring selective attention, shifting focus) ( $t = 2.73$ ,  $p < .01$ ,  $\eta^2 = .106$ ) (Table 4). Considering the contribution of the attention and visuo-spatial working memory variables, measured in the 2nd grade on accuracy in calculation, was significantly

**Table 1** Descriptive statistics of all measures about calculus, attention, and visuo-spatial working memory skills in 2nd grade (T<sub>1</sub>) and in the next year (T<sub>2</sub>): minimum, maximum, mean, standard deviation, skewness, and kurtosis

	T <sub>1</sub> (2nd grade)					T <sub>2</sub> (3rd grade)						
	Min	Max	M	SD	Skewness	Kurtosis	Min	Max	M	SD	Skewness	Kurtosis
<b>Calculus</b>												
Written calculation*	0	4	3.33	.960	-1.54	2.11	2	8	7.04	1.43	2.05	4.51
Numerical knowledge*	6	22	19.97	3.47	-2.69	7.70	14	22	20.19	2.50	-1.12	-0.27
Accuracy (errors)*	0	18	3.17	3.07	2.20	8.23	0	26	2.95	4.36	3.34	14.12
Speed (sec)*	17	270	82.45	46.18	1.66	4.46	48	265	100.95	45.08	1.63	2.73
<b>Attention</b>												
Matching numbers	4	19	10.86	2.80	.08	.13	6	15	10.32	2.13	.04	-48
Planned codes	3	15	10.01	2.55	-71	.35	3	15	8.68	2.79	-41	-03
Expressive attention	1	13	7.65	2.95	.14	-71	4	16	9.64	3.27	.37	-1.08
Number detection	2	19	11.97	3.41	-35	.64	8	15	11.1	1.95	.25	-99
Receptive attention	3	19	11.13	3.32	.12	-26	5	16	11.32	2.28	-54	.01
<b>Visuo-spatial working memory tasks</b>												
Paths	0	29	10.16	6.17	.73	.50						
Corsi's test backward	2	6	3.86	.90	.28	-47						

Cognitive functions involved in each test; number detection = visual selective attention, shifting focus; receptive attention = focused attention; expressive attention = inhibit automatic responses, interference control; planned codes = planning, inhibition; matching numbers = planning, selective attention

\*Variable normalized by an increasing monotonic transformation

**Table 2** Descriptive statistics of all measures about calculus, attention, and visuo-spatial working memory skills in 3rd grade (T<sub>1</sub>) and in the next year (T<sub>2</sub>): minimum, maximum, mean, standard deviation, skewness, and kurtosis

	T1 (3rd grade)					T2 (4th grade)						
	Min	Max	M	SD	Skewness	Kurtosis	Min	Max	M	SD	Skewness	Kurtosis
<b>Calculus</b>												
Written calculation*	0	4	3.03	1.15	-1.04	0.08	0	8	6.79	1.65	-1.92	4.30
Numerical knowledge*	2	22	19.16	4.58	-2.19	4.62	12	22	19.95	2.71	-1.20	0.20
Accuracy (errors)*	0	16	3.05	3.63	1.78	3.02	0	28	6.81	6.66	1.40	1.68
Speed (sec)*	38	536	111.12	73.34	3.37	16.97	43	500	139.39	81.60	2.14	6.08
<b>Attention</b>												
Matching numbers	5	17	1.57	2.32	.21	.48	6	14	1.31	2.17	-.28	-.93
Planned codes	1	18	1.1	3.23	.12	-.12	5	19	11.13	3.50	.40	-.52
Expressive attention	4	18	9.45	3.61	.56	-.51	1	16	9.38	3.43	.21	-.31
Number detection*	3	16	11.41	2.66	-.81	1.35	8	17	11.78	2.62	.35	-1.03
Receptive attention	4	16	1.4	2.42	-.17	-.13	5	18	1.96	2.81	-.13	.32
<b>Visuo-spatial working memory tasks</b>												
Paths	2	29	13.28	6.94	.48	.06						
Corst's test backward	2	7	4.52	1.33	.11	.15						

Cognitive functions involved in each test; number detection = visual selective attention, shifting focus; receptive attention = focused attention; expressive attention = inhibit automatic responses, interference control; planned codes = planning, inhibition; matching numbers = planning, inhibition, selective attention

\*Variable normalized by an increasing monotonic transformation

**Table 3** Correlation analyses between all measures about calculation measures, attention, and visuo-spatial working memory skills for both 2nd and 3rd grades: Pearson's linear correlation coefficient

Grades	Measure	Matching numbers	Planned codes	Expressive attention	Number detection	Receptive attention	Paths	Corsi's test backward
2nd	Written operations	0.10	0.07	-0.05	0.33**	0.07	0.26*	0.07
	Numerical knowledge	0.07	0.17	-0.16	0.19	-0.01	0.23	0.13
	Accuracy (errors)	-0.17	-0.21	0.28*	-0.24*	-0.07	-0.19	-0.21
	Speed (sec)	-0.18	-0.19	0.02	-0.19	-0.00	-0.10	0.00
3rd	Written operations	0.24*	0.01	0.18	0.25	0.25*	0.01	0.03
	Numerical knowledge	0.16	0.04	-0.24*	-0.13	-0.11	-0.15	-0.11
	Accuracy (errors)	0.01	0.01	-0.32**	-0.01	-0.21	-0.27*	-0.01
	Speed (sec)	-0.31*	-0.16	-0.25*	-0.31	-0.34**	-0.01	-0.07

\* $p < .05$ ; \*\* $p < .01$

**Table 4** Summary of the regression model, with written operations in 2nd grade as a dependent variable and CAS subtest and visuo-spatial working memory scores measured in 2nd grade as independent variables: regression parameter  $B$ , standard error of  $B$  ( $SEB$ ), Student's  $t$  test ( $t$ ),  $p$  value, and partial eta-squared (partial  $\eta^2$ )

Source	$B$	$SEB$	$t$	$p$	Partial $\eta^2$
Intercept	1.754	.922	1.902	.062	.054
Matching numbers	-.010	.059	-1.67	.868	.000
Planned codes	.004	.061	.070	.945	.000
Number detection	.006	.002	2.732	.008	.106
Expressive attention	-.016	.044	-.363	.718	.002
Receptive attention	-.096	.056	-1.711	.092	.044
Paths	.286	.147	1.948	.056	.057
Corsi's test backward	.197	.149	1.325	.190	.027

$R^2$  - adjusted = .13,  $p < .05$

predicted by expressive attention task (measuring inhibition of automatic responses, interference control) ( $t = -2.60$ ,  $p < .05$ ,  $\eta^2 = .097$ ) (Table 5), measured in 2nd grade. Notably, no significant predictive associations emerged between either speed or numerical knowledge and attention variables, measured in the 2nd grade.

With regard to the contribution of the attention variables, measured in 2nd grade, on calculation scores collected in 3rd grade, matching numbers task, measuring planning and selective attention ( $t = -2.13$ ,  $p < .05$ ,  $\eta^2 = .085$ ), and paths, measuring sequential-spatial working memory ( $t = -2.72$ ,  $p < .01$ ,  $\eta^2 = .131$ ), resulted as the two statistically significant regressors for accuracy (errors) (Table 6), while matching numbers ( $t = -4.00$ ,  $p < .001$ ,  $\eta^2 = .246$ ) emerged as a statistically significant regressor for speed (Table 7).

Attention and visuo-spatial working memory variables assessed in 2nd grade during the first data collection were not a significant predictor of written calculation or numerical knowledge measured in 3rd grade during the second evaluation. Notably, the same variables assessed in 3rd grade did not emerge as significant predictors of calculation variables, either in 3rd or in 4th grade.

## Discussion

This study investigated the contribution of different processes of attentional skills over core calculation skills development, between 2nd and 4th grade of elementary school in a typical

**Table 5** Summary of the regression model, with accuracy (errors) in calculation in 2nd grade as a dependent variable and CAS subtest and visuo-spatial working memory scores measured in 2nd grade as independent variables: regression parameter  $B$ , standard error of  $B$  ( $SEB$ ), Student's  $t$  test ( $t$ ),  $p$  value and partial eta-squared (partial  $\eta^2$ )

Source	$B$	$SEB$	$t$	$p$	Partial $\eta^2$
Intercept	2.188	.661	3.311	.002	.148
Matching numbers	-.071	.042	-1.681	.098	.043
Planned codes	-.023	.044	-.535	.595	.005
Expressive attention	-.082	.032	-2.596	.012	.097
Number detection	-.003	.002	-1.647	.105	.041
Receptive attention	.064	.040	1.581	.119	.038
Paths	-.131	.105	-1.247	.217	.024
Corsi's test backward	-.155	.107	-1.456	.150	.033

$R^2$  - adjusted = .19,  $p < .05$

**Table 6** Summary of the regression model, with accuracy (errors) in calculation in 3rd grade as a dependent variable and CAS subtest and visuo-spatial working memory scores measured in 2nd grade as independent variables: regression parameter *B*, standard error of *B* (*SEB*), Student's *t* test (*t*), *p* value, and partial eta-squared (partial  $\eta^2$ )

Source	<i>B</i>	<i>SEB</i>	<i>t</i>	<i>p</i>	Partial $\eta^2$
Intercept	18.018	5.613	3.210	.002	.174
Matching numbers	-.799	.375	-2.130	.038	.085
Planned codes	.526	.405	1.298	.200	.033
Expressive attention	.183	.286	.641	.524	.008
Number detection	-.022	.016	-1.325	.191	.035
Receptive attention	.295	.387	.764	.448	.012
Paths	-2.500	.920	-2.718	.009	.131
Corsi's test backward	-.478	.968	-.494	.624	.005

$R^2$  - adjusted = .25,  $p < .01$

sample. The results showed that different components of attention affected different features of calculation abilities over time between 2nd and 3rd grade and between 3rd and 4th grade. The results also showed that different factors of attention affected different features of calculation abilities over a 1-year time-lapse and that attentional skills appear to be less involved as the learning process progresses and specific core processes consolidate, becoming automatic, and these results are coherent with those documented in the same age range by previous studies (Commodari and Di Blasi 2014). Regression analysis results showed that specific attentional skills may contribute to calculation skills development between 2nd and 3rd grade and 3rd and 4th grade. Indeed, in 2nd grade, the analysis performed considering variables measured at  $T_1$ , during the first data collection; analysis showed that at  $T_1$  specifically, selective visuo-spatial attention (measured throughout the number detection task; see Table 4) emerged as a significant predictor of written calculation. This finding is consistent with results documented in the literature concerning the importance that the ability to visually organize the procedures has in performing written operations, for example, when putting numbers into the right columns, when handling spatial orientation of the operation and when positioning accordingly the sign of the operation (Cornoldi et al. 2002). With regard to the accuracy score, the ability to inhibit distracting information, measured through the expressive attention task, resulted as associated with being proficient in both written and oral calculation. This result is coherent with the existing literature that addresses the importance of inhibitory processes in

**Table 7** Summary of the regression model for, with speed in calculation in 3rd grade as a dependent variable and CAS subtest and visuo-spatial working memory scores measured in 2nd grade as independent variables: regression parameter *B*, standard error of *B* (*SEB*), Student's *t* test (*t*), *p* value, and partial eta-squared (partial  $\eta^2$ )

Source	<i>B</i>	<i>SEB</i>	<i>t</i>	<i>p</i>	Partial $\eta^2$
Intercept	438.538	59.019	7.430	< .001	.530
Matching numbers	-15.778	3.942	-4.002	< .001	.246
Planned codes	3.307	4.263	.776	.442	.012
Expressive attention	-1.267	3.007	-.421	.675	.004
Number detection	-.152	.172	-.886	.380	.016
Receptive attention	-.470	4.065	-.116	.908	.000
Paths	-17.987	9.669	-1.860	.069	.066
Corsi's test backward	-19.942	10.180	-1.959	.056	.073

$R^2$  - adjusted = .45,  $p < .001$

mathematical ability development (D'Amico and Passolunghi 2009; Lan et al. 2011). Indeed, this task particularly elicits the ability to control interference and inhibit distracting information, two core abilities of the cognitive system, very much implied in calculation task performance. Children at this learning and developmental stage, in fact, are still engaged in learning how to automate computing strategies, being meta-cognitively aware while actively and voluntarily directing cognitive processes in order to inhibit irrelevant or interfering information in order to perform the task properly (Fernandez-Duque et al. 2000; Tiego et al. 2018). These abilities, in fact, allow the focus of attention over specific information, e.g., the sign of the operation, important to select the correct set of rules that is necessary to perform a specific operation. This ability is very important both in written and oral calculation for different reasons: In written calculation, this ability is particularly important as it allows children not to be distracted by the presence of multiple operations with multiple operators or to inhibit interference when performing multiplications or subtractions with complex numbers that need complex procedures such as borrowing or carrying over while transcribing numbers handling spatial orientation, without losing track of the steps they need to perform in order to solve them. When performing these operations, in fact, the ability to manage interferences and to inhibit distracting information allows one to stay focus on the procedure keeping the rules actively in mind. Considering oral calculation, these abilities continue to play a crucial role, although for different reasons with respect to the written calculation : oral calculation, in fact, to be performed proficiently, needs the application of different strategies. In oral calculation, in fact, children are not required to handle number transcription yet to strategically handle numerical information already stored in mind, for example supporting the process with the use of numerical facts (Passolunghi and Cornoldi 2008).

These skills that emerged as important in 2nd grade at  $T_1$ , in fact, are strongly related, but the cognitive load may change on one or the other depending on whether the calculation is asked to be performed mentally/orally or in a written form (Cornoldi et al. 2002). In this perspective, our data confirm previous studies about the calculation competence of children with visuo-spatial learning disabilities (VLD). With regard to these children, difficulties have been documented whenever they are required to complete written operations but not when they are asked to perform the same operations orally; in particular, they present specific difficulties when operations require borrowing or carrying over (Venneri et al. 2003).

Analysis performed to investigate the role of attentional features measured during the first evaluation over calculation skills measured during the 2nd evaluation, 1 year later, outlined that planning, selective attention, and sequential-spatial working memory measured in 2nd grade emerged as the most central cognitive features that seemed to contribute to accuracy in calculation measured in 3rd grade. Accordingly, planning and selective attention measured at  $T_1$  in 2nd grade resulted as predictive of speed in calculation measured at  $T_2$  in 3rd grade. This result documents the role that strategic attention-related abilities may have in predicting a better outcome in calculation skills later on in development. Planning is in fact a complex cognitive ability that involves both inhibition and WM (Diamond 2013), two core cognitive abilities, as mentioned, very much implied in the matching numbers task, and that register a prolonged development over time (Malagoli and Usai 2018) and support several high-level processes in addition to planning, such as reasoning and problem-solving (Diamond, 2013).

With regard to the passage from 3rd ( $T_1$ ) to 4th grade ( $T_2$ ), the analysis did not show any significant association between the attention and calculation skills investigated in this study. Considering these results, it is thus possible to hypothesize that the procedures needed to perform a specific calculation task may already be automated at this stage of development,



implying that children's cognitive skills progress over time and structure, possibly, throughout the contribution of a specific environmental stimulation (Guarnera and D'Amico 2014), e.g., the one that happens in school in a regulated environmental learning setting, which is able to foster the automation-related procedures/strategies (Guarnera and D'Amico 2014, Rinaldi and Karmiloff-Smith 2017).

With regard to the numerical knowledge dimension, none of the investigated attentional features emerged as predictive of this calculation skill-related component either at  $T_1$  or at  $T_2$ . This data is not surprising as the first year of elementary school is specifically dedicated to teaching pivotal basic math skills, in order to strengthen the number system knowledge (see Bigozzi et al. 2016) working on the ability to relate a quantity to the numerical symbol that represents it, and, in general, on the ability to manipulate quantities the numerical knowledge AC-MT dimension is meant to specifically measure these skills, which in 2nd grade, are considered already acquired as constitute the basis on which learning more complex calculation procedures rely on.

In conclusion, this study contributes to the existing literature adding knowledge about the evolving role of attentional-related processes, such as interference control, planning, and maintaining information in an active state, in learning how to calculate in the first years of elementary school through a longitudinal cross-sectional design, using a reasonably wide battery of tasks in order to investigate different aspects of attention and cognitive functioning.

Despite these strengths, a few limitations to this work warrant mention. The first limitation is that we did not measure the role of attentional processes over calculation skills development up to 5th grade which, in the Italian system, would represent the end of primary school, which may be interesting, as 3rd and 4th-grade programs imply the use of core basic cognitive procedures that children automate, whereas in 5th grade, task complexity increases again in preparation for transitioning to algebra in middle school. A second limitation to this study may concern the use of the Cognitive Assessment System, although it's an interesting tool to measure attention and planning, it provides tasks that exert also more general cognitive features, in some cases, and this feature may lead to task impurity, in particular with regard to basic cognitive skills such as inhibition and WM implied in planning. Future research will also have to involve a wider range of classes again in a longitudinal perspective but extending data collection for the entire duration of elementary school, enrolling more classes per age range in order to contain the effects of the sample mortality, possibly also taking into account the variable of environmental noise that may play an important role in influencing attentional skills in the classrooms (Dockrell and Shield, 2006). Despite the above-cited limitations, this preliminary study allows the broadening of the existing literature, which is still quite scarce, about the influence of attentional processes over calculation related skills development in a typically developed sample, using a longitudinal approach and a paper-pencil cognitive battery to investigate core attentional processes that support learning. The illustrated findings evidence the potential usefulness in measuring children's attention skills during primary school, before children learn more complex aspects of mathematics processing, in order not only to strengthen core cognitive features that may support the stabilization of basic skills and strategies connected to calculation, but also to allow an easier transition to more complex and abstract aspects of mathematical reasoning later on in education.

## Conclusions

In conclusion, the current study supports evidence for a specific role of specific attentional processes over math learning in early elementary school. During 2nd grade, selective visuo-spatial attention emerged as an important predictor in the written calculation, while the ability to inhibit distracting information seems to better predict accuracy in calculation. Instead, at T<sub>2</sub>, planning, interference control, and spatial-sequential working memory abilities emerged as predictive in terms of accuracy in calculation. These results support evidence for a progressive decreasing role of attentional processes together with the ability to automate specific learning skills.

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**Code availability** Not applicable.

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**Data availability** Not Available.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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## References

- Alexander, K. L., Entwisle, D. R., & Dauber, S. L. (1994). *On the success of failure. A reassessment of the effects of retention in the primary grades*. Cambridge: Cambridge University Press.
- Anobile, G., Cicchini, G. M., & Burr, D. C. (2012a). Linear mapping of numbers onto space requires attention. *Cognition*, 122(3), 454–459. <https://doi.org/10.1016/j.cognition.2011.11.006>.
- Anobile, G., Turi, M., Cicchini, G. M., & Burr, D. C. (2012b). The effects of cross-sensory attentional demand on subitizing and on mapping number onto space. *Vision Research*, 74, 102–109. <https://doi.org/10.1016/j.visres.2012.06.005>.
- Anobile, G., Stievano, P., & Burr, D. C. (2013). Visual sustained attention and numerosity sensitivity correlate with math achievement in children. *Journal of Experimental Child Psychology*, 116(2), 380–391. <https://doi.org/10.1016/j.jecp.2013.06.006>.
- Barkley, R. A., Fischer, M., Edelbrock, C. S., & Smallish, L. (1990). The adolescent outcome of hyperactive children diagnosed by research criteria: An 8-year prospective follow-up study. *Journal of the American Academy of Child and Adolescent Psychiatry*, 29(4), 546–557. <https://doi.org/10.1097/00004583-199007000-00007>.
- Baroody, A. J., & Wilkins, J. L. (1999). The development of informal counting, number, and arithmetic skills and concepts. In J. V. Copley (Ed.), *Mathematics in the early years* (pp. 48–65). Washington, DC: National Association for the Education of Young Children.

- Berninger, V., Abbott, R., Cook, C. R., & Nagy, W. (2017). Relationships of attention and executive functions to oral language, reading, and writing skills and systems in middle childhood and early adolescence. *Journal of Learning Disabilities, 50*(4), 434–449. <https://doi.org/10.1177/0022219415617167>.
- Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81*(6), 1641–1660. <https://doi.org/10.1111/j.1467-8624.2010.01499.x>.
- Bigozzi, L., Grazi A., and Pezzica, S. (2016). Attentional factors involved in learning in the first grade. *Journal of Intellectual Disability – Diagnosis and Treatment 4*, 94–109. <https://doi.org/10.6000/2292-2598.2016.04.02.3>.
- Bigozzi, L., Pezzica, S., & Grazi, A. (2018) Attentional processes predictive of reading in second and third classes: the role of selective/focused attention and planning. *Educational Research Applications, ERCA–142*. <https://doi.org/10.29011/2575-7032/100042>.
- Booth, J., & Siegler, R. (2006). Developmental and individual differences in pure numerical estimation. *Developmental Psychology, 42*, 189–201. <https://doi.org/10.1037/0012-1649.41.6.189>.
- Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of Children's mathematics ability: inhibition. *Switching, and Working Memory, Developmental Neuropsychology, 19*(3), 273–293. [https://doi.org/10.1207/S15326942DN1903\\_3](https://doi.org/10.1207/S15326942DN1903_3).
- Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33*(3), 205–228. <https://doi.org/10.1080/87565640801982312>.
- Burr, D. C., Turi, M., & Anobile, G. (2010). Subitizing but not estimation of numerosity requires attentional resources. *Journal of Vision, 10*(6), 20. <https://doi.org/10.1167/10.6.20>.
- Canobi, K. H., Reeve, R. A., & Pattison, P. E. (2002). Young children's understanding of addition concepts. *Educational Psychology, 22*(5), 513–532. <https://doi.org/10.1080/0144341022000023608>.
- Checa, P., & Rueda, M. R. (2011). Behavioral and brain measures of executive attention and school competence in late childhood. *Developmental Neuropsychology, 36*, 1018–1032. <https://doi.org/10.1080/87565641.2011.591857>.
- Commodari, E. (2012). Attention skills and risk of developing learning difficulties. *Current psychology: a journal for diverse perspectives on diverse psychological issues, 31*(1), 17–34. <https://doi.org/10.1007/s12144-012-9128-3>.
- Commodari, E., & Di Blasi, M. (2014). The role of the different components of attention on calculation skill. *Learning and Individual Differences, 32*, 225–232. <https://doi.org/10.1016/j.lindif.2014.03.005>.
- Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*, 201–215. <https://doi.org/10.1038/nrn755>.
- Cornoldi, C., & Lucangeli, D. (2004). Arithmetic education and learning disabilities in Italy. *Journal of Learning Disabilities, 37*(1), 42–49. <https://doi.org/10.1177/00222194040370010501>.
- Cornoldi, C., Lucangeli, D., & Bellina, M. (2002). *Ac-MT 6–11*. Erickson: Test di autovalutazione delle abilità di calcolo e soluzione di problemi. Gruppo MT. Trento.
- Cowan, N. (2016). Working memory maturation: can we get at the essence of cognitive growth? *Perspectives on psychological science: a journal of the Association for Psychological Science, 11*(2), 239–264. <https://doi.org/10.1177/1745691615621279>.
- Cragg, L., & Gilmore, C. (2014). Skills underlying mathematics: the role of executive function in the development of mathematics proficiency. *Trends in Neuroscience and Education, 63*, 63–68. <https://doi.org/10.1016/j.tine.2013.12.001i>.
- D'Amico, A., & Passolunghi, M. C. (2009). Naming speed and effortful and automatic inhibition in children with arithmetic learning disabilities. *Learning and Individual Differences, 19*, 170–180. <https://doi.org/10.1016/j.lindif.2009.01.001>.
- Das, J. P., Naglieri, J. A., & Kirby, J. R. (1994). *Assessment of cognitive processes: The PASS theory of intelligence*. Allyn & Bacon.
- Dehaene, S. (1997). *The number sense: how the mind creates mathematics*. USA: Oxford University.
- Dehaene, S., Dupoux, E., & Mehler, J. (1990). Is numerical comparison digital? Analogical and symbolic effects in two-digit number comparison. *Journal of Experimental Psychology. Human Perception and Performance, 16*(3), 626–641. <https://doi.org/10.1037/0096-1523.16.3.626>.
- Dehaene, S., Spelke, E., Pinel, P., Stanescu, R., & Tsivkin, S. (1999). Sources of mathematical thinking: behavioral and brain-imaging evidence. *Science (New York, N.Y.)*, 284(5416), 970–974. <https://doi.org/10.1126/science.284.5416.970>
- Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*(1), 135–168. <https://doi.org/10.1146/annurev-psych-113011-143750>.
- Dockrell, J., & Shield, B. (2006). Acoustical barriers in classrooms: the impact of noise on performance in the classroom. *British Educational Research Journal, 32*, 509–525. <https://doi.org/10.1080/01411920600635494>.

- Dowker, A. (1998). Individual differences in normal arithmetical development. In C. Donlan (Ed.), *The development of mathematical skills* (pp. 275–302). Hove: Psychology Press.
- Dowker, A. D. (2003). Interventions in numeracy: Individualized approaches. In I. Thompson (Ed.), *Enhancing primary mathematics teaching* (pp. 127–138). Maidenhead: Open University Press.
- Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., Pagani, L. S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology*, 43(6), 1428–1446. <https://doi.org/10.1037/0012-1649.43.6.1428>.
- Eriksson, J., Vogel, E. K., Lansner, A., Bergström, F., & Nyberg, L. (2015). Neurocognitive architecture of working memory. *Neuron*, 88(1), 33–46. <https://doi.org/10.1016/j.neuron.2015.09.020>.
- Eslinger, P. J. (1996). Conceptualizing, describing, and measuring components of executive function: a summary. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory, and executive function*. Brookes: Baltimore.
- Fergusson, D. M., Lynskey, M. T., & Horwood, L. J. (1997). Attentional difficulties in middle childhood and psychosocial outcomes in young adulthood. *Journal of Child Psychology and Psychiatry*, 38(6), 633–644. <https://doi.org/10.1111/j.1469-7610.1997.tb01690.x>.
- Fernandez-Duque, D., Baird, J. A., & Posner, M. I. (2000). Executive attention and metacognitive. *regulation consciousness and cognition*, 9(2), 288–307. <https://doi.org/10.1006/ccog.2000.0447>.
- Field, A. (2005). *Discovering statistics using SPSS* (second ed.). London: Sage Publications Ltd..
- Geary, D., Hamson, C., & Hoard, M. (2000). Numerical and arithmetical cognition: a longitudinal study of process and concept deficits in children with Learning disability. *Journal of Experimental Child Psychology*, 77, 236–263. <https://doi.org/10.1006/jecp.2000.2561>.
- Gersten, R., Jordan, N. C., & Flojo, J. R. (2005). Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities*, 38(4), 293–304. <https://doi.org/10.1177/00222194050380040301>.
- Gordon, P. (2004). Numerical cognition without words: evidence from Amazonia. *Science (New York, N.Y.)*, 306, 496–499. <https://doi.org/10.1126/science.1094492>.
- Guamera, M., & D'Amico, A. (2014). Training of Attention in Children With Low Arithmetical Achievement. *Europe's Journal of Psychology*, 10(2), 277–290. <https://doi.org/10.5964/ejop.v10i2.744>.
- Hubbard, E., Piazza, M., Pinel, P., & Dehaene, S. (2005). Interactions between number and space in parietal cortex. *Nature Reviews Neuroscience*, 6(6), 435–448. <https://doi.org/10.1038/nrn1684>.
- Imbo, I., & Vandierendonck, A. (2007). The development of strategy use in elementary school children: Working memory and individual differences. *Journal of Experimental Child Psychology*, 96(4), 284–309. <https://doi.org/10.1016/j.jecp.2006.09.001>.
- Itti, L., & Koch, C. (2001). Computational modelling of visual attention. *Nature Reviews Neuroscience*, 2, 194–203. <https://doi.org/10.1038/35058500>.
- Jaekel, J., Wolke, D., & Bartman, P. (2013). Poor attention rather than hyperactivity/impulsivity predicts academic achievement in very preterm and full-term adolescents. *Psychological Medicine*, 43(1), 183–196. <https://doi.org/10.1017/S0033291712001031>.
- Johnson, B., Altmeyer, E. M., & Richman, L. C. (1999). Attention deficits and reading disabilities: are immediate memory deficits additive? *Developmental Neuropsychology*, 15(2), 213–226. <https://doi.org/10.1080/87565649909540746>.
- Jordan, N. C., & Montani, T. O. (1997). Cognitive arithmetic and problem solving: a comparison of children with specific and general mathematics difficulties. *Journal of Learning Disabilities*, 30(624–34), 684–634. <https://doi.org/10.1177/002221949703000606>.
- Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working memory capacity, executive attention, and general fluid intelligence: an individual-differences perspective. *Psychonomic Bulletin and Review*, 9(4), 637–671. <https://doi.org/10.3758/BF03196323>.
- LaBerge, D. (1990). Thalamic and cortical mechanisms of attention suggested by recent positron emission tomographic experiments. *Journal of Cognitive Neuroscience*, 2, 358–372. <https://doi.org/10.1162/jocn.1990.2.4.358>.
- Lan, X., Legare, C. H., Cameron Ponitz, C., Li, S., & Morrison, F. J. (2011). Investigating the links between the subcomponents of executive function and academic achievement: a cross-cultural analysis of Chinese and American preschoolers. *Journal of Experimental Child Psychology*, 108(3), 677–692. <https://doi.org/10.1016/j.jecp.2010.11.001>.
- Levine, S. C., Jordan, N. C., & Huttenlocher, J. (1992). Development of calculation abilities in young children. *Journal of Experimental Child Psychology*, 53(1), 72–103. [https://doi.org/10.1016/S0022-0965\(05\)80005-0](https://doi.org/10.1016/S0022-0965(05)80005-0).
- Malagoli, C., & Usai, M. C. (2018). The effects of gender and age on inhibition and working memory organization in 14- to 19-year-old adolescents and young adults. *Cognitive Development*, 45, 10–23. <https://doi.org/10.1016/j.cogdev.2017.10.005>

- Mammarella, I. C., Toso, C., Pazzaglia, F., & Cornoldi, C. (2008). *BVS-Corsi: Batteria per la valutazione della memoria visiva e spaziale [BVS-Corsi: A test battery for assessing visual and spatial memory]*. Trento: Erickson.
- Mayes, S. D., & Calhoun, S. L. (2006). Frequency of reading, math and writing disabilities in children with clinical disorders. *Learning and Individual Differences, 16*(2), 145–157. <https://doi.org/10.1016/j.lindif.2005.07.004>.
- McCloskey, M., Caramazza, A., & Basili, A. (1985). Cognitive mechanisms in number processing and calculation: evidence from dyscalculia. *Brain and Cognition, 4*(2), 171–196. [https://doi.org/10.1016/0278-2626\(85\)90069-7](https://doi.org/10.1016/0278-2626(85)90069-7).
- Mirsky, A. F., Anthony, B. J., Duncan, C. C., Aheam, M. B., & Kellam, S. G. (1991). Analysis of the elements of attention: a neuropsychological approach. *Neuropsychology Review, 2*(2), 109–145. <https://doi.org/10.1007/BF01109051>.
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex frontal lobe tasks: a latent variable analysis. *Cognitive Psychology, 41*(1), 49–100. <https://doi.org/10.1006/cogp.1999.0734>.
- Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundations of early reading development: evidence from a longitudinal study. *Developmental Psychology, 40*, 665. <https://doi.org/10.1037/0012-1649.40.5.66>
- Naglieri, J. A. (1999). How valid is the PASS theory and CAS? *School Psychology Review, 28*(1), 145–162. <https://doi.org/10.1080/02796015.1999.12085953>.
- Naglieri, J. A. & Das, J. P. (1997). *Das Naglieri Cognitive Assessment System*. Riverside Publishing, Itasca, IL (ad. it.: a cura di S. Taddei, *Cognitive Assessment System*. O.S. Organizzazioni Speciali, Firenze, 2005).
- Naglieri, J. A., & Das, J. P. (1997b). *Cognitive assessment system interpretive handbook*. Itasca: Riverside Publishing Company.
- Naglieri, J. A., & Das, J. P. (2005). Planning, Attention, Simultaneous, Successive (PASS) theory: A revision of the concept of intelligence. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 120–135). New York, NY: Guilford.
- Orsini, A., & Picone, L. (2006). *WISC-III Contributo alla taratura italiana*. Firenze: Organizzazioni Speciali.
- Passolunghi, M. C. & Cornoldi, C. (2008) Working memory failures in children with arithmetical difficulties *Child Neuropsychology, iFirst*: 1–14 doi: <https://doi.org/10.1080/09297040701566662>.
- Piazza, M., Pica, P., Izard, V., Spelke, E. S., & Dehaene, S. (2013). Education enhances the acuity of the nonverbal approximate number system. *Psychological Science, 24*(6), 1037–1043. <https://doi.org/10.1177/0956797612464057>.
- Polderman, T. J., Derks, E. M., Hudziak, J. J., Verhulst, F. C., Posthuma, D., & Boomsma, D. I. (2007). Across the continuum of attention skills: a twin study of the SWAN ADHD rating scale. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 48*, 1080–1087. <https://doi.org/10.1111/j.1469-7610.2007.01783.x>.
- Posner, M., & Fan, J. (2008). Attention as an organ system. In J. Pomerantz (Ed.). *Topics in integrative neuroscience: From cells to cognition* (pp.31-61). Cambridge: Cambridge University Press. <https://doi.org/10.1017/CBO9780511541681.005>
- Posner, M. I., & Rothbart, M. K. (2005). Influencing brain networks: implications for education. *Trends in Cognitive Sciences, 9*(3), 99–103. <https://doi.org/10.1016/j.tics.2005.01.007>.
- Pureza, J. R., Gonçalves, H. A., Branco, L., Grassi-Oliveira, R., & Fonseca, R. P. (2013). Executive functions in late childhood: age differences among groups. *Psychology & Neuroscience, 6*(1), 79–88. <https://doi.org/10.3922/j.psns.2013.1.12>.
- Re, A. M., & Cornoldi, C. (2010). ADHD expressive writing difficulties of ADHD children: when good declarative knowledge is not sufficient. *European Journal of Psychology of Education, 25*(3), 315–323. <https://doi.org/10.1007/s10212-010-0018-5>.
- Rinaldi, L., & Karmiloff-Smith, A. (2017). Intelligence as a developing function: a neuroconstructivist approach. *Journal of Intelligence, 5*(2), 18. <https://doi.org/10.3390/jintelligence5020018>
- Rittle-Johnson, B., & Siegler, R. S. (1998). The relation between conceptual and procedural knowledge in learning mathematics: a review. In C. Donlan (Ed.), *The development of mathematical skills* (pp. 75–110). London: Psychology Press.
- Sattler, J. M., & Dumont, R. (2004). *Assessment of children: WISC-IV and WPPSI-III supplement*. San Diego: Author.
- Scerif, G. (2010). Attention trajectories, mechanisms and outcomes: at the interface between developing cognition and environment. *Developmental Science, 13*, 805–812. <https://doi.org/10.1111/j.1467-7687.2010.01013.x>.
- Siegler, R. S., & Booth, J. L. (2004). Development of numerical estimation in young children. *Child Development, 75*(2), 428–444. <https://doi.org/10.1111/j.1467-8624.2004.00684.x>.

- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662. <https://doi.org/10.1037/h0054651>.
- Suades-González, E., Forns, J., García-Esteban, R., López-Vicente, M., Esnaola, M., Álvarez-Pedrerol, M., Julvez, J., Cáceres, A., Basagaña, X., López-Sala, A., & Sunyer, J. (2017). A longitudinal study on attention development in primary school children with and without teacher-reported symptoms of ADHD. *Frontiers in Psychology*, *8*, 655. <https://doi.org/10.3389/fpsyg.2017.00655>.
- Szucs, D., Devine, A., Soltesz, F., Nobes, A., & Gabriel, F. (2013). Developmental dyscalculia is related to visuo-spatial memory and inhibition impairment. *Cortex*, *49*(10), 2674–2688. <https://doi.org/10.1016/j.cortex.2013.06.007>.
- Taddei, S., & Naglieri, J. A. (2005). L'adattamento italiano del Cognitive Assessment System. In J. A. Naglieri & J. P. Das (Eds.), *Cognitive Assessment System*. Firenze: O.S. Organizzazioni Speciali.
- Theeuwes, J. (2010). Top-down and bottom-up control of visual selection. *Acta Psychologica*, *135*, 77–99. <https://doi.org/10.1016/j.actpsy.2010.02.006>
- Tiego, J., Testa, R., Bellgrove, M. A., Pantelis, C., & Whittle, S. (2018). A hierarchical model of inhibitory control. *Frontiers in Psychology*, *9*, 1339. <https://doi.org/10.3389/fpsyg.2018.01339>.
- Tobia, V., Bonifacci, P., & Marzocchi, G. M. (2016). Concurrent and longitudinal predictors of calculation skills in preschoolers. *European Journal of Psychology of Education*, *31*, 155–174. <https://doi.org/10.1007/s10212-015-0260-y>.
- Vellutino, F., Fletcher, J., Snowling, M., & Scanlon, D. (2004). Specific reading disability (dyslexia): what have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *45*, 2–40. <https://doi.org/10.1046/j.0021-9630.2003.00305.x>.
- Venneri, A., Comolli, C., & Garuti, M. (2003). Arithmetic difficulties in children with visuospatial learning disability (VLD). *Child neuropsychology: a journal on normal and abnormal development in childhood and adolescence*, *9*, 175–183. <https://doi.org/10.1076/chin.9.3.175.16454>.
- Wetzel, N. (2014). Development of control of attention from different perspectives. *Frontiers in Psychology*, *5*, 1000. <https://doi.org/10.3389/fpsyg.2014.01000>
- Wynn, K. (1992). Addition and subtraction by human infants. *Nature*, *358*(6389), 749–750. <https://doi.org/10.1038/358749a0>.
- Xu, F., Spelke, E. S., & Goddard, S. (2005). Number sense in human infants. *Developmental Science*, *8*(1), 88–101. <https://doi.org/10.1111/j.1467-7687.2005.00395.x>.
- Zorzi, M., Proffis, K., & Umiltà, C. (2002). Brain damage: Neglect disrupts the mental number line. *Nature*, *417*, . <https://doi.org/10.1038/417138a>

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#### *Current Themes of Research*

Attentional skills development, Learning, Literacy development

#### *Most Relevant Publications*

Vettori, G., Vezzani, C., Bigozzi, L., Pinto, G. (in press). Cluster profiles of university students' conceptions of learning according to gender, educational level, and academic disciplines. *Learning and Motivation*, *70*, ISSN:0023-9690.

Vettori, G., Pinto, G., Bigozzi, L., Miniati, F., Vezzani, C. (2019). Identifying pre-service teachers' profiles of conceptions of learning: a cluster analysis. *Social Psychology of Education*, *22*, 1131–1152, ISSN:1381-2890. <https://doi.org/https://doi.org/10.1007/s11218-019-09516-3>.

- Pinto, G.; Tarchi, C.; Bigozzi, L. (2019). Improving children's textual competence in kindergarten through genre awareness. *European Journal Of Psychology Of Education*, 1-18, ISSN:0256-2928 <https://doi.org/https://doi.org/10.1007/s10212-019-00418-8>
- Pinto, G., Bigozzi, L., Tarchi, C. & Camilloni, M. (2018). Improving conceptual knowledge of the Italian writing system in kindergarten: A cluster randomized trial. *Frontiers in Psychology*. Doi: <https://doi.org/10.3389/fpsyg.2018.01396>
- Vettori Giulia; Vezzani Claudio; Bigozzi Lucia; Pinto Giuliana (2018). The mediating role of conceptions of learning in the relationship between metacognition and academic outcomes among middle school students. *Frontiers in Psychology*., 9: 1985, ISSN:1664-1078. <https://doi.org/10.3389/fpsyg.2018.01985>
- Bigozzi, L., Tarchi, C., Fiorentini, C., Falsini, P. & Stefanelli, F. (2018). The influence of teaching approach on students' conceptual learning in Physics. *Frontiers in Psychology*. <https://doi.org/10.3389/fpsyg.2018.02474>
- Bigozzi, L., Tarchi, C., Vagnoli, L., Valente, E. & Pinto, G. (2017). Reading fluency as a predictor of school outcomes across Grades 4-9. *Frontiers in Psychology, Educational psychology*. <https://doi.org/10.3389/fpsyg.2017.00200>
- Bigozzi L, Tarchi C, Caudex C and Pinto G (2016). Predicting reading and spelling disorders: a 4-year prospective cohort study. *Front. Psychol.* 7:337. <https://doi.org/10.3389/fpsyg.2016.00337>.
- Bigozzi L, Tarchi C, Pinto G (2016) Spelling across Tasks and Levels of Language in a Transparent Orthography. *PLoS ONE* 11(9): e0163033. <https://doi.org/10.1371/journal.pone.0163033>
- Pinto, G., Tarchi, C., Gamannossi, B. A., & Bigozzi, L. (2016). Mental state talk in children's face-to-face and telephone narratives. *Journal of Applied Developmental Psychology*, 21–27. <https://doi.org/10.1016/j.appdev.2016.02.004>
- Pinto, G., Bigozzi, L., Tarchi, C. & Vezzani, C. (2016). Emergent literacy and reading acquisition: a longitudinal study from kindergarten to primary school. *European Journal of Psychology of Education*.. <https://doi.org/10.1007/s10212-016-0314-9>
- Bigozzi, L., Tarchi, C., Pezzica, S. & Pinto, G. (2014 /2016). Evaluating the Predictive Impact of an Emergent Literacy Model on Dyslexia in Italian Children: A Four-Year Prospective Cohort Study. *Journal of Learning Disabilities*, pp. 1-14. <https://doi.org/10.1177/0022219414522708>.
- Pezzica S., Pinto G., Bigozzi L., Vezzani C., (2015), Where is my attention? Children's metaknowledge through drawings, *Educational Psychology*. <https://doi.org/10.1080/01443410.2014.1003035>
- Pinto, G., Tarchi, C., & Bigozzi, L. (2015). The relationship between oral and written narratives: A three-year longitudinal study of narrative cohesion, coherence, and structure. *British Journal of Educational Psychology*, 85, 551-569. <https://doi.org/10.1111/bjep.12091>
- Pinto G., Bigozzi L., Tarchi C., Accorti Gamannossi B., Canneti E. (2015), Cross-lag analysis of longitudinal associations between primary school students' writing and reading skills, *Reading and Writing*, 28, 1235-1255. <https://doi.org/10.1007/s11145-015-9569-9>.
- Pinto, G., Tarchi, C., & Bigozzi, L. (2015). Development in Narrative Competences from Oral to Written Stories in Five- to Seven-year-old Children. *Early Childhood Research Quarterly*. <https://doi.org/10.1016/j.ecresq.2015.12.001>.
- Bigozzi, L., Tarchi, C., Falsini, P. & Fiorentini, C. (2014). "Slow Science." Building scientific concepts in physics in high school. *International Journal of Science of Education*, 36, 2221-2242. <https://doi.org/10.1080/09500693.2014.919425>
- Bigozzi L., Giulia Vettori (2015/16). To tell a story, to write it: Developmental patterns of narrative skills from pre-school to first grade. *European Journal of Psychology of Education, advance online publication*, <https://doi.org/10.1007/s10212-015-0273-6>.
- Bigozzi, L., Vezzani, C., Tarchi, C. & Fiorentini, C. (2011). The role of individual writing The role of individual writing in fostering scientific conceptualization. *European Journal of Psychology of Education*, 26, 45–59. <https://doi.org/10.1007/s10212-010-0031-8>
- Pinto G., Bigozzi L., Accorti Gamannossi B., Vezzani C. (2009), Emergent literacy and learning to write: a predictive model for Italian language, *European Journal of Psychology of Education*, XXIV(1), 724-742.
- Bigozzi L., Biggeri A., Boschi F., Fiorentini C., Conti P., (2002), Children "scientists" know the reason why and they are "poets" too. Non-randomized controlled trial to evaluate the effectiveness of a strategy aimed at improving the learning of scientific concepts, *European Journal of Psychology of Education*, n.17, 343-362 <https://doi.org/10.1007/BF03173590>

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*Current Themes of Research*

Attentional Skills development, learning, learning disabilities

*Most Relevant Publications*

- Bigozzi, L., Grazi A. & Pezzica, S. (2016) Attentional Factors Involved in Learning in the First Grade. *Journal of Intellectual Disability – Diagnosis and Treatment* 4, 94-109. <https://doi.org/10.6000/2292-2598.2016.04.02.3>
- Pezzica S., Pinto G., Bigozzi L., Vezzani C., (2015), Where is my attention? Children's metaknowledge through drawings, *Educational Psychology*.<https://doi.org/10.1080/01443410.2014.1003035>
- Bigozzi, L., Tarchi, C., Pezzica, S. & Pinto, G. (2014 /2016). Evaluating the Predictive Impact of an Emergent Literacy Model on Dyslexia in Italian Children: A Four-Year Prospective Cohort Study. *Journal of Learning Disabilities*,. 1-14. <https://doi.org/10.1177/0022219414522708>.
- Pezzica, S., Venucci, C. & Bigozzi, L. (2014) Bambini con ADHD a scuola: cosa pensano i genitori? *Psicologia dell'educazione* 8 (2), 173-188.

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*Current Themes of Research*

Attentional skills development, learning, literacy development, Executive Functions

*Most Relevant Publications*

- Traverso, L., Viterbori, P., Malagoli, C., & Usai, M. C. (2020). Distinct inhibition dimensions differentially account for working memory performance in 5-year-old children. *Cognitive Development*. 55. 100909. [10.1016/j.cogdev.2020.100909](https://doi.org/10.1016/j.cogdev.2020.100909).
- Malagoli, C., Cerro, P.F., Vecchiato, C & Usai, M.C. (2020). Cognitive and emotional regulation in adolescents and young women with eating disorders *Eating and Weight Disorders* 1-9 <https://doi.org/10.1007/s40519-020-00859-x>
- S. Piana, C. Malagoli, M. C. Usai & A. Camurri, (2019) Effects of Computerized Emotional Training on Children with High Functioning Autism, in *IEEE Transactions on Affective Computing*. <https://doi.org/10.1109/TAFFC.2019.2916023>
- Malagoli C & Usai MC (2018) WM in Adolescence: What Is the Relationship With Emotional Regulation and Behavioral Outcomes? *Front. Psychol.* 9:844. <https://doi.org/10.3389/fpsyg.2018.00844>
- Malagoli, C. & Usai, M.C. (2018). The effects of gender and age on inhibition and working memory organization in 14- to 19-year-old adolescents and young adults. *Cognitive Development*,45, 10-23. <https://doi.org/10.1016/j.cogdev.2017.10.005>.

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