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Training of Attention in Children With Low Arithmetical Achievement

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Abstract

This study focuses on the role of attentional processes in arithmetical skills and examines if training of basic attentive skills may improve also working memory abilities reducing arithmetic difficulties. In order to study the efficacy of attentional treatment in arithmetic achievement and in enhancing working memory abilities a test-treatment-retest quasi experimental design was adopted. The research involved 14 children, attending fourth and fifth grades, with Arithmetical Learning Disabilities (ALD) assigned to experimental and control conditions. The numerical comprehension and calculation processes were assessed using the ABCA battery (Lucangeli, Tressoldi, & Fiore, 1998). Attentional abilities were evaluated using a multitask computerized assessment battery Attenzione e Concentrazione (Di Nuovo, 2000). WM abilities were evaluated by Listening span task, Digit span backward, Making verbal trails and Making colour trails. The results showed that intensive computerized attention training increased basic attentive skills and arithmetical performances with respect to numeric system in children with ALD. No effect on working memory abilities was found. Results are also important from a clinical perspective, since they may suggest strategies for planning individualized training programs.

Keywords: arithmetical skills, working memory, attentional abilities, attention training, children with dyscalculia

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Mathematical competence entails a variety of complex skills that encompass somewhat different conceptual content and procedures (e.g., arithmetic, algebra, and geometry); problem solving in these domains often involves the holding of partial information and the processing of new information to arrive at a solution, which ought to require working memory resources. Indeed, individual difference studies that compare working memory performance in children with and without difficulties in math discovered differences in various aspects of working memory. Even if the results of different studies are sometimes inconsistent with regard to the functioning of verbal short term memory (see Raghubar, Barnes, & Hecht, 2010, for a review), there is a general agreement about the relationship between children's arithmetical skills and their performance in visuo-spatial tasks (D'Amico & Guarnera, 2005; McLean & Hitch, 1999) and working memory tasks involving central executive abilities.

In a treatment study, D'Amico (2006) reported also that working memory training had a significant effect in improving visual spatial working memory abilities of children belonging to the experimental group as well as in the improvement of knowledge about quantity and spatial relationships. In this study, the visual spatial working memory tasks (now included in the PML working memory test battery by D'Amico and Lipari, 2012) required higher executive functions, asking children, at the same time, to maintain and to process visual spatial information. Thus, in the experimental group, improved executive visual spatial abilities were accompanied by improved knowledge about quantity and spatial relationships.

Indeed, many studies demonstrated that children with Arithmetical Learning Disabilities (ALD) do not always show difficulties in working memory tasks requiring lower executive resources, such as backward word span tasks or digit span tasks (D'Amico & Guarnera, 2005; Fuchs et al., 2008; Passolunghi & Cornoldi, 2008; Reuhkala, 2001; Siegel & Ryan, 1989; Swanson & Beebe-Frankenberger, 2004; van der Sluis, van der Leij, & de Jong, 2005), while they more consistently fail in tasks, such as the listening span task and the counting span task, requiring specific executive processes such as inhibitory control, updating, and attention switching, in line with models of working memory that focus on the importance of attentional control (e.g., Engle, 2002).

The relation between updating and inhibitory processes and later math outcomes have been investigated even in longitudinal studies (Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008; English, Barnes, Taylor, & Landry, 2009; Mazzocco & Kover, 2007). Blair and Razza (2007) found that inhibitory control in preschoolers predicted kindergarten mathematical abilities, such as basic numeracy, knowledge of shapes, quantity, relative size, addition, subtraction, and simple graphic relations. Bull et al. (2008) found that inhibitory processes in the preschool years predicted general learning outcomes in both math and reading at the end of the third year of primary school.

Mazzocco and Kover (2007), noting that the relationship between the executive processes and math was dependent on age, have suggested that strong executive skills in the early primary grades may help mathematical learning and performance, even if they are not necessarily associated with mathematical performance across age or across all mathematical tasks or all domains of mathematics.

Despite these limitations, the results so far described seem to indicate a general central executive deficit in children with ALD and this hypothesis is also supported by the high grade of comorbidity between mathematical and attention deficit hyperactivity disorder (Alloway & Passolunghi, 2011; Commodari, 2012; Gross-Tsur, Manor, & Shalev, 1996; Raghubar et al., 2010; Shalev, Manor, & Gross-Tsur, 1997).

Most arithmetical tasks, in fact, require children to simultaneously hold relevant information in memory (i.e., carrying relevant information in arithmetical problems) and discharge information which is no longer relevant (i.e., already processed numbers or non-task-relevant information). In this sense, a deficit in the effortful cognitive inhibition of information that disrupts working memory capacity may be considered one of the key factors in arithmetical disabilities.

An inhibition deficit could likely impair learning of different arithmetical skills. For example, Barrouillet, Fayol, and Lathulière (1997) propose that difficulties in the ability to suppress or inhibit irrelevant or non-pertinent information may give rise to disruption in the retrieval process of simple arithmetical facts in children with ALD (see also Conway & Engle, 1994; Geary, Brown, & Samaranayake, 1991; Geary, Hamson, & Hoard, 2000; Koontz, 1996). Similarly, Passolunghi, Cornoldi, and De Liberto (1999; see also Passolunghi & Cornoldi, 2000) showed that the arithmetical problem solving of children with ALD is significantly influenced by their poor memory recall for critical information and enhanced memory recall for irrelevant information of arithmetic problem texts. "Memory overload" resulting from the failure to inhibit irrelevant information could impair, for example, accurate representations of arithmetical word problem.

However, we know that attention is not a unitary process. Following classification by Nigg (2000), attentive tasks may involve effortful or automatic cognitive inhibition. The first is more executive in nature and more similar to what requested in working memory tasks, while the second is more automatic and require lower level attentional resources.

There are not so many studies examining both effortful or automatic attentional processes in children with ALD, but they seems to demonstrate that automatic attentional processes are less important for arithmetic skills.

Censabella and Noël (2007) in a study investigating the inhibition capacities of children with mathematical disabilities using effortful suppression tasks of irrelevant information from working memory, and automatic tasks of inhibition of prepotent responses, and a task of interference control, did not find evidence for impairment of children with ALD in none of the measures used.

A partially different result was reported by D'Amico and Passolunghi (2009) that showed that children with ALD suffered from a deficit in effortful inhibition mechanisms, measured rating intrusion errors in listening span task, while no evidence for dysfunction of the automatic inhibition processes was found. In this study, even though children with ALD were slower than controls in performing the tasks in general, they were sensitive to the same extent as the control group to the Negative Priming effect, an indicator of normal automatic inhibitory functions measuring the individual effort necessary to "reactivate" the previously inhibited information (see May, Kane, & Hasher, 1995, for a review).

No studies, so far, have investigated whether the training of basic attentive processes may have a positive effect in reducing arithmetic difficulties.

For this reason, a first aim of this study was to investigate the role of automatic attentional processes in arithmetical skills using a test-treatment-retest quasi experimental study, involving a total of 14 children with ALD assigned to experimental and control conditions.

Considering the important role played by attentional processes in working memory processes, we also wondered if the treatment of basic attentional processes may lead to an improvement of working memory function. No studies, to our knowledge, explored such an issue and the result is not taken for granted, since the working memory model involve executive attentional processes rather than basic or automatic attentional processes. The treatment studies we could refer to used the opposite method, studying if a working memory training may have effect on attentional processes. However, the results are not consistent: Klingberg, Forssberg, and Westerberg, 2002 using CogMed, a computerised training programme designed to enhance working memory (Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009), demonstrated training effects on working memory performances but not effect in choice reaction time task. On the contrary, CogMed training revealed to be useful for reducing inattentive behaviors in children with ADHD (Klingberg et al., 2005).

For this reason, a second aim of the present study has been to examine if training of basic attentive skills may lead to an improvement of working memory abilities.

Method

A test-treatment-retest quasi experimental design was adopted in order to study the efficacy of attentional treatment and its role in arithmetic achievement and in enhancing working memory abilities.

During the test phase, a group of children with ALD were administered with a series of arithmetical, attentional and working memory tasks. During the treatment phase, children assigned to the Experimental group followed the attentional training program described below, while children assigned to Control group carried out the normal scholastic activities. During the retest phase children were again administered with the same arithmetical, attentional and working memory tasks used in the test phase.

Participants and test-treatment-retest phases are described in more details below.

Participants

A group of teachers at a primary school of a Sicilian city was asked to identify all the pupils attending their classes (fourth and fifth grades) who showed scholastic difficulties in the arithmetical area. The teachers identified 25 children, 8-10 years old, with low arithmetical achievement. Participants in fourth and fifth grades were in an equivalent number and their socio-cultural level was medium/high. The next step in the group selection relied upon the use of standardized tests as described below.

Materials Used for Phase 1 - Test

Arithmetical Skills — The numerical comprehension and calculation processes of the whole group were assessed using 10 subtests drawn from the ABCA battery (Lucangeli et al., 1998). The 10 subtests included were: mental calculation, written calculation, retrieval of combinations and numerical facts, seven-table completion forward, four-table completion backward, number dictation, denomination of arithmetic symbols, insertion of symbols “ < ” and “ > ” between two numbers, increasing arrangements of numbers and decreasing arrangements of numbers.

The subtests *Mental Calculation* and *Written Calculation* measured child ability to solve basic operations. Children were required to perform calculations using the four basic arithmetical operations. The experimenter observed the participants, checking the use of appropriate rules and noting whether they used fingers to reach solutions. *Retrieval of Combinations and Numerical Facts* subtests assessed basic knowledge of addition and subtraction with one-digit numbers, multiplication tables, and other facts. The subtests required that children solved verbally a series of addition and subtraction combinations and used tables, recalling information from long-term memory. Child response was considered correct only if it is given immediately and not as a result of a computation. To perform *Tables Completion Forward* and *Backward* subtests, children were required to complete respectively the seven and the four tables. In *Number Dictation* subtest, the experimenter dictated a series of numbers asking children to write them on a piece of paper. In the subtest *Denomination of Arithmetic Symbols*, children were required to say the name of the main arithmetic symbols (+, -, x, ÷, <, >, =) and to show their use with some examples. The *Insertion of Symbols “ < ” and “ > ” Between Two Numbers* implied that children compared two numbers saying if the first was smaller/greater than the second. *Increasing* and *Decreasing Arrangements of Numbers* assessed semantic and syntactic knowledge. Children were required to order, according to an increase or decrease order respectively, numbers that were randomly displayed.

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These 10 subtests were scored following the author's recommendations as follows: (1) for each one is calculated the total number of correct answers and the execution time. The speed of execution is important only if the performance is correct. The raw score obtained in each subtest was compared to the ABCA normative data; (2) if the raw score was below the 10th percentile a standard score of "0" was given, otherwise if the raw score was above the 10th percentile a standard score of "1" was given (Lucangeli et al., 1998). Thus, the total arithmetical standard score could range from 0 to 10. Children who obtained a total standard score below 5 were then considered as "poor arithmetical achievers".

Furthermore, two reading tasks, considered to test different aspects of reading abilities, were administered to exclude all children with below average reading abilities from the poor arithmetic group. The first was a reading comprehension task (Prova MT; Cornoldi & Colpo, 1981) requiring pupils to read a passage to themselves and to answer 10 questions about its content. Following the norms of the MT test (Cornoldi & Colpo, 1981), the children that answered at least six questions correctly were considered to be normal readers. The second task, drawn from the Sartori, Job, and Tressoldi (1995) battery, required children to read a list of 48 non-words aloud. For the particular error distribution reported in normative data from the test, Sartori et al. (1995) suggest considering normal readers to be those children that perform at least 36 non-words correctly (> 5^{th} percentile).

Only 14 children, with a mean age of 9 years and 5 months (6 males, 8 females, M_{age} in months = 113.1, *SD* = 4.8), out of the initial 25, matched the criterion for diagnosis of poor arithmetical achievers. They showed normal reading ability (Reading Comprehension *M* = 7.6, *SD* = 1.6, Non-words Reading *M* = 40, *SD* = 5.4) but low achievement in the arithmetical area (total standard score *M* = 2.2, *SD* = 1.5).

Selected children were then assessed using a series of attentional and WM tasks, described below.

Attentional Tasks — Attentional abilities were evaluated using a computerized battery of tasks (Attenzione e Concentrazione; Di Nuovo, 2000) whose characteristics of reliability and validity have been successfully verified. The test involves 7 tasks that assess simple reaction time and choice reaction time, visual, visuo-spatial and auditory selectivity, digit span, divided attention, resistance to distraction, and attentive shifting.

The first *Simple Reaction Time* test measures the visual reaction time to unselected stimuli and consists in pushing a particular computer key following a visual stimulus.

The second test, *Speed and Accuracy*, measures the reaction time related with a choice; the task measures speed and accuracy of response to complex stimuli and requires the participant to push the key corresponding to one of a groups of stimuli.

The third test includes auditory and visual tasks; the *Auditory Recognition test* measures auditory selectivity and requires recognition of an auditory target among vocal distracters. The *Visual Recognition test* includes two different tasks: the first one requires recognition of a visual target among a group of distracters appearing in sequence, the second is a computerized version of symbols barrage test.

The fourth test, *Digit Span*, is an adjustment of classic Digit Span and – as in the well-known Wechsler Scale subtest – it includes two different tasks: digit forward and digit backward. The task requires repetition of each digit sequence exactly as it is given in Forward test, in reversed order in Backward test. The tasks measure simple immediate span attention (Lezak, 1995).

The fifth test values the *Divided Attention* by a double contemporaneous task (visual recognition and auditory recognition). To perform this task, children were asked to use both hands on the computer keyboard; children were instructed to push a particular key following a visual stimulus, a different key following an auditory stimulus.

The sixth test, *Colour Word Interference Task*, measures selectivity and the capacity to inhibit interference of non-pertinent signals. It is an adjustment of classic Stroop test that requires the naming of the colour of ink used to print a word describing a different colour (e.g., “red” written using blue ink), overcoming the interference originating from the habit of reading the word. The computerized adaptation of this test consists of two sequential tasks, the first - base line task - used as baseline and the second - interference task - as interference test. The difference between the scores obtained in the first and second tasks measures the subjects’ overcoming the distraction induced by irrelevant stimuli.

The seventh test measures the *Attentive Shifting* through two search tasks, the first one with verbal symbols (letters) and the other one with visual-spatial symbols (some rectangles, each of them having a small pole differently oriented). In both tasks, children were instructed to search and cross out, pushing a particular key, three targets in each matrix, so that they had to change attentive focus.

For each task, except Digit Span, the software stores data concerning three parameters: times, omissions and errors in answers. These 7 subtests were scored as follows: the raw score obtained in each subtest was compared to the Attenzione e Concentrazione normative data; if the raw score, even in just one parameter, was above the superior quartile (while for Digit Span, the raw score has to be below the superior quartile) a standard score of “0” was given, otherwise if the raw score was below the superior quartile a standard score of “1” was given. Thus, the *total attentive standard score* could range from 0 to 7. Furthermore, a score was calculated for each subtest, obtained by the sum of 0 and 1, given to times, errors and omissions of each task. A total score for the variables *times*, *errors* and *omissions* was calculated transversally to all tasks.

Working Memory Tasks — The central executive component of WM was measured using 4 tasks.

Listening span task: the experimenter reads a set of sentences aloud, asking the child to express a true/false judgment on the content of each sentence and to recall, at the end of the set, the last word of each sentence. Following the Daneman and Carpenter (1980) procedure, the listening span score corresponds to the longest set of sentences of which the last words have been correctly recalled.

Digit span backward: the experimenter reads a series of digits aloud, asking the children to recall the digit set in the reverse order. The score correspond to the maximum length of the digit set recalled in the reverse order of presentation.

Making verbal/colour trails: we used two making trails tasks for their high correlation with arithmetical abilities as demonstrated in the study by McLean and Hitch (1999). To perform the Verbal Trails task, children were asked to shift between numerical and alphabetical code, starting to recite the numerical sequence (from 1 to 11) and the alphabetical sequence (from A to M), alternating each number with the corresponding letter (i.e.: 1, A, 2, B, 3, C, etc.). The Verbal Trails score corresponds to the total time taken to perform the task. The making Colour Trails task (adapted by McLean & Hitch, 1999, from an adult version by D’Elia & Satz, 1989) consisted in the presentation of an A4 sheet on which 22 circles were printed. Half the circles were pink and half yellow. Each series of coloured circles contained a number from 1 to 11 and each number appeared once in the pink circles and once in the yellow circles. The children were asked to make a written trail, alternating colours and numbers, starting with "yellow 1" up to "pink 11". The Colour Trails score corresponds to the total time taken to complete the task.

Assignment of Children With ALD to Experimental and Control Groups

Children were assigned to Experimental and Control groups on the base of the scores obtained at the arithmetic, attentive and WM tests of the Phase 1.

Two ANOVAs performed on the arithmetic and attentive total scores and one MANOVA performed on the scores of different WM tasks revealed that the two groups did not differ significantly with respect to arithmetic ($F = .024$, $p > .05$), attentional ($F = .034$, $p > .05$), and WM ($F = 1.99$, $p > .05$) skills.

Moreover, children in Experimental group and Control group have been matched for age ($t = -.543$ $p > .05$) and gender.

The Experimental group included 4 girls and 3 boys (M_{age} in months = 112.43, $SD = 5.80$) and the Control group had the same gender composition (M_{age} in months = 113.86, $SD = 3.85$).

Materials Used for Phase 2 - The Attentional Training

Children in the Experimental group were submitted to training in individual sessions, in a computer laboratory, during school time. Training was performed at least 30 min per day, 4-6 days a week, for a period of 4 weeks.

In each training session seven tasks included in the Attenzione e Concentrazione (Di Nuovo, 2000) battery were presented: simple reaction time and choice reaction time, visual, visuo-spatial and auditory selectivity, digit span, divided attention, resistance to distraction, and attentive shifting.

The tasks used in the training session are the same as those included in the section test of Attenzione e Concentrazione (Di Nuovo, 2000) battery described above.

Unlike the section test, visual and verbal feedback and personal report were implemented in the computer program to increase compliance during the training. Specifically, on the screen appeared a cartoon character saying words of encouragement during each task and an outcomes report at the end of each task.

During the training session children in Experimental group missed different lessons each time, while children in the Control group attended regular lessons.

Materials Used for Phase 3 - Retest Phase

After the attentional training all children were administered again the same tasks used in the test phase and described above: the ABCA battery's subtests (Lucangeli et al., 1998), Attenzione e Concentrazione battery's tasks (Di Nuovo, 2000) and WM tasks.

Results

Test-retest changes in the group of subjects undertaking the treatment program (Experimental group) were compared to test-retest changes in the group of subjects not undertaking the treatment program (Control group).

Concerning arithmetic abilities, a series of 2 x 2 Analyses of Variance with between factor Group (Experimental group and Control group) and within factor Time (Pre-test and Post-test), were performed on the total arithmetical standard score and on total scores of tasks assessing the Numerical System (number dictation, denomination of arithmetic symbols, insertion of symbols " < " and " > " between two numbers, increasing arrangements of numbers and decreasing arrangements of numbers) and the Calculation System (mental calculation, written calculation, retrieval of combinations and numerical facts, seven table completion forward, four table completion backward).

Results, detailed in Table 1, showed that children in Experimental group improved more than Controls in total arithmetical standard score (F = 4.941, p = .046, Partial η^2 = .29). However, this result was principally due to the improvement of standard scores in the Numerical System tasks (F = 15.187, p = .002, Partial η^2 = .56), while treatment had no effect on standard scores in Calculation System tasks (F = .750, p > .05, Partial η^2 = .06).

A second series of 2 x 2 ANOVAs was performed on attentional tasks (total score, scores on each attentive subtest, overall times, errors and omissions scores).

Results revealed again that children in the Experimental group improved more than Controls in total attentive score (F = .533, p = .025); concerning each attentive subtest, a significant treatment effect was pointed out only for the Simple Reaction Time (F = 8.333, p = .014), while a tendency to statistical significance of treatment was evidenced for Speed and Accuracy (F = 3.868, p = .073); a significant treatment effect was proved also for the Overall Times score (F = 10.226, p = .008), evidencing that children in Experimental group improved their speed in all considered tasks. No effect of treatment was evidenced in any of the other attentional tasks.

The third series of analysis was performed on working memory scores. In this case, a multivariate 2 x 2 ANOVA performed on all the WM scores failed to reveal a significant treatment effect (F = .57, p > .05). ANOVAs performed on scores of each WM task did no revealed any significant treatment effect on WM abilities.

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Table 1

Performances of Two Groups Before and After the Treatment in All Considered Tasks, and Results of Group X Time ANOVAs

	Treatment Group				Control Group				ANOVAs’ results					
	Before		***After***		***Before***		***After***		**Time**		**Group**		***Group X Time***	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***F***	***p***	***F***	***p***	***F***	***p***
ABCA test														
Total Arithmetic Score	2.29	1.70	6.28	2.14	2.42	1.72	4.43	2.37	44.47	<.001	*.778*	*ns*	4.941	*.046*
Numeric system	1.14	0.69	3.00	0.82	1.57	0.98	2.14	1.35	54.188	<.001	.182	*ns*	15.187	.002
Calculation system	1.14	1.21	3.29	1.80	0.86	0.90	2.29	1.89	18.750	.001	.862	*ns*	.750	*ns*
Working memory tasks														
Listening span task	1.92	0	3.28	0.55	2.21	0.70	*2.93*	0.5	31.148	<.001	.032	*ns*	3.000	*ns*
Digit span backward	3.43	0.53	4.14	0.89	*2.57*	0.53	*3.57*	0.97	9.191	.010	5.882	.032	.255	*ns*
Making verbal trails	56.71	14.32	56.14	11.61	59.14	19.17	*54.00*	20.04	.387	*ns*	.000	*ns*	.248	*ns*
Making colours trails	62.00	19.39	51.86	9.14	80.86	30.25	*75.71*	24.26	1.125	*ns*	5.161	.042	.120	*ns*
Attentional tasks														
Total Attentive Score	2.57	1.40	5.71	0.95	2.43	1.51	*3.57*	1.27	30.000	<.001	*3.959*	*ns*	.533	*.025*
Simple Reaction Time	0.28	0.49	0.86	0.38	0.43	0.53	*0.28*	0.48	3.000	*ns*	.931	*ns*	8.333	.014
Speed and Accuracy	2.71	1.11	4	0	3.14	1.07	*3.43*	0.97	9.553	.009	*.029*	*ns*	3.868	.073
Auditory, Visual, and Visuo-Spatial Recognition	6.14	2.11	7.71	1.60	6	1.73	*5.86*	1.57	1.250	*ns*	2.056	*ns*	1.800	*ns*
Digit Span	2.43	1.13	3	0	2	1.54	*2.86*	0.38	5.172	.042	.828	*ns*	.207	*ns*
Divided Attention	3.28	0.75	4.14	0.90	2.86	1.07	*3.71*	0.49	12.706	.004	*1.317*	*ns*	.000	*ns*
Colour Word Interference	5.57	0.79	6	0	5.71	0.49	*5.86*	0.38	2.087	*ns*	*.000*	*ns*	.522	*ns*
Attentive Shifting	2.57	1.39	4	0	2.28	1.50	*3.71*	0.75	14.634	.002	*.407*	*ns*	.000	*ns*
Overall Times’ score[a]	6.29	2.56	10.43	1.13	7.00	1.73	*7.14*	2.27	11.739	.005	2.199	*ns*	10.226	.008
Overall Errors’ score[a]	7.86	1.21	8.14	0.69	7.29	1.70	*8.00*	0.58	1.361	*ns*	.682	*ns*	.250	*ns*
Overall Omissions’ score[a]	6.29	1.11	8.14	0.69	6.14	2.12	*7.71*	0.95	14.281	.003	*.271*	*ns*	.099	*ns*

[a]The increase of the scores indicates an improvement of the performance (see *Materials Used for Phase 1 - Test*).

Discussion

The present study showed that intensive computerized attention training increased basic attentive skills in children with ALD. In particular, children with ALD showed a significant reaction times reduction in attentional tasks. This result demonstrated that also very basic automatic skills such as reaction time may be modified by treatment, contrary to what was affirmed by Sohlberg, McLaughlin, Pavese, Heidrich, & Posner (2000). This is a very interesting result if we consider that reduced reaction times may reflect an improvement in speed of processing, a very basic cognitive ability, important for a whole range of higher level cognitive skills, and in particular for arithmetic learning, since a number of studies demonstrated that children with ALD and children with typical development often differ each other for their speed of processing abilities (see D'Amico & Passolunghi, 2009, for a short overview).

On the other hand, another important result of the present study is that attention training produced a significant improvement on number processing scores of children with ALD. Thus, it is possible that the attentional training increase speed of processing that, in turn, improve the abilities of number processing. These results partially support the findings of Ashkenazi and Henik (2012). These authors showed that attentional training in university students with developmental dyscalculia (DD) improved attention abilities. However, in contrast to our findings, they found no improvement either in tasks requiring numerical or calculation abilities. However, this study differs from ours both for the type of training used and for the age of the participants, as it is known that the relation between attentive processes and ability in maths is dependent on age (Mazzocco & Kover, 2007; Raghubar et al., 2010).

Finally, our results did not evidence any improvement of WM performance of children with ALD as effect of attentive training. This result is somewhat coherent with Klingberg et al.'s (2002) study demonstrating that a WM training does not improve choice reaction time task.

In conclusion, the present study opens up a new treatment perspective in the field of arithmetic learning difficulties and supports the literature demonstrating the influence of basic attentive skills on arithmetical abilities (Fuchs et al., 2005).

There are however some limitations, since:

1. treatment effects were limited to very basic attentional skills and not to higher level one
2. the treatment significantly improved only numerical abilities and not calculation ones
3. the treatment had no effect in improving working memory abilities.

Looking deeply into these results, it is clear that they are all interconnected: indeed, while attentional training improved basic attentional abilities, no effect of treatment were observed for higher level attentional abilities such as spatial recognition, digit span, divided attention, colour word interference or attentive shifting.

Since literature discussed in the introduction demonstrated that calculation processes relies on higher attentional abilities more than on lower level and automatic processes, it is not surprising that no improvement of high attentional processes corresponds to no improvement of calculation abilities.

Similarly, literature investigating the relationships between attentional processed and working memory affirms that working memory involves higher level and executive attentional processes, rather than lower level and automatic ones (Baddeley, 1986; Conway, Tuholski, Shisler, & Engle, 1999; Cowan, 1995; Kane, Bleckley, Conway,

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& Engle, 2001); thus, again, no improvement of high attentional processes, no improvement in working memory abilities.

With the data available in this study it is not possible to say why the treatment had no effect in higher level attentional abilities; it is highly probable that this result could be afforded in a longer and more intensive training, but only future treatment study may help to answer to this question.

With the available result, we can only affirm that a reduction in simple reaction time lead to improved number processing abilities.

Since we know that children with ALD may differ from each other, showing selective or more important number processing or calculation difficulties, this is an important result in a clinical perspective. Indeed, it might suggest strategies for planning individualized training programs, relying, case by case, on automatic or executive attentional processes. In other words, it might suggest that the treatment for children with numerical processing problems could be focused in simple reaction times tasks, processing speed tasks and so on, whereas treatment for children with calculation problems could be focused on inhibition of irrelevant information, strategies planning and other executive processes tasks.

We hope that further studies will support and extend our results in order to give more strength to this very useful research perspective.

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Competing Interests

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References

Alloway, T. P., & Passolunghi, M. C. (2011). The relationship between working memory, IQ, and mathematical skills in children. *Learning and Individual Differences, 21*, 133-137. doi:10.1016/j.lindif.2010.09.013

Ashkenazi, S., & Henik, A. (2012). Does attentional training improve numerical processing in developmental Dyscalculia? *Neuropsychology, 26*(1), 45-56. doi:10.1037/a0026209

Baddeley, A. D. (1986). *Working memory*. Oxford, United Kingdom: Oxford University Press.

Barrouillet, P., Fayol, M., & Lathulière, E. (1997). Selecting between competitors in multiplication tasks: An explanation of the errors produced by adolescents with learning difficulties. *International Journal of Behavioral Development, 21*, 253-275. doi:10.1080/016502597384857

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*, 647-663. doi:10.1111/j.1467-8624.2007.01019.x

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 7 years. *Developmental Neuropsychology, 33*, 205-228. doi:10.1080/87565640801982312

Censabella, S., & Noël, M.-P. (2007). The inhibition capacities of children with mathematical disabilities. *Child Neuropsychology, 14*, 1-20. doi:10.1080/09297040601052318

Commodari, E. (2012). Attention skills and risk of developing learning difficulties. *Current Psychology, 31*, 17-34. doi:10.1007/s12144-012-9128-3

Conway, A. R. A., & Engle, R. W. (1994). Working memory and retrieval: A resource-dependent inhibition model. *Journal of Experimental Psychology: General, 123*, 354-373. doi:10.1037/0096-3445.123.4.354

Conway, A. R. A., Tuholski, S. W., Shisler, R. J., & Engle, R. W. (1999). The effect of memory load on negative priming: An individual differences investigation. *Memory & Cognition, 27*, 1042-1050. doi:10.3758/BF03201233

Cornoldi, C., & Colpo, G. (1981). *La verifica dell'apprendimento della lettura*. Firenze, Italy: Organizzazioni Speciali.

Cowan, N. (1995). *Attention and memory: An integrated framework*. New York, NY: Oxford University Press.

D’Amico, A. (2006). Potenziare la memoria di lavoro per prevenire l'insuccesso in matematica. *Età Evolutiva, 83*, 90-99.

D’Amico, A., & Guarnera, M. (2005). Exploring working memory in children with low arithmetical achievement. *Learning and Individual Differences, 15*, 189-202. doi:10.1016/j.lindif.2005.01.002

D’Amico, A., & Lipari, C. (2012). *La batteria PML per la misurazione della memoria di Lavoro*. Rome, Italy: Firera & Liuzzo Group.

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. doi:10.1016/j.lindif.2009.01.001

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19*, 450-466. doi:10.1016/S0022-5371(80)90312-6

D’Elia, L., & Satz, P. (1989). *Color trails 1 and 2.* Odessa, FL: Psychological Assessment.

Di Nuovo, S. (2000). *Attenzione e concentrazione.* Trento, Italy: Erickson.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science, 11*, 19-23. doi:10.1111/1467-8721.00160

English, L. H., Barnes, M. A., Taylor, H. B., & Landry, S. H. (2009). Mathematical development in spina bifida. *Developmental Disabilities Research Reviews, 15*, 28-34. doi:10.1002/ddrr.48

Fuchs, L. S., Compton, D. L., Fuchs, D., Paulsen, K., Bryant, J. D., & Hamlett, C. L. (2005). The prevention, identification, and cognitive determinants of math difficulty. *Journal of Educational Psychology, 97*(3), 493-513. doi:10.1037/0022-0663.97.3.493

Fuchs, L. S., Fuchs, D., Stuebing, K., Fletcher, J. M., Hamlett, C. L., & Lambert, W. (2008). Problem solving and computational skill: Are they shared or distinct aspects of mathematical cognition? *Journal of Educational Psychology, 100*, 30-47. doi:10.1037/0022-0663.100.1.30

Geary, D. C., Brown, S. C., & Samaranayake, V. A. (1991). Cognitive addition: A short longitudinal study of strategy choice and speed-of-processing differences in normal and mathematically disabled children. *Developmental Psychology, 27*(5), 787-797. doi:10.1037/0012-1649.27.5.787

Geary, D. C., Hamson, C. O., & Hoard, M. K. (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. doi:10.1006/jecp.2000.2561

Gross-Tsur, V., Manor, O., & Shalev, R. S. (1996). Developmental dyscalculia: Prevalence and demographic feature. *Developmental Medicine and Child Neurology, 38*, 25-33.

Kane, M. J., Bleckley, M. K., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130*, 169-183. doi:10.1037/0096-3445.130.2.169

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., . . . Westerberg, H. (2005). Computerized training of working memory in children with ADHD: A randomized, controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*, 177-186. doi:10.1097/00004583-200502000-00010

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology, 24*(6), 781-791. doi:10.1076/jcen.24.6.781.8395

Koontz, K. L. (1996). Identifying simple numerical stimuli: Processing inefficiencies exhibited by arithmetic learning disabled children. *Mathematical Cognition, 2*(1), 1-24. doi:10.1080/135467996387525

Lezak, M. D. (1995). *Neuropsychological assessment*. Oxford, United Kingdom: Oxford University Press.

Lucangeli, D., Tressoldi, P., & Fiore, C. (1998). *Test ABCA – Abilità di calcolo aritmetico*. Trento, Italy: Erickson.

May, C. P., Kane, M. J., & Hasher, L. (1995). Determinants of negative priming. *Psychological Bulletin, 118*(1), 35-54. doi:10.1037/0033-2909.118.1.35

Mazzocco, M. M., & Kover, S. T. (2007). A longitudinal assessment of executive function skills and their association with math performance. *Child Neuropsychology, 13*, 18-45. doi:10.1080/09297040600611346

McLean, J. F., & Hitch, G. J. (1999). Working memory impairments in children with specific arithmetic learning difficulties. *Journal of Experimental Child Psychology, 74*(3), 240-260. doi:10.1006/jecp.1999.2516

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin, 126*, 220-246. doi:10.1037/0033-2909.126.2.220

Passolunghi, M. C., & Cornoldi, C. (2000). Working memory and cognitive abilities in children with specific difficulties in arithmetic word problem solving. *Advances in Learning and Behavioral Disabilities, 14*, 155-178.

Passolunghi, M. C., & Cornoldi, C. (2008). Working memory failures in children with arithmetical difficulties. *Child Neuropsychology, 14*, 387-400. doi:10.1080/09297040701566662

Passolunghi, M. C., Cornoldi, C., & De Liberto, S. (1999). Working memory and intrusions of irrelevant information in a group of specific poor problem solvers. *Memory & Cognition, 27*, 779-790. doi:10.3758/BF03198531

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences, 20*, 110-122. doi:10.1016/j.lindif.2009.10.005

Reuhkala, M. (2001). Mathematical skills in ninth-graders: Relationship with visuo-spatial abilities and working memory. *Educational Psychology, 21*, 387-399. doi:10.1080/01443410120090786

Sartori, G., Job, R., & Tressoldi, P. E. (1995). *Batteria per la valutazione della dislessia e della disortografia evolutiva*. Firenze, Italy: Organizzazioni Speciali.

Shalev, R. S., Manor, O., & Gross-Tsur, V. (1997). Neuropsychological aspects of developmental dyscalculia. *Mathematical Cognition, 3*, 105-120. doi:10.1080/135467997387434

Siegel, L. S., & Ryan, E. B. (1989). The development of working memory in normally achieving and subtypes of learning disabled children. *Child Development, 60*, 973-980. doi:10.2307/1131037

Sohlberg, M. M., McLaughlin, K. A., Pavese, A., Heidrich, A., & Posner, M. I. (2000). Evaluation of attention process training and brain injury education in persons with acquired brain injury. *Journal of Clinical and Experimental Neuropsychology, 22*, 656-676. doi:10.1076/1380-3395(200010)22:5;1-9;FT656

Swanson, H. L., & Beebe-Frankenberger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology, 96*, 471-491. doi:10.1037/0022-0663.96.3.471

Thorell, L. B., Lindqvist, S., Bergman, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science, 12*(1), 106-113. doi:10.1111/j.1467-7687.2008.00745.x

van der Sluis, S., van der Leij, A., & de Jong, P. F. (2005). Working memory in Dutch children with reading- and arithmetic-related LD. *Journal of Learning Disabilities, 38*, 207-221. doi:10.1177/00222194050380030301

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