Trends in Psychology / Temas em Psicologia
ISSN 2358-1883 (online edition)
DOI: 10.9788/TP2018.3-05En

Article

Resolution of Arithmetic Problems, Processing Speed and Working Memory in Children

Jesica Formoso[*, 1, 2]
Orcid.org/0000-0003-3062-4036
Silvia Jacubovich[1]
Orcid.org/0000-0002-6180-6011
Irene Injoque-Ricle[1, 2]
Orcid.org/0000-0002-7043-677X
Juan Pablo Barreyro[1, 2]
Orcid.org/0000-0002-1606-1049

[1]*Universidad de Buenos Aires, Buenos Aires, Argentina*
[2]*CONICET – Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires, Argentina*

Abstract

This study sought to characterize the performance of children in an arithmetic word problem test regarding choice of strategy, type of operation and age. It also analyzed possible links between the resolution of addition and subtraction problems, processing speed and working memory. Four tests were administered with 233 children of 4, 5 and 6 years of age from Buenos Aires, Argentina: (a) an arithmetic word problem test, (b) the Corsi block tapping test, (c) a digit span test, and (d) a reaction time task. Results showed a significant increase in precision when solving arithmetic word problems between ages 4 and 6. While 4-year-old children relied mainly on visual aids to solve the problems, 5 and 6-year-olds incorporated finger counting and mental calculation as efficient strategies. Arithmetic scores were associated with both verbal and visuospatial working memory scores. While only the visuospatial component predicted accuracy in the children that depended on visual aids or finger counting, both components of working memory predicted the performance of the children that primarily used mental calculation.

Keywords: Arithmetic problems, working memory, processing speed, children.

Resolução de Problemas Aritméticos, Velocidade de Processamento e Memória de Trabalho em Crianças

Resumo

A presente pesquisa procurou estudar o desempenho das crianças na resolução de problemas aritméticos ao analisar à estratégia, o tipo de operação e a idade. Também se analisou possíveis relações entre a

* Mailing address: Av. Hipólito Yrigoyen, 3242, C1174 CABA, Argentina. E-mail: jformoso@psi.uba.ar, sjacubov@psi.uba.ar, iinjoque@psi.uba.ar and jpbarreyro@gmail.com
Financing: Secretaría de Ciencia y Técnica, Universidad de Buenos Aires.

resolução de adições e subtrações, a velocidade de processamento e a memória de trabalho. Quatro testes foram administrados a 233 crianças de 4, 5 e 6 anos: (a) Um de problema aritmético, (b) A tarefa de blocos de Corsi, (c) A retenção de dígitos, (d) Uma tarefa de tempo de reação. Os resultados mostraram um aumento significativo na precisão para resolver problemas de aritmética entre 4 e 6 anos. Aos 4 anos a estratégia mais eficaz foi o uso dos recursos visuais, e aos 5 e 6 anos foram mais eficazes a contagem com os dedos e o cálculo mental. As pontuações nos problemas aritméticos associaram-se com a capacidade de memória de trabalho verbal e viso-espacial. No caso das crianças que usaram recursos visuais ou a contagem com os dedos para resolver operações, o componente da memória de trabalho que significativamente previu o seu desempenho foi o viso-espacial. Enquanto as crianças que fizeram uso do cálculo mental, os dois componentes da memória de trabalho previram o seu desempenho.

Palavras-chave: Problemas aritméticos, memória de trabalho, velocidade de processamento, crianças.

Resolución de Problemas Aritméticos, Velocidad de Procesamiento y Memoria de Trabajo en Niños

Resumen

El presente estudio buscó caracterizar el desempeño de niños en problemas aritméticos teniendo en cuenta la estrategia utilizada, el tipo de operación y la edad. Se analizó, además, los posibles *vínculos entre* la resolución de operaciones, la velocidad de procesamiento y la memoria de trabajo. Se administraron cuatro pruebas a 233 niños de 4, 5 y 6 años de edad de Buenos Aires, Argentina: (a) problemas aritméticos, (b) bloques de Corsi, (c) span de dígitos, (d) tiempos de reacción. Se observó un aumento en la precisión en problemas aritméticos entre los 4 y los 6 años. Los niños de 4 años recurrieron principalmente a ayudas visuales, mientras que los niños de 5 y 6 años utilizaron mayormente el conteo de dedos y el *cálculo mental. Los* puntajes en problemas aritméticos se asociaron con los obtenidos para los componentes verbal y viso-espacial de la memoria de trabajo. En el caso de los niños que dependían de ayudas visuales o conteo con dedos para resolver las operaciones el componente que predijo de forma significativa su rendimiento fue el viso-espacial, mientras que ambos componentes de la memoria de trabajo predijeron el rendimiento de aquellos niños que utilizaban principalmente el *cálculo mental.*

Palabras clave: Problemas aritméticos, memoria de trabajo, velocidad de procesamiento, niños.

The ability to solve arithmetic problems fluently and efficiently is considered a basic and necessary achievement for the posterior development of more complex mathematical skills (Geary, Frensch, & Wiley, 1993; Mazzocco, Devlin, & McKenney, 2008; Price, Mazzocco, & Ansari, 2013). Arithmetic problem solving includes the encoding of visual or verbal information (depending of the format in which the problems are presented), the identification and retrieval from the long-term memory of subtraction, addition, multiplication or division algorithms, as well as their implementation (DeStefano & LeFevre, 2004; LeFevre & Bisanz, 1996). Previous studies have shown that during their development children become more efficient and accurate when solving these problems (Geary & Brown, 1991; Price et al., 2013). Furthermore, some studies have described a developmental change in the strategy children use. This varies from explicit strategies, such as using material elements, back counting processes, finger counting and verbal counting, to implicit strategies, such as silent counting and the automatic retrieval of numerical combinations (e.g. 2 + 2 = 4) from the long-term memory (Ashcraft, 1982; Carpenter & Moser, 1982, 1984; Geary, Hoard, Byrd-Craven, & DeSoto, 2004; Groen & Resnick, 1977; Ostad, 2000).

The modeling of elements to solve arithmetic problems involves the representation of the operands, their combination in the case of addition or their decomposition in the case of subtraction, and the counting of the resulting set of elements. Finger counting is considered a necessary step in acquiring number words, as it provides a constant physical reference (Andres, Olivier, & Badets, 2008; Crollen & Noël, 2015). More sophisticated counting strategies include counting on from the larger operand (addition) or, from the larger cipher, counting down a number of units equal to the other operand (subtraction), which have been observed in 4-year-olds, however, are common strategies in 6-year-olds (Carpenter & Moser, 1984). Several authors propose that mastering efficient counting provides the basis for the acquisition of arithmetic skills (Carpenter & Moser, 1984; Crollen & Noël, 2015; Geary, 2011; Gray & Reeve, 2014; Hubber, Gilmore, & Cragg, 2014; LeFevre et al., 2006; Moeller, Martignon, Wessolowski, Engel, & Nuerk, 2011; Watts, Duncan, Siegler, & Davis-Kean, 2014). Eventually, the constant use of counting to solve addition and subtraction tasks leads to the construction of representations in the long-term memory called arithmetic facts, which are recalled automatically when performing mathematical calculations (Ashcraft, 1982; Grabner et al., 2009; LeFevre et al., 2013; Ostad, 2000). The use of silent counting and arithmetic fact retrieval allow children to mentally solve addition and subtraction problems, without the use of explicit strategies (Berg, 2008; Geary et al., 2004).

Siegler, Adolph, and Lemaire (1996) indicated that the specific moment each child starts using a particular strategy varies significantly from one child to another, and also that the majority of children in kindergarten, first and second grades use different strategies at different times, as well as the combination of a number of them simultaneously. These authors suggested that the changes that occur in development regarding the use of strategies can be summarize in the acquisition of new strategies, the change in the frequency with which they use the existing ones, the improvement in performance when executing them, and the choice of the most adaptive strategy depending on the situation. For example, Siegler (1989) found that between the ages 4 and 7, in additions with single digit operands, children used arithmetic fact retrieval, counting or guessing to solve them. The frequency of the last two strategies tended to decrease steadily towards the start of the second grade, while the use of arithmetic facts tended to increase.

Considering the characteristics of arithmetic problem solving, cognitive abilities, specifically working memory and processing speed, may be related to a subject's proficiency in this area (Berg, 2008; DeStefano & LeFevre, 2004; Fuchs et al., 2012; Fuchs et al., 2006; Geary, 2011; Geary et al., 2004; Hubber et al., 2014; McLean & Hitch, 1999; Noël, 2009).

Working memory is a limited capacity, active memory system, responsible for the temporary storage and concurrent processing of information (Baddeley, 2010; Baddeley & Hitch, 1974). One of the most studied models regarding working memory is the one proposed by Baddeley and Hitch (1974) which describes a cognitive system consisting of an amodal central executive that supervises two slave subsystems: the phonological loop, in charge of keeping verbal information active, and the visuospatial sketchpad, which sustains visuospatial information for short periods of time. The central executive, meanwhile, identifies the necessary processes to manipulate the information, activates them and monitors their correct functioning.

Alloway, Gathercole, and Pickering (2006) studied the development of working memory in children of 4 to 11 years of age. They assessed each component in charge of the storage and manipulation of verbal and visuospatial information in the working memory. The study showed a constant improvement in performance from ages 4 to 11. It also demonstrated that the structural organization of working memory described for adults is valid for children of at least 4 years of age and that it remains constant throughout childhood.

Regarding arithmetic problems, working memory is thought to be involved in the visual and phonological coding of the relevant information and, in turn, in keeping this information active for subsequent processing (Berg, 2008; DeStefano & LeFevre, 2004; Geary et al., 2004; Raghubar, Barnes, & Hecht, 2010). With multistep operations, working memory may also be in charge of sustaining any partial results to be integrated (Fürst & Hitch, 2000). General working memory capacity has been associated with accuracy when solving simple addition and subtraction arithmetic problems (Adams & Hitch, 1997; Hecht, 2002; Seyler, Kirk, & Ashcraft, 2003), even in preschool children with no knowledge of formal mathematics (Rasmussen & Bisanz, 2005). It has also been related to the selection of a strategy, as higher working memory capacity has been linked to the use of more sophisticated strategies, such as mental arithmetic, while lower working memory capacity has been associated with the predominant use of finger counting (Barrouillet & Lépine, 2005; Geary et al., 2004; Imbo & Vandierendonck, 2007). This may be explained by the fact that the use of a material support reduces the working memory load (Alibali & DiRusso, 1999; Costa et al., 2011). Imbo and Vandierendonck (2007) showed that, even though manipulating the working memory load interfered with children's effectiveness to solve arithmetic problems, the relation between working memory resources and arithmetic varied with age. According to these authors, when children become more skilled at solving arithmetic problems by retrieval of arithmetic facts and more efficient counting strategies, they do not depend as strongly on working memory resources.

The verbal component of working memory, the phonological loop, has been specifically related to exact calculations in addition and subtraction (Lemaire, Abdi, & Fayol, 1996). It is also related to counting and keeping all relevant information active (Fürst & Hitch, 2000), especially during an ongoing mental calculation (Trbovich & LeFevre, 2003). Noël, Désert, Aubrun, and Seron (2001) found associations between the verbal working memory capacity and children's ability to solve arithmetic problems presented visually, in the absence of a significant relation with visuospatial working memory. For this reason, the authors suggested that when the digits are presented visually, the Arabic representation is recoded phonologically (turned into the corresponding verbal label).

However, other studies have found associations between visuospatial working memory and the use of counting procedures during the execution of multi-digit addition (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Trbovich & LeFevre, 2003). McKenzie, Bull, and Gray (2003) showed that the disruption of the phonological loop by articulatory suppression affected the ability of children of 8 and 9 years of age to solve single-digit operations, while it had little effect on those aged 6 and 7 years. Simultaneously, they found the opposite pattern when interfering with visuospatial working memory. That is, there was a significant effect on the ability of the younger children to perform arithmetic problems, however, not on that of the older children. In addition, the authors established a significant positive association between the scores of the older children in a verbal working memory task and in an arithmetic task. They concluded that 6-year-old children rely mainly on visuospatial working memory to keep information from the operations active and manipulate it. The ability to keep it active through subvocal rehearsal is not sufficient at this age for them to resort primarily to verbal strategies, On the contrary, when children turn 8 or 9 years of age, verbal strategies become dominant in solving this type of problem.

Another cognitive skill that has been linked to children's performance in arithmetic is information processing speed, the velocity with which a subject executes a simple and relatively automated cognitive task, such as in a basic reaction time test (Jensen, 2006). Several authors have identified it as an efficient cognitive predictor of arithmetic calculation in children (Berg, 2008; Bull & Johnston, 1997; Fuchs et al., 2006; Geary, Hamson, & Hoard, 2000; Swanson & Beebe-Frankenberger, 2004). Processing speed, together with working memory, increases with age until early adulthood (Droit-Volet & Zélanti, 2013). Studies suggest that the developmental changes in processing speed may protect other cognitive processes from the interference of irrelevant information, which could also explain age-related changes in these processes (Luna, Garver, Urban, Lazar, & Sweeney, 2004). For example, it is possible that higher processing speed relates to greater availability of short-term memory, as the elements that have to be active are used and discarded faster (Case, Kurland, & Goldberg, 1982). However, evidence suggests that the speed with which children implement computational strategies contributes to their arithmetic skills, independent of working memory capacity (Fuchs et al., 2012; Fuchs et al., 2006). Processing speed may also be related to the consolidation of arithmetic facts in the long-term memory. Slow processing speed may result in the representation of each operand in the working memory fading faster, preventing them from being associated with the correct response and stored in the long-term memory (Bull & Johnston, 1997; Geary & Brown, 1991).

Studies suggest that a rudimentary understanding of addition and subtraction when entering elementary school predicts later mathematical performance (Geary, 2011; Groen & Resnick, 1977) and that the efficiency of the strategies used is related to the subsequent learning of more complex arithmetic skills (Geary et al., 2004; Price et al., 2013). Furthermore, deficits in arithmetic problem solving have been related to mathematical difficulties in school-age children (Geary et al., 2000; Hanich, Jordan, Kaplan, & Dick, 2001). The majority of studies assessed this mathematical ability by presenting children with arithmetic problems using Arabic numerals (e.g. McKenzie et al., 2003). Previous studies have suggested that 5 and 6-year-old children are beginning to learn this representation of numbers (Knudsen, Fischer, Henning, & Aschersleben, 2015; von Aster & Shalev, 2007), which could affect their performance in the task independent of their ability to solve arithmetic problems. For these reasons, analyzing the development of this particular skill at an early age, using arithmetic word problems instead of Arabic numerals, and studying the association of it with other cognitive abilities that may influence it, could help to identify early indicators of difficulty in mathematics and design comprehensive interventions.

The aim of this study was to characterize the performance in arithmetic word problems of 4 to 6-year-old children, specifically regarding strategy choice and age. An additional aim was to identify possible associations between proficiency in arithmetic problem solving and processing speed, as well as verbal and visuospatial working memory. It was hypothesized that the efficiency with which children solve arithmetic problems increases with age and that this development is accompanied by a change in the use of strategies. It was further predicted that working memory and processing speed would be directly and positively related to arithmetic word problem resolution and to the strategy used.

Method

Participants

The sample consisted of 233 children of 4, 5 and 6 years of age from a private school in Ciudad de Buenos Aires, Argentina (see Table 1 for descriptive statistics), selected by non-probabilistic, convenience sampling. The school that participated volunteered to do so. The children that participated were those that were authorized by their parents.

The parents were informed of the scope of the study and the type of tests that would be used, after which they were asked to give their written consent for their children to participate. The information gathered was anonymous and confidential. Children with hearing or speech deficits, neurological or psychiatric disorders informed by the school, and with IQs lower than 80 were excluded from the study.

Materials

Arithmetic Word Problems (ad-hoc). As no specific task has been adapted and validated for local children aged 4 to 6 years, to assess the resolution of arithmetic problems one was design ad hoc. In this test, the examiner recited 16 simple arithmetic word problems out loud that included both additions and subtractions of

Table 1
Descriptive Statistics for Age and Sex

Age	*n*	Sex (%)		Age in months			
		Female	Male	Mean	*SD*	Min	Max
4 years	84	62	38	52.82	3.05	46	58
5 years	73	52	48	66.78	3.45	60	71
6 years	76	46	55	76.80	3.76	72	83

Note. *M* = Mean; *SD* = Standard deviation; Min = Minimum value; Max = Maximum value.

increasing difficulty, 4 of which were administered at the beginning as training items. While the latter were not regarded for the statistical analyses, their correct resolution was necessary to continue with the task itself. Regarding the structure of the items, each included a maximum of three propositions, and the operations were performed on elements of the same type (adding apples to apples, pencils to pencils), avoiding as much irrelevant information as possible, such as names or places. The aim was to facilitate the construction of the mental representation of the text as much as possible. Each item is transcribed below.

Additions:

1. If you have two cookies in a blue tin and two cookies in a red tin, how many cookies do you have?
2. If you have three balloons and your mom buys you four more, how many balloons do you have?
3. If your dad gives you six pieces of candy and a friend gives you three more, how many pieces of candy do you have?
4. If you have six blue crayons and five red ones, how many crayons do you have?
5. If you have nine cookies in a tin and your mom adds three more, how many cookies are there?
6. If you have three green marbles, three blue marbles and two red ones, how many marbles do you have?

Subtractions:

1. If you have four cars and you lose two, how many cars do you have left?
2. If you have six balloons and three get blown away, how many balloons do you have left?
3. If you have eight pieces of candy and you eat three, how many pieces of candy do you have left?
4. If you have ten marbles and you give five to a friend, how many marbles do you have left?
5. If you have twelve cookies and you eat two of them, how many cookies do you have left?
6. If you have eight crayons, you give three to one friend and two to another, how many crayons do you have left?

The responses were assigned to one of four categories: Error, Correct response through visual aids, Correct response through finger counting and Correct response through mental calculation. In the event that the child did not resolve the problem mentally and did not resort to finger counting spontaneously, he or she was encouraged to do so, and, if neither of these strategies were effective, the examiner presented the objects included in the word problem on a screen as a visual aid (see Figure 1). Finally, if the child could not achieve a correct response the trial was registered as an error. A total score was registered for each child (maximum of 12 points).

Visuospatial Working Memory (Corsi, 1972). This component was assessed through a computerized version of the traditional Corsi block tapping test, which was designed and administered through OpenSesame (Mathôt, Schreij, & Theeuwes, 2012), an open source software program for the design of psychological experiments. In this particular case, nine white identical squares positioned unevenly and spatially separated were presented on a computer screen. Some of them lit up one at a

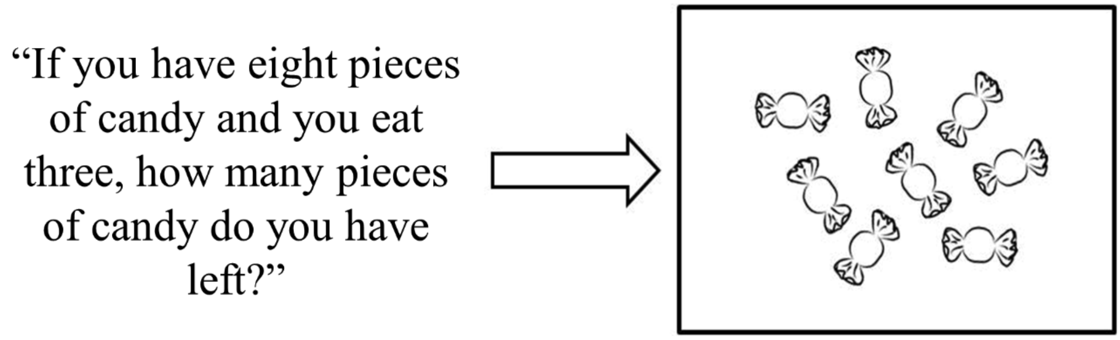

Figure 1. Example of visual aid for one of the arithmetic word problems.

time generating a specific sequence. The child had to retain which squares lit up and reproduce the pattern on an empty matrix. The test has two parts: in the first the participants had to show the sequence in the same order in which it was presented (forward), while in the second they had to reproduce the pattern in an inverse order, starting with the last item to light up (backward; see Figure 2). This assessed both storage and processing of visuospatial information. Each part of the test included two training trials and six levels of three trials each. The child had to complete a minimum of two trials successfully to pass onto the next level. The task started with three sequences of two blocks each. In each subsequent level patterns were formed that included one block more than the previous task, reaching a total of 7 items to remember in the final one. For each subject the total number of correct responses was registered.

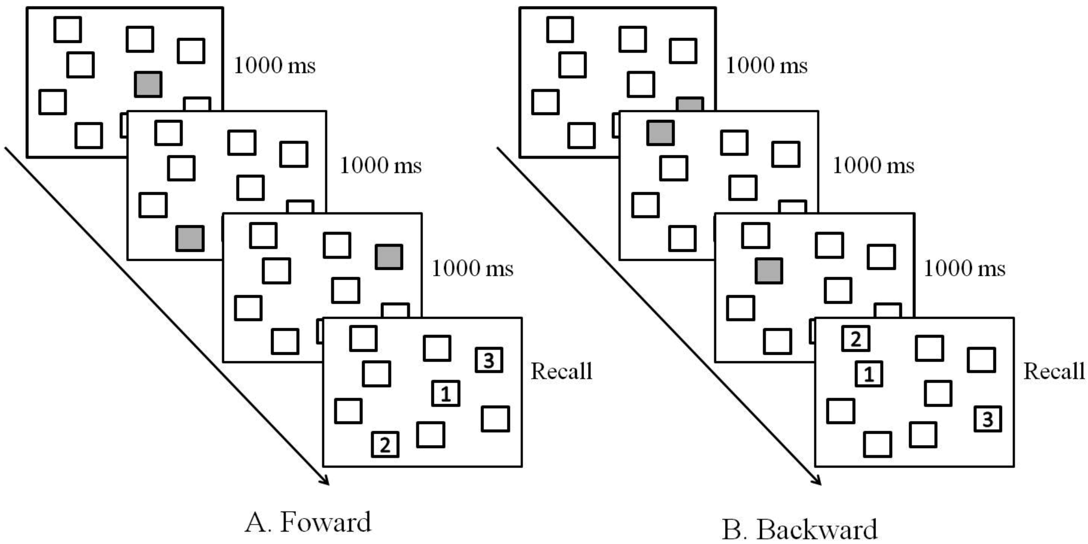

Figure 2. Computerized version of the Corsi block tapping test. Example of stimuli, trial structure and timing.

Verbal Working Memory (Wechsler, 1994). This component was measured through the Digit Span subtest from the Wechsler Intelligence Scales for Children-Revised (WISC-III), which includes two versions: forward and backward. In both cases the examiner recited a sequence of digits, consisting of numbers from 1 to 9, which the child had to retain and later reproduce, either in the exact order in which they were presented (forward) or in the reverse order (backward). Both versions consisted of two training trials that were not included in the statistical analysis, followed by six levels with two trials of identical length each. In the initial level the child had to remember only two digits, after which an additional digit was included in every subsequent level, reaching a sequence of 7 numbers in the final one. To pass from one level to the next, the child had to correctly reproduce at least one of the trials. After two simultaneous errors in the same level the administration was stopped. For each subject the total number of correct responses was registered.

Processing Speed (ad-hoc). A simple reaction time task (ad-hoc) was designed for this study to measure the time elapsed between the presentation of a stimulus and the pressing of a button as an indication of the subject's processing speed. In this case, the child was asked to press a button as fast as possible when a circle appeared on a screen. An additional item (a star) was included as a distractor to prevent the child from continuously pressing the button and therefore attaining lower RTs that did not reliably represent the processing speed. The task included 4 training trails, and 20 stimuli: 12 targets and 8 distractors. The test was designed and administered through OpenSesame (Mathôt et al., 2012). Responses were recorded and monitored through the same software. Only RTs related to correct responses were used for the statistical analysis.

Procedure

The study was conducted within the school, in a well lit room free from distracting noises. Each participant individually completed five tasks. The tasks were administered in a random order.

Results

Initially, the participant's performance in each task was analyzed (see Table 2 for descriptive statistics).

Table 2
Descriptive Statistics for the Scores in Each Task

		M	*SD*	Min	Max	Skewness	Kurtosis
Age 4	Arithmetic	6.33	0.32	1	12	-0.22	-0.82
	Visuospatial WM	6.29	0.25	1	12	0.19	-0.03
	Verbal WM	5.54	0.23	2	10	0.14	-0.84
	Processing speed	1024	21.23	577	1458	-0.09	-0.23
Age 5	Arithmetic	9.77	0.32	2	12	-1.42	1.13
	Visuospatial WM	10.81	0.29	5	16	-0.22	-0.23
	Verbal WM	7.88	0.28	2	12	-0.39	0.41
	Processing speed	938	26,81	529	1471	0.30	-0.62
Age 6	Arithmetic	11.45	0.10	7	12	-2.67	9.92
	Visuospatial WM	13.96	0.46	7	26	0.88	0.81
	Verbal WM	9.17	0.23	5	15	0.62	-0.16
	Processing speed	837	24.19	473	1332	0.07	-0.86

Note. *M* = Mean; *SD* = Standard deviation; Min = Minimum value; Max = Maximum value; WM = Working memory.

A between subjects one-way ANOVA was conducted to compare the effect of age on the total number of correct responses for each task. The results showed significant age related differences in each task. In arithmetic word problems, a significant effect of age was found for the total number of correct responses at the level $p < .001$ [$F_{(2, 230)} = 95.43, p < .001$]. Post hoc comparisons using the Bonferroni test indicated that the mean score for the 6-year-old children was significantly different from the 5-year-olds, and, at the same time, the 5-year-olds differed significantly from the 4-year-olds. Differences in scores were always in favor of the older children. Age also had a significant effect on the visuospatial working memory scores [$F_{(2, 230)} = 129.13$, $p < .001$], verbal working memory scores [$F_{(2, 230)} = 66.99$, $p < .001$] and processing speed scores [$F_{(2, 230)} = 10.24$, $p < .001$]. In each case, post hoc comparisons using the Bonferroni test showed that the differences found where significant between all ages, always showing better performance by older children, with the exception of processing speed scores, that showed no significant differences between the aged 5 and 6-year-old children ($p = .18$).

Arithmetic Word Problems: Analysis of the Effect of Strategies and Age

To analyze whether there was an interaction between age and strategy choice with regard to correct responses, for each participant the percentage of correct responses for each strategy was obtained. Then, a 3 x 3 mixed design ANOVA was conducted, with age as a between-subjects factor and strategy (visual aids, finger counting and mental calculation) as a within-subjects factor, as suggested by Imbo and Vandierendonck (2007). The results showed a significant main effect of strategy over percentage of correct responses [$F_{(2, 460)} = 17.00$, $p < .001$, $\eta 2 = .06$] and of age over percentage of correct responses, which was described above. Regarding strategy use, the post hoc comparison, using the Bonferroni test, showed that more arithmetic problems were solved correctly through mental calculation and the use of visual aids, than through finger counting. Furthermore, an interaction was found between the factors age and strategy [$F_{(4, 469)} = 51.10$, $p < .001$, $\eta 2 = .31$).

Figure 3 shows the means and interaction between variables.

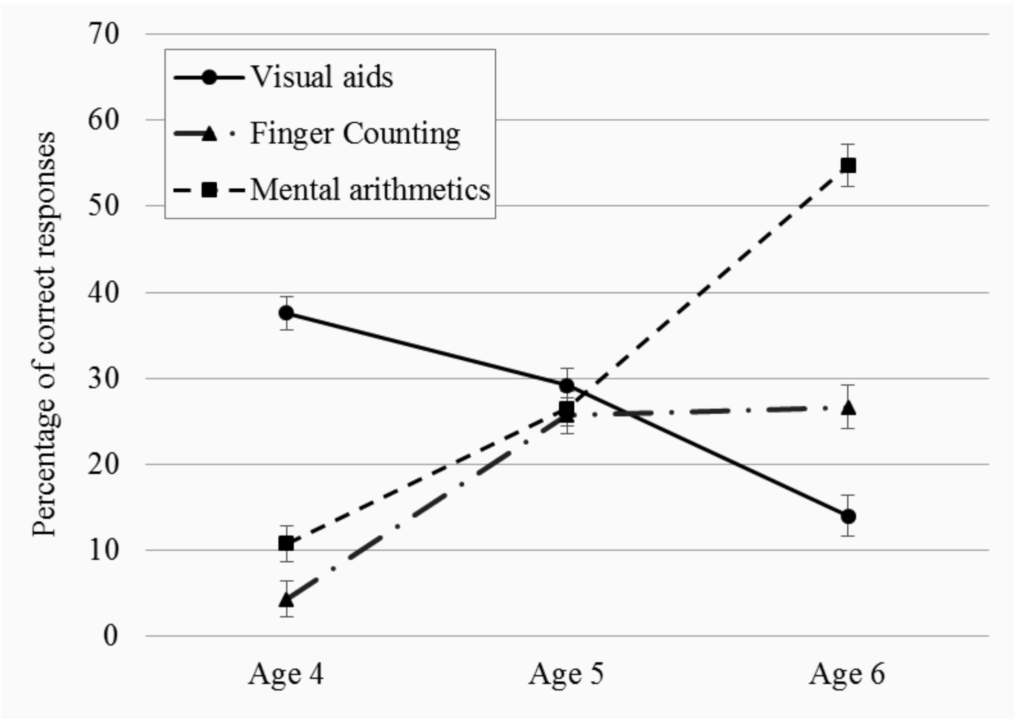

Figure 3. Mean percentages of correct responses in strategy choice as a function of age, with SEM bars.

Through the analysis of the confidence intervals within the group of 4-year-old children, it was established that there was a significant difference in favor of the use of visual aids, as the majority of the correct responses in the arithmetic problems were achieved using this method. At age 5 no differences were found between the different strategies, whereas at age 6 significant differences were found in favor of mental calculation. The 4-year-old group solved significantly more arithmetic problems using visual aids than the 6-year-old group. Additionally, both the 5 and 6-year-old groups resorted to finger counting to efficiently solve the problem significantly more than the younger group. Finally, the older group achieved the correct responses by mental calculation significantly more than both the 4 and 5-year-old groups (See Table 3 for confidence intervals).

Table 3
Confidence Intervals for Group Comparison

				95% CI	
	Strategy	*M*	*SD*	Lower limit	Upper limit
Age 4	Visual aids	37.60	1.97	33.71	41.49
	Finger counting	4.36	1.97	0.48	8.25
	Mental calculation	10.81	2.36	6.16	15.46
Age 5	Visual aids	29.22	2.12	25.05	33.39
	Finger counting	25.68	2.12	21.52	29.85
	Mental calculation	26.48	2.53	21.50	31.47
Age 6	Visual aids	14.04	2.07	9.95	18.12
	Finger counting	26.64	2.07	22.56	30.73
	Mental calculation	54.71	2.48	49.83	59.60

Resolution Strategies and other Cognitive Abilities

Initially, the children were divided into three groups: those who primarily used visual aids to achieve the correct result in the arithmetic problems, those who mainly resorted to finger counting and, finally, those who efficiently used mental calculation. Only the participants that used one strategy twice as much as each of the others were selected (see Table 4 and Figure 4).

To analyze the relation between resolution strategies and the cognitive abilities previously described, a correlation analysis was performed between total number of correct responses in the arithmetic problems and visuospatial working memory, verbal working memory and processing speed scores for each strategy group. The results showed significant positive associations between arithmetic scores and both components of working memory, however not with processing speed (Table 5).

A hierarchical multiple regression analysis was performed within each strategy group to investigate the ability of verbal and visuospatial working memory to predict performance in arithmetic word problems, after controlling for age.

Visual aids group: In the first step of the hierarchical multiple regression analysis, age in months was entered as a predictor. This model was statistically significant [$F_{(1, 65)} = 10.29$; $p < .01$] and explained 13% of the variance in the arithmetic problems. After entering verbal and visuospatial working memory in Step 2, the total variance explained by the model as a whole was 27% [$F_{(1, 65)} = 7.81$; $p < .001$]. The introduction of the working memory variables explained an additional 10% of the variance in the arithmetic word problems, after controlling for age in months [R^2 Change = .14; $F_{(1, 63)} = 5.80$; $p < .01$]. In the final adjusted model only visuospatial working memory was statistically significant ($\beta = .40$, $p = .01$).

Finger counting group: In the first step of the hierarchical multiple regression analysis, age in months was entered as a predictor. This model was statistically significant [$F_{(1, 18)} = 5.48$; $p = .03$] and explained 24% of the variance in the arithmetic problems. The change in R^2 after en-

Table 4
Descriptive Statistics (mean and standard deviation) for Each Strategy Group

		Strategy group		
		Visual aids	Finger counting	Mental calculation
Age 4	*n*	56	2	7
	Arithmetic	6.20 (2.83)	8.50 (.71)	4.14 (2.79)
	Verbal WM	5.05 (.27)	7.00 (.00)	6.14 (1.12)
	Visuospatial WM	6.02 (2.00)	3.50 (3.53)	6.14 (2.90)
	Processing speed	1025 (181)	991 (62)	961 (272)
Age 5	*n*	9	9	12
	Arithmetic	8.89 (2.82)	9.67 (2.91)	8.17 (4.13)
	Verbal WM	7.56 (1.66)	8.22 (1.56)	8.83 (2.32)
	Visuospatial WM	11.78 (1.78)	10.89 (1.83)	11.00 (1.59)
	Processing speed	1004 (303)	793 (88)	1038 (220)
Age 6	*n*	2	8	39
	Arithmetic	11.00 (1.83)	11.63 (.52)	11.59 (.82)
	Verbal WM	10.00 (1.41)	9.00 (1.60)	9.67 (2.10)
	Visuospatial WM	10.50 (.71)	13.00 (2.61)	15.51 (4.00)
	Processing speed	1018 (66)	961 (236)	835 (220)

tering verbal and visuospatial working memory was not significant and did not explain any additional variance in the arithmetic word problems.

Mental calculation group: In the first step of the hierarchical multiple regression analysis, age in months was entered as a predictor. This model was statistically significant [$F_{(1, 56)} = 75.78$; $p < .001$] and explained 57% of the variance in the arithmetic problems. After entering verbal and visuospatial working memory in Step 2, the total variance explained by the model as a whole was 63% [$F_{(3, 54)} = 30.48$; $p < .001$]. The introduction of the working memory variables explained an additional 6% of the variance in the arithmetic word problems, after controlling for age in months [R^2 Change = .06; $F_{(2, 54)} = 3.90$; $p = .02$]. In the final adjusted model only verbal working memory was statistically significant ($\beta = .28$, $p = .01$).

Discussion

The aim of this study was to analyze the performance of 4 to 6-year-old children in arithmetic word problems presented verbally, in relation to the strategy chosen and their age. Additionally, the study sought to identify possible associations between performance in this task and the working memory capacity and processing speed of the children. In order to achieve this, a series of tests was administered that aimed to measure efficiency in solving arithmetic problems, verbal and visuospatial working memory and processing speed.

Regarding the scores obtained by the participants in the arithmetic word problems task, the group of 6-year-olds was significantly more accurate than the group of younger children, and the 5-year-olds were also more effective than the 4-year-olds. This evidence is consistent with previous studies that suggest that the ability to solve arithmetic word problems increases with age, at least within this age range (Carpenter & Moser, 1982; Geary & Brown, 1991; Price et al., 2013).

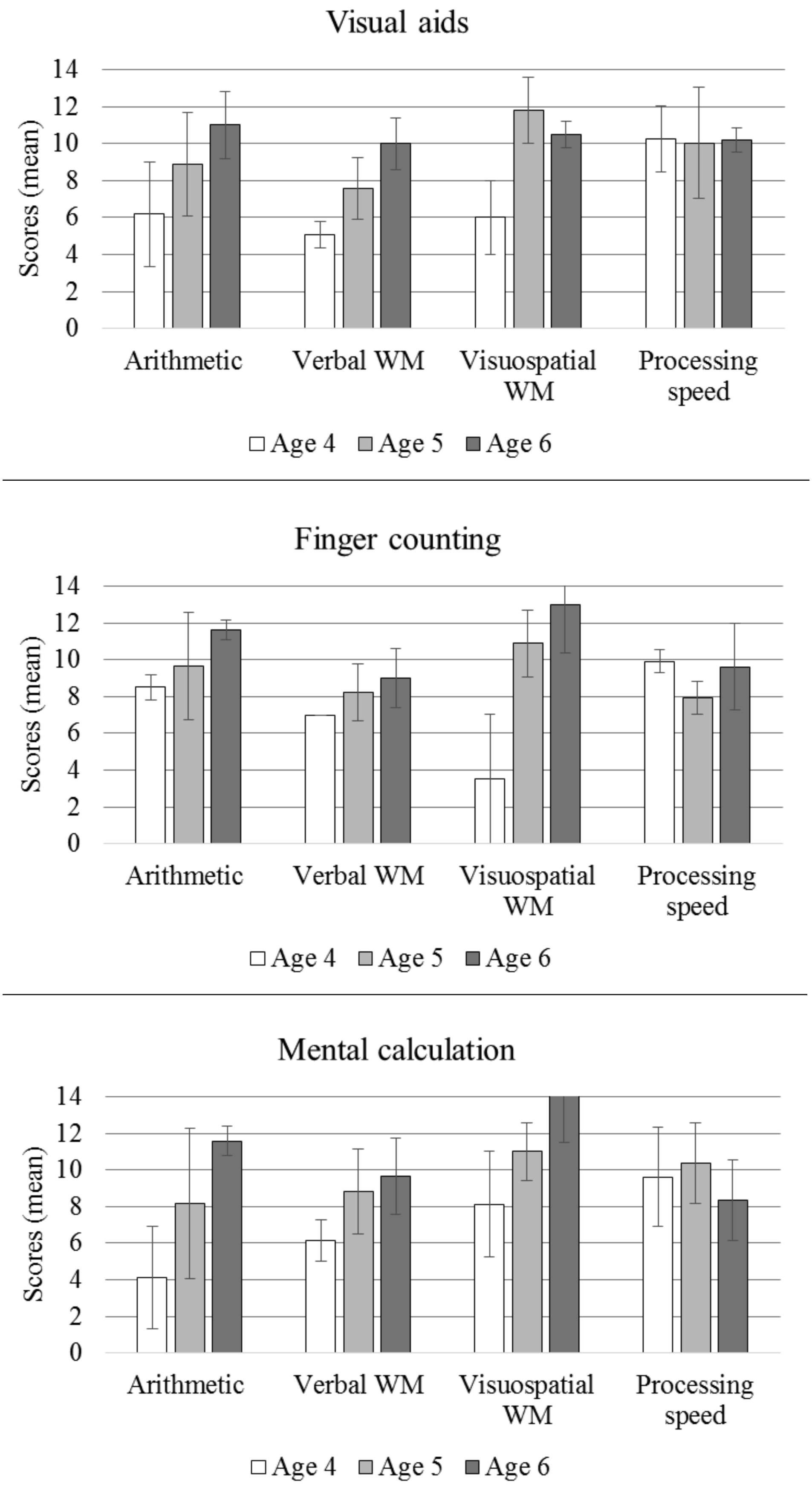

Figure 4. Performance in the different tasks according to the strategy group and age. Scores for processing speed were divided by a hundred.

Table 5
Spearman's Correlation Coefficients (Rho) between Total Number of Correct Responses in Arithmetic and Scores in the Other Cognitive Skills

Strategy groups	Verbal WM	Visuospatial WM	Processing Speed
Visual aid	$.41^{**}$	$.52^{**}$	-0.06
Finger Counting	$.57^{**}$	$.56^{**}$	0.03
Mental calculation	$.47^{**}$	$.51^{**}$	-0.15

$^{**}p < .01$.

Subsequently, the number of operations solved mentally, by finger counting or by the counting of visual aids was registered from the total score in the arithmetic problems of each participant. The analysis of whether there was an interaction between age and the choice of strategy in the resolution of arithmetic operations was performed. The results showed that while the 4-year-olds relied primarily on visual aids, the 5-year-olds showed no significant differences in the selection of strategies and the 6-year-olds mainly depended on mental calculation. Consistent with previous studies, the results of the present study suggest younger children depend more on explicit strategies, with this tending to shift towards the use of implicit ones, such as silent verbal counting or the retrieval of arithmetic facts from the long term memory, which are both used to performed operations mentally (Carpenter & Moser, 1982, 1984; Geary, et al., 2004; Groen & Resnick, 1977).

Evidence also revealed that visual aids and mental calculation were effectively used more than finger counting. Due to the way the data was collected there was no information on strategies used inaccurately (e.g. finger counting that led to an incorrect answer). In line with previous studies, the 4-year-old children relied heavily on visual aids to solve the word problems, while the 5 and 6-year-olds incorporated finger counting and mental calculation as efficient strategies (Carpenter & Moser, 1984; Geary & Brown, 1991; Geary et al., 2004). The older group, in fact, used mental calculation in the majority of cases and significantly more than the other age groups, which suggests that at this age children can use subvocal counting efficiently and that they can probably retrieve some basic arithmetic facts from the long-term memory (Barrouillet & Lépine, 2005; Imbo & Vandierendonck, 2007). Considering that the 6-year-olds used mental calculation more than the younger groups and, at the same time, were more effective in solving arithmetic word problems, it is possible that the development of long-term memory and its administration of arithmetic facts may explain, to a certain extent, the development of mathematical skills (Geary & Brown, 1991).

Additional findings revealed that the children that mainly resorted to finger counting and mental calculation solved arithmetic problems more accurately than the children that depended on visual aids, however, no differences were found between the first two strategies. Even though the use of external objects or the child's own fingers are considered an explicit strategy (Carpenter & Moser, 1982), differences between these groups may be due to the fact that the visual aids, in this study, were provided by the researcher, whereas the children resorted to finger counting on their own initiative. Visual aids may not be a strategy children would use on their own. The evidence did not indicate that, when solving arithmetic problems, mental calculation is a more efficient strategy than finger counting at this particular stage. Due to the way in which the data was collected in the arithmetic word problems task, it was not possible to estimate the incorrect use of a particular strategy. The type of error or the distance between the error and the target were not considered, nor was the child asked about the way in which the task was solved. An analysis of this type could have provided information about the type of strategy used, and even about the working memory resources involved in the resolution of the task.

Considering that the operations were presented verbally their resolution included keeping the necessary information active in a working memory system (Berg, 2008; DeStefano & LeFevre, 2004; Fuchs et al., 2012). Furthermore, the child needed to identify which type of operation it was, identify which algorithm needed to be retrieved from the long-term memory to solve it, and monitor its application (Fuchs et al., 2006). As was previously mentioned, all these requirements are thought to be associated with the working memory capacity and processing speed (Berg, 2008; DeStefano & LeFevre, 2004; Geary et al., 2004; Raghubar et al., 2010).

A number of authors have suggested that the shift from overt to internal strategies mentioned above reflects the maturation of the working memory system. For example, McKenzie et al. (2003) and Palmer (2000) proposed that from 5 to 8 or 9 years of age children go from the use of strictly visual strategies, to a dual stage of both verbal and visual strategies, and finally, to the primary use of verbal strategies. Palmer (2000) considered that the stage of dual strategies gives the central executive time to mature and take charge of recoding the material presented visually into a phonological representation. This would also allow refinement of the subvocal rehearsal associated with the phonological loop. In the present study the children were divided into groups depending on their choice of primary strategy (mental calculation, finger counting and visual aids), and correlation analyses were run within each strategy group with the scores from the arithmetic word problems and the visuospatial and verbal working memory scores. The three groups showed positive significant associations between arithmetic and working memory measures. To further analyze the effect of the different components of working memory on arithmetic problem resolution within each strategy group regression analyses were performed to assess the capacity of the verbal and visuospatial working memory to predict the outcome in the arithmetic word problems, while controlling for age. In line with McKenzie et al. and Palmer, visuospatial working memory predicted efficiency in children with primary use of visual aids as the strategy, and verbal working memory predicted performance in the children that predominantly used mental calculation. Contrary to these studies, finger counting was not predicted by any of the variables when controlling for age.

The groups that used finger counting and mental calculation also showed greater verbal and visuospatial working memory capacity, as well as faster processing speed, than those that predominantly used visual aids, which is consistent with previous studies (Berg, 2008; DeStefano & LeFevre, 2004; Fuchs et al., 2012; Fuchs et al., 2006; Geary, 2011; Geary et al., 2004; Hubber et al., 2014; McLean & Hitch, 1999; Noël, 2009).

It is important to consider that this study measured the efficiency in mental calculation by recording only the correct answers. The type of error or the distance between the error and the target was not considered. The children were not asked about the way they solved the problem. An analysis of this type could provide information about the choice of strategy, the application of algorithms, and even about resources of the working memory that were in play. Also, the incorrect use of strategies was not registered. This could provide information regarding the spontaneous use of strategies, the types and rate of mistakes children make when applying them and their approach according to the algorithm.

It would be of interest to analyze the existence of a different association between visuospatial working memory and mental calculation in younger children, depending on the resolution of the problems being achieved through silent verbal counting or the recovery of arithmetic facts. However, due to the design of the task used to measure the arithmetic problems in this study it was not possible to differentiate the two methods.

Additionally, the conclusions reached raise the need for new longitudinal studies to assess, either the association between the different components of working memory and mental calculation, or the different effects of verbal or visuospatial interference on this mathematical ability. It would also be of interest to perform these analyses on a broader age range than previously studied. Studies of this style would confirm or refute the findings described so far. These limitations present possible starting points for future lines of research.

Regarding the implications of this study, the present work provides new evidence in favor of the theory of a shift between explicit strategies, dependent on visuospatial working memory resources, and implicit strategies, that mainly rely on verbal resources. Evidence was also found that the same pattern is observed for 4-year-olds, whereas previous studies focused on children of 5 or 6 years of age or older. Previous research has shown that not only is the early ability to solve arithmetic problems a strong predictor of later mathematical achievement, but that, even in very young children, this ability is significantly impaired when they have mathematical difficulties (McLean, & Hitch, 1999; Swanson & Beebe-Frankenberger, 2004). For this reason, studying and identifying the patterns of development of this ability in children, as well as the type of strategies used and associations with other cognitive abilities may result in new approaches for the teaching of the subject, early identification of children with mathematical difficulties and even for the design of strategies to work with them.

Authors' Contributions

Substantial contribution in the concept and design of the study: Jesica Formoso and Silvia Jacubovich

Contribution to data collection: Jesica Formoso

Contribution to data analysis and interpretation: Jesica Formoso and Juan Pablo Barreyro

Contribution to manuscript preparation: Jesica Formoso and Irene Injoque-Ricle

Contribution to critical revision, adding intelectual content: Irene Injoque-Ricle and Juan Pablo Barreyro

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

References

Adams, J. W., & Hitch, G. J. (1997). Working memory and children's mental addition. *Journal of Experimental Child Psychology, 67*(1), 21-38. doi: https://doi.org/10.1006/jecp.1997.2397

Alibali, M. W., & DiRusso, A. A. (1999). The function of gesture in learning to count: More than keeping track. *Cognitive Development, 14*(1), 37-56. doi: https://doi.org/10.1016/s0885-2014(99)80017-3

Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and visuospatial short-term and working memory in children: Are they separable?. *Child Development, 77*(6), 1698-1716. doi: https://doi.org/10.1111/j.1467-8624.2006.00968.x

Andres, M., Olivier, E., & Badets, A. (2008). Actions, words, and numbers a motor contribution to semantic processing? *Current Directions in Psychological Science, 17*(5), 313-317. doi: https://doi.org/10.1111/j.1467-8721.2008.00597.x

Ashcraft, M. H. (1982). The development of mental arithmetic: A chronometric approach. *Developmental Review, 2*, 213-236.

Baddeley, A. D. (2010). Working memory. *Current Biology, 20*(4), 136-140.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. *Psychology of Learning and Motivation, 9*, 47-89.

Barrouillet, P., & Lépine, R. (2005). Working memory and children's use of retrieval to solve addition problems. *Journal of Experimental Child Psychology, 91*(3), 183-204. doi: https://doi.org/10.1016/j.jecp.2005.03.002

Berg, D. H. (2008). Working memory and arithmetic calculation in children: The contributory roles of processing speed, short-term memory, and reading. *Journal of Experimental Child Psychology, 99*(4), 288-308. doi: https://doi.org/10.1016/j.jecp.2007.12.002

Bull, R., & Johnston, R. S. (1997). Children's arithmetical difficulties: Contributions from processing speed, item identification, and short-term memory. *Journal of Experimental Child Psychology, 65*(1), 1-24.

Carpenter, T. P., & Moser, J. M. (1982). The development of addition and subtraction problem-solving skills. In J. M. M. T. A. M. P. Carpenter (Ed.), *Addition and subtraction: A cognitive perspective* (pp. 9-24). Hillsdale, NJ: Lawrence Erlbaum Associates.

Carpenter, T. P., & Moser, J. M. (1984). The acquisition of addition and subtraction concepts in grades one through three. *Journal for Research in Mathematics Education, 15*(3), 179-202.

Case, R., Kurland, D. M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology, 33*.

Corsi, P. M. (1972). *Human memory and the medial temporal region of the brain*. Montreal, CA: McGill University.

Costa, A. J., Silva, J. B. L., Chagas, P. P., Krinzinger, H., Lonneman, J., Willmes, K., ...Haase, V. G. (2011). A hand full of numbers: A role for offloading in arithmetics learning? *Frontiers in Psychology, 2*. doi: http://dx.doi.org/10.3389/fpsyg.2011.00368

Crollen, V., & Noël, M. P. (2015). The role of fingers in the development of counting and arithmetic skills. *Acta Psychologica* (Amsterdam), *156*, 37-44. doi: 10.1016/j.actpsy.2015.01.007

DeStefano, D., & LeFevre, J. A. (2004). The role of working memory in mental arithmetic. *European Journal of Cognitive Psychology, 16*(3), 353-386. doi: https://doi.org/10.1016/0010-0285(78)90002-6

Droit-Volet, S., & Zélanti, P. (2013). Development of time sensitivity: Duration ratios in time bisection. *Quarterly Journal of Experimental Psychology, 66*(4), 671-686. doi: https://doi.org/10.1080/17470218.2012.712148

Fuchs, L. S., Compton, D. L., Fuchs, D., Powell, S. R., Schumacher, R. F., Hamlett, C. L., …Vukovic, R. K. (2012). Contributions of domain-general cognitive resources and different forms of arithmetic development to pre-algebraic knowledge. *Developmental Psychology, 48*(5), 1315. doi: https://doi.org/10.1037/a0027475.

Fuchs, L. S., Fuchs, D., Compton, D., Powell, S., Seethaler, P., Capizzi, A., & Schatschneider, C. (2006). The Cognitive Correlates of Third-Grade Skills in Arithmetic, Algorithmic Computation and Arithmetic Word Problems. *Journal of Educational Psychology, 98*(1), 29-43. doi: https://doi.org/10.1037/0022-0663.98.1.29.

Fürst, A. J., & Hitch, G. J. (2000). Separate roles for executive and phonological components of working memory in mental arithmetic. *Memory and Cognition, 28*(5), 774-782. doi: https://doi.org/10.3758/bf03198412.

Geary, D. C. (2011). Cognitive predictors of achievement growth in mathematics: A 5-year longitudinal study. *Developmental Psychology, 47*(6), 1539. doi: 10.1037/a0025510

Geary, D. C., & Brown, S. C. (1991). Cognitive addition: Strategy choice and speed-of-processing differences in gifted, normal, and mathematically disabled children. *Developmental Psychology, 27*, 398-406. doi: https://doi.org/10.1037//0012-1649.27.3.398

Geary, D. C., Frensch, P. A., & Wiley, J. G. (1993). Simple and complex mental subtraction: strategy choice and speed-of-processing differences in younger and older adults. *Psychology and Aging, 8*(2), 242-256.

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*(3), 236-263. doi: 10.1006/jecp.2000.2561

Geary, D. C., Hoard, M., Byrd-Craven, J., Nugent, L., & Numtee, C. (2007). Cognitive mechanisms underlying achievement deficits in children with mathematical learning disability. *Children Development, 78*(4), 1343-1359. doi: 10.1111/j.1467-8624.2007.01069.x

Geary, D. C., Hoard, M. K., Byrd-Craven, J., & DeSoto, M. C. (2004). Strategy choice in simple and complex addition: Contributions of working memory and counting knowledge for children with mathematical disability. *Journal of Experimental Child Psychology, 88*, 121-151. doi: 10.1016/j.jecp.2004.03.002

Grabner, R. H., Ansari, D., Koschutnig, K., Reishofer, G., Ebner, F., & Neuper, C. (2009). To retrieve or to calculate? Left angular gyrus mediates the retrieval of arithmetic facts during problem solving. *Neuropsychologia, 47*(2), 604-608. doi: https://doi.org/10.1016/j.neuropsychologia.2008.10.013

Gray, S., & Reeve, A. (2014). Preschoolers dot enumeration abilities are markers of their arithmetic competence. *PLoS One, 9*(4), e94428. doi: 10.1371/journal.pone.0094428

Groen, G., & Resnick, L. B. (1977). Can preschool children invent addition algorithms? J*ournal of Educational Psychology, 69*(6), 645-652.

Hanich, L. B., Jordan, N., Kaplan, D., & Dick, J. (2001). Performance across different areas of mathematical cognition in children with learning difficulties. *Journal of Educational Psychology, 93*(3), 615-626. Retrieved from http://psycnet.apa.org/buy/2001-18059-016

Hecht, S. A. (2002). Counting on working memory in simple arithmetic when counting is used for problem solving. *Memory & Cognition, 30*(3), 447-455. doi: https://doi.org/10.3758/bf03194945

Hubber, P. J., Gilmore, C., & Cragg, L. (2014). The roles of the central executive and visuospatial storage in mental arithmetic: A comparison across strategies. *Quaterly Journal of Experimental Psychology, 67*(5), 936-954. doi: 10.1080/17470218.2013.838590

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.

Jensen, A. R. (2006). *Clocking the mind: Mental chronometry and individual differences*. Amsterdam: Elsevier. doi: https://doi.org/10.1016/b978-008044939-5/50002-1

Knudsen, B., Fischer, M. H., Henning, A., & Aschersleben, G. (2015). The development of Arabic digit knowledge in 4- to 7-year-old children. *Journal of Numerical Cognition, 1*(1), 21-37. doi: https://doi.org/10.5964/jnc.v1i1.4

LeFevre, J. A., Berrigan, L., Vendetti, C., Kamawar, D., Bisanz, J., Skwarchuk, S. L., & Smith-Chant, B. L. (2013). The role of executive attention in the acquisition of mathematical skills for children in Grades 2 through 4. *Journal of Experimental Child Psychology, 114*(2), 243-261. doi: https://doi.org/10.1016/j.jecp.2012.10.005

LeFevre, J. A., & Bisanz, J. (1996). Selection of procedures in mental addition: Reassessing the problem size effect in adults. *Journal of Experimental Psychology: Learning, Memory and Cognition, 22*(1), 216-230. doi: https://doi.org/10.1037//0278-7393.22.1.216

LeFevre, J. A., Smith-Chant, B. L., Fast, L., Skwarchuk, S. L., Sargla, E., & Arnup, J. S. (2006). What counts as knowing? The development of conceptual and procedural knowledge of counting from kindergarten through grade 2. *Journal of Experimental Child Psychology, 93*, 285-303.

Lemaire, L., Abdi, H., & Fayol, M. (1996). Working memory and cognitive arithmetic: Evidence from the disruption of the associative confusion effect. *European Journal of Cognitive Psychology, 8*, 73-103. doi: https://doi.org/10.1080/095414496383211

Luna, B., Garver, K. E., Urban, T. A., Lazar, N. A., & Sweeney, J. A. (2004). Maturation of cognitive processes from late childhood to adulthood. *Child Development, 75*(5), 1357-1372. doi: https://doi.org/10.1111/j.1467-8624.2004.00745.x

Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. *Behavior Research Methods, 44*(2), 314-324. doi: http://dx.doi.org/10.3758/s13428-011-0168-7

Mazzocco, M. M., Devlin, K. T., & McKenney, S. J. (2008). Is it a fact? Timed arithmetic performance of children with mathematical learning disabilities (MLD) varies as a function of how MLD is defined. *Developmental Neuropsychology, 33*(3), 318-344. doi: 10.1080/87565640801982403

McKenzie, B., Bull, R., & Gray, C. (2003). The effects of phonological and visualspatial interference on children's arithmetical performance. *Educational and Child Psychology, 20*(3), 93-108. doi: https://doi.org/10.1037/0022-0663.98.1.29

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

Moeller, K., Martignon, L., Wessolowski, S., Engel, J., & Nuerk, H. C. (2011). Effects of finger counting on numerical development – The opposing views of neurocognition and mathematics education. *Frontiers in Psychology, 2*, 328. doi: 10.3389/fpsyg.2011.00328

Noël, M. P. (2009). Counting on working memory when learning to count and to add: A preschool study. *Developmental Psychology, 45*(6), 1630-1643. doi: 10.1037/a0016224

Noël, M. P., Désert, M., Aubrun, A., & Seron, X. (2001). Involvement of short-term memory in complex mental calculation. *Memory & Cognition, 29*(1), 34-42. doi: https://doi.org/10.3758/bf03195738

Ostad, S. A. (2000). Cognitive subtraction in a developmental perspective: Accuracy, speed-of-processing and strategy-use differences in normal and mathematically disabled children. *Focus on Learning Problems in Mathematics, 22*(2), 18-32. doi: https://doi.org/10.1080/0885625990140103

Palmer, S. (2000). Working memory: A developmental study of phonological recoding. *Memory, 8*(3), 179-193. doi: https://doi.org/10.1080/096582100387597

Price, G. R., Mazzocco, M. M., & Ansari, D. (2013). Why mental arithmetic counts: Brain activation during single digit arithmetic predicts high school math scores. *The Journal of Neuroscience, 33*(1), 156-163.

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: https://doi.org/10.1016/j.lindif.2009.10.005

Rasmussen, C., & Bisanz, J. (2005). Representation and working memory in early arithmetic. *Journal of Experimental Child Psychology, 91*(2), 137-157. doi: https://doi.org/10.1016/J.JECP.2005.01.004

Seyler, D. J., Kirk, E. P., & Ashcraft, M. H. (2003). Elementary subtraction. *Journal of Experimental Psychology: Learning, Memory and Cognition, 29*(6), 1339. doi: https://doi.org/10.1037/0278-7393.29.6.1339

Siegler, R. S. (1989). How domain-general and domain-specific knowledge interact to produce strategy choices. *Merrill-Palmer Quarterly, 35*(1), 1-26.

Siegler, R. S., Adolph, K. E., & Lemaire, P. (1996). Strategy choices across the life span. *Implicit Memory and Metacognition*, 79-121.

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*(3), 471. doi: https://doi.org/10.1037/0022-0663.96.3.471

Trbovich, P. L., & LeFevre, J.-A. (2003). Phonological and visual working memory in mental addition. *Memory & Cognition, 31*(5), 738-745. doi: 10.3758/bf03196112

Von Aster, M. G., & Shalev, R. S. (2007). Number development and developmental dyscalculia. *Developmental Medicine & Child Neurology, 49*(11), 868-873. doi: https://doi.org/10.1111/j.1469-8749.2007.00868.x

Watts, T. W., Duncan, G. J., Siegler, R. S., & Davis-Kean, P. E. (2014). What's past is prologue: Relations between early mathematics knowledge and high school achievement. *Education Research, 43*(7), 352-360. doi: 10.3102/0013189X14553660

Wechsler, D. (1994). *Test de inteligencia para niños WISC-III, Manual*. Buenos Aires: Paidós.

Received: 10/01/2017
1st revision: 27/07/2017
Accepted: 31/07/2017