

Children's competence at solving arithmetic operations in a working memory task.

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Introduction

In a study reported elsewhere (Towse, Hitch & Hutton, in prep.), we took a measure known as operation span by asking children (age ranging 7;5 - 11;5) to solve visually presented arithmetic operations and to remember the solutions for subsequent recall. In order to investigate the effect of processing time on memory span, the operations varied according to the number of constituent processes (i.e. length of the operations). Sums took the form of the addition or subtraction of a series of 0s and 1s. Sets of varying-length operations with the same numerical solution were prepared, so that the memory items for the long and short experimental manipulations would be equivalent. All answers were single-digit.

It was felt that these constraints on the operations would result in comparable processing demands for children ranging in age between approximately 7 yrs and 11 years, and so facilitate developmental comparisons in operation span across these ages.

Results

As the tabled information illustrates, the general accuracy of processing the operations was high, although there were a number of processing sequences that were frequently mis-calculated by some children. Sequences involving 0s and subtraction appeared to present the most problems, however, overall the majority of children were successful at correctly solving most operations. Note that differences between schools could represent any number of factors, such as testing conditions, computer used etc.

References

Towse, J. N., Hitch, G. J., & Hutton, U. (in prep.). On mechanisms underlying working memory capacity in children. Manuscript in preparation.

Table 1: Proportion Correct Responses by age group and by school¹

No.	Answer	Operation	School 1			School 2		
			YR 3	YR 5	YR 6	YR 3	YR 5	YR 6
1	3	$2 + 1 =$	100	100	100	100	100	100
2		$3 + 0 =$	100	100	100	96	100	100
3		$4 - 1 =$	87	83	100	65	85	95
4		$3 - 0 =$	74	77	94			
5		$1 + 1 + 1 =$	100	100	100	100	100	100
6		$3 + 1 - 1 =$	100	0/3	33	50	100	100
7		$3 + 0 + 0 =$	100	100	100		100	100
8		$3 - 1 + 1 =$	100	100	100	33	25	50
9		$2 + 1 + 0 =$	0/1	100	100			
10		$1 + 1 + 1 + 0 =$	100	100	100	100	100	100
11		$2 + 1 + 1 - 1 =$	89	75	69	50	73	95
12		$2 - 1 + 1 + 1 =$	100	93	80	60	77	88
13		$1 + 0 + 1 + 1 =$	100	100	100	100	83	100
14	4	$3 + 1 =$	100	100	100	93	92	95
15		$4 + 0 =$	95	100	100	91	100	100
16		$5 - 1 =$	67	75	96	80	93	96
17		$4 - 0 =$	100	96	96	100	97	94
18		$2 + 1 + 1 =$	67	100	83	100	100	
19		$3 + 0 + 1 =$	100		100	50	100	100
20		$4 + 1 - 1 =$		67	63	50	100	100
21		$4 - 1 + 1 =$	100		67	0/1	71	100
22		$3 + 1 + 0 =$	100	50	100			
23		$2 + 0 + 1 + 1 =$	100	100	100	87	91	100
24		$1 + 1 + 1 + 1 =$	100	100	100	100	95	100
25		$3 - 1 + 1 + 1 =$	45	63	86	46	82	81
26		$2 + 1 + 1 + 0 =$	80	100	100	94	88	100
27	5	$4 + 1 =$	100	94	100	95	100	94
28		$5 + 0 =$	100	92	100	100	100	92
29		$6 - 1 =$	93	100	88	55	100	100
30		$5 - 0 =$	83	100	100	100	88	95
31		$3 + 1 + 1 =$	100	100	100	86	91	100
32		$4 + 1 + 0 =$	100	100	100	100	100	100
33		$4 + 0 + 1 =$	100	100	89	50	91	100
34		$5 + 1 - 1 =$	100	60	60		92	78
35		$5 - 1 + 1 =$	67	83	70	100		
36		$2 + 1 + 1 + 1 =$	100	100	100	44	84	100
37		$4 - 1 + 1 + 1 =$	50	50	92	92	58	80
38		$3 + 0 + 1 + 1 =$	89	100	96	79	100	94
39		$3 - 0 + 1 + 1 =$	87	50	80	100	87	92

¹ Accuracy ratings for operations which were never answered correctly, in any particular group, are expressed as a fraction of the number of presentations (e.g. 0/2)

No.	Answer	Operation	YR 3	School 1		YR 3	School 2	
				YR 5	YR 6		YR 5	YR 6
40	6	$5 + 1 =$	100	100	100	100	96	90
41		$6 + 0 =$	100	100	100	54	97	100
42		$7 - 1 =$	75	60	85	94	96	83
43		$6 - 0 =$	92	87	100	100	100	100
44		$4 + 1 + 1 =$	100	100	100	100	100	100
45		$5 + 1 + 0 =$	100	100	100	50	100	67
46		$6 + 1 - 1 =$		0/1	100		100	71
47		$7 + 0 - 1 =$	100	0/3	57	50		
48		$8 - 1 - 1 =$	50	100	100	88	88	71
49		$3 + 1 + 1 + 1 =$	86	87	96	60	88	71
50		$5 - 1 + 1 + 1 =$	57	67	88	33	77	92
51		$7 - 1 - 1 + 1 =$	83	88	67	37	79	88
52		$6 + 0 + 1 - 1 =$	43	86	68	100	67	100
53	7	$6 + 1 =$	92	100	100	89	100	100
54		$7 + 0 =$	100	100	100	55	100	100
55		$8 - 1 =$	67	73	100	100	96	93
56		$7 - 0 =$	85	80	95	38	100	83
57		$5 + 1 + 1 =$		100	70	50	50	100
58		$6 + 1 + 0 =$	100		100		86	100
59		$6 + 0 + 1 =$		100	100	100	100	100
60		$7 + 1 - 1 =$	100		67		100	80
61		$6 + 1 + 1 - 1 =$	86	54	60	100	85	67
62		$5 + 1 + 1 + 0 =$	91	83	100	88	100	100
63		$4 + 1 + 1 + 1 =$	67	100	94	57	90	93
64		$8 - 1 - 1 + 1 =$	57	42	73	100	82	100
65		$8 - 1 + 0 + 0 =$				100	75	100
66	8	$7 + 1 =$	100	91	100	100	96	100
67		$8 + 0 =$	100	100	100	82	100	100
68		$9 - 1 =$	88	78	88	100	100	100
69		$8 - 0 =$	100	100	94	100	100	89
70		$6 + 1 + 1 =$	100	100	100	100	100	88
71		$7 + 1 + 0 =$	100	100	100	67	100	100
72		$7 + 1 - 0 =$		67	100	40	86	100
73		$8 + 1 - 1 =$	0/3	67	78		88	100
74		$7 + 0 + 1 =$		67	100	50		
75		$5 + 1 + 1 + 1 =$	100	100	100	40	89	100
76		$7 - 1 + 1 + 1 =$	100	57	87	100	85	79
77		$6 + 1 + 1 + 0 =$	90	92	100		93	87
78		$9 - 1 + 0 + 0 =$					88	100
79	$8 - 1 + 1 + 0 =$	100	55	82	100	100		
80	9	$8 + 1 =$	100	100	100	100	94	86
81		$9 - 0 =$	75	92	100	100	100	90
82		$9 + 0 =$	100	100	100	100	100	100
83		$10 - 1 =$	80	82	100	70	94	94
84		$7 + 1 + 1 =$		100	100	100	100	100

No.	Answer	Operation	School 1			School 2		
			YR 3	YR 5	YR 6	YR 3	YR 5	YR 6
85		$9 - 1 + 1 =$	100	67	75	50	67	78
86	9 (cont)	$9 + 1 - 1 =$	100	67	100	100	60	100
87		$8 + 0 + 1 =$	100	100	100	100	100	86
88		$8 + 1 + 0 =$	100	100	100			
89		$6 + 1 + 1 + 1 =$	100	100	94	100	94	100
90		$7 + 1 + 1 + 0 =$	100	89	94	86	79	100
91		$8 + 1 + 0 + 0 =$	100	100	100	80	88	100
92		$7 + 0 + 1 + 1 =$	100	100	100	83	100	100

Table 2: Absolute Number of Correct and Incorrect Answers by School and Year Group

School 1

Year 3 (mean age = 7;10; n = 17)

No.	Operation	Correct	Incorrect	List of incorrect solutions
1	$2 + 1 =$	7		
2	$3 + 0 =$	15		
3	$4 - 1 =$	13	2	4, 5
4	$3 - 0 =$	5	2	0, 0
5	$1 + 1 + 1 =$	1		
6	$3 + 1 - 1 =$	1		
7	$3 + 0 + 0 =$	2		
8	$3 - 1 + 1 =$			
9	$2 + 1 + 0 =$	0	1	2
10	$1 + 1 + 1 + 0 =$	9		
11	$2 + 1 + 1 - 1 =$	17	2	4, 4
12	$2 - 1 + 1 + 1 =$	4		
13	$1 + 0 + 1 + 1 =$	11		
14	$3 + 1 =$	17		
15	$4 + 0 =$	21	1	0
16	$5 - 1 =$	6	3	5, 6, 6
17	$4 - 0 =$	8		
18	$2 + 1 + 1 =$	2	1	3
19	$3 + 0 + 1 =$	3		
20	$4 + 1 - 1 =$			
21	$4 - 1 + 1 =$	1		
22	$3 + 1 + 0 =$	2		
23	$2 + 0 + 1 + 1 =$	7		

No.	Operation	Correct	Incorrect	List of incorrect solutions
24	$1 + 1 + 1 + 1 =$	22		
25	$3 - 1 + 1 + 1 =$	5	6	1, 3, 5, 6, 6, 6
26	$2 + 1 + 1 + 0 =$	8	2	3, 5
27	$4 + 1 =$	11		
28	$5 + 0 =$	5		
29	$6 - 1 =$	13	1	7
30	$5 - 0 =$	7	1	0
31	$3 + 1 + 1 =$	5		
32	$4 + 1 + 0 =$	4		
33	$4 + 0 + 1 =$	4		
34	$5 + 1 - 1 =$	3		
35	$5 - 1 + 1 =$	2	1	7
36	$2 + 1 + 1 + 1 =$	5		
37	$4 - 1 + 1 + 1 =$	2	2	6, 6
38	$3 + 0 + 1 + 1 =$	17	2	4, 7
39	$3 - 0 + 1 + 1 =$	13	2	3, 4
40	$5 + 1 =$	11		
41	$6 + 0 =$	10		
42	$7 - 1 =$	9	3	0, 8, 8
43	$6 - 0 =$	11	1	0
44	$4 + 1 + 1 =$	1		
45	$5 + 1 + 0 =$	1		
46	$6 + 1 - 1 =$			
47	$7 + 0 - 1 =$	4		
48	$8 - 1 - 1 =$	2	2	5, 7
49	$3 + 1 + 1 + 1 =$	12	2	7, 7
50	$5 - 1 + 1 + 1 =$	4	3	7, 8, 8
51	$7 - 1 - 1 + 1 =$	5	1	8
52	$6 + 0 + 1 - 1 =$	6	8	1, 4, 7, 7, 7, 7, 8, 8, 8
53	$6 + 1 =$	11	1	6
54	$7 + 0 =$	6		
55	$8 - 1 =$	2	1	8
56	$7 - 0 =$	11	2	6, 6
57	$5 + 1 + 1 =$			
58	$6 + 1 + 0 =$	1		
59	$6 + 0 + 1 =$			
60	$7 + 1 - 1 =$	1		
61	$6 + 1 + 1 - 1 =$	6	1	8
62	$5 + 1 + 1 + 0 =$	10	1	8
63	$4 + 1 + 1 + 1 =$	2	1	8
64	$8 - 1 - 1 + 1 =$	4	3	6, 9, 9
65	$8 - 1 + 0 + 0 =$			
66	$7 + 1 =$	6		
67	$8 + 0 =$	9		
68	$9 - 1 =$	7	1	9

No.	Operation	Correct	Incorrect	List of incorrect solutions
69	$8 - 0 =$	14		
70	$6 + 1 + 1 =$	3		
71	$7 + 1 + 0 =$	2		
72	$7 + 1 - 0 =$			
73	$8 + 1 - 1 =$	0	3	9, 9, 10
74	$7 + 0 + 1 =$			
75	$5 + 1 + 1 + 1 =$	9		
76	$7 - 1 + 1 + 1 =$	6		
77	$6 + 1 + 1 + 0 =$	9	1	9
78	$9 - 1 + 0 + 0 =$			
79	$8 - 1 + 1 + 0 =$	3		
80	$8 + 1 =$	10		
81	$9 - 0 =$	3	1	0
82	$9 + 0 =$	5		
83	$10 - 1 =$	8	2	1, 1
84	$7 + 1 + 1 =$			
85	$9 - 1 + 1 =$	2		
86	$9 + 1 - 1 =$	1		
87	$8 + 0 + 1 =$	3		
88	$8 + 1 + 0 =$	1		
89	$6 + 1 + 1 + 1 =$	9		
90	$7 + 1 + 1 + 0 =$	6		
91	$8 + 1 + 0 + 0 =$	6		
92	$7 + 0 + 1 + 1 =$	11		

Year 5 (mean age = 10 yrs; n = 18)

No.	Operation	Correct	Incorrect	List of incorrect solutions
1	$2 + 1 =$	7		
2	$3 + 0 =$	9		
3	$4 - 1 =$	15	3	5, 5, 5
4	$3 - 0 =$	10	3	0, 0, 0
5	$1 + 1 + 1 =$	2		
6	$3 + 1 - 1 =$	0	3	5, 5, 5
7	$3 + 0 + 0 =$	1		
8	$3 - 1 + 1 =$	2		
9	$2 + 1 + 0 =$	1		
10	$1 + 1 + 1 + 0 =$	20		
11	$2 + 1 + 1 - 1 =$	12	4	4, 4, 5, 5
12	$2 - 1 + 1 + 1 =$	13	1	4
13	$1 + 0 + 1 + 1 =$	8		

No.	Operation	Correct	Incorrect	List of incorrect solutions
15	$4 + 0 =$	24		
16	$5 - 1 =$	12	4	6, 6, 6, 6
17	$4 - 0 =$	23	1	5
18	$2 + 1 + 1 =$	4		
19	$3 + 0 + 1 =$			
20	$4 + 1 - 1 =$	4	2	5, 6
21	$4 - 1 + 1 =$			
22	$3 + 1 + 0 =$	1	1	0
23	$2 + 0 + 1 + 1 =$	12		
24	$1 + 1 + 1 + 1 =$	19		
25	$3 - 1 + 1 + 1 =$	10	6	3, 3, 3, 5, 5, 5
26	$2 + 1 + 1 + 0 =$	11		
27	$4 + 1 =$	16	1	3
28	$5 + 0 =$	11	1	6
29	$6 - 1 =$	12		
30	$5 - 0 =$	21		
31	$3 + 1 + 1 =$	4		
32	$4 + 1 + 0 =$	4		
33	$4 + 0 + 1 =$	5		
34	$5 + 1 - 1 =$	3	2	6, 6
35	$5 - 1 + 1 =$	5	1	5
36	$2 + 1 + 1 + 1 =$	18		
37	$4 - 1 + 1 + 1 =$	5	5	1, 3, 6, 6, 7
38	$3 + 0 + 1 + 1 =$	17		
39	$3 - 0 + 1 + 1 =$	5	5	2, 2, 4, 6, 6
40	$5 + 1 =$	21		
41	$6 + 0 =$	13		
42	$7 - 1 =$	9	6	8, 8, 8, 8, 8, 8
43	$6 - 0 =$	13	2	0
44	$4 + 1 + 1 =$	1		
45	$5 + 1 + 0 =$	4		
46	$6 + 1 - 1 =$	0	1	8
47	$7 + 0 - 1 =$	0	3	6, 8, 8
48	$8 - 1 - 1 =$	2		
49	$3 + 1 + 1 + 1 =$	13	2	5, 7
50	$5 - 1 + 1 + 1 =$	8	4	3, 3, 3, 7
51	$7 - 1 - 1 + 1 =$	15	2	8, 10
52	$6 + 0 + 1 - 1 =$	12	2	5, 8
53	$6 + 1 =$	8		
54	$7 + 0 =$	4		
55	$8 - 1 =$	8	3	8, 9, 9
56	$7 - 0 =$	8	2	6, 6
57	$5 + 1 + 1 =$	3		

No.	Operation	Correct	Incorrect	List of incorrect solutions
58	$6 + 1 + 0 =$			
59	$6 + 0 + 1 =$	1		
60	$7 + 1 - 1 =$			
61	$6 + 1 + 1 - 1 =$	7	6	8, 8, 8, 8, 9, 9
62	$5 + 1 + 1 + 0 =$	10	2	8, 8
63	$4 + 1 + 1 + 1 =$	13		
64	$8 - 1 - 1 + 1 =$	5	7	5, 5, 6, 6, 6, 6, 8
65	$8 - 1 + 0 + 0 =$			
66	$7 + 1 =$	10	1	6
67	$8 + 0 =$	11		
68	$9 - 1 =$	7	2	1, 1
69	$8 - 0 =$	13		
70	$6 + 1 + 1 =$	2		
71	$7 + 1 + 0 =$	1		
72	$7 + 1 - 0 =$	2	1	7
73	$8 + 1 - 1 =$	4	2	7, 9
74	$7 + 0 + 1 =$	2	1	9
75	$5 + 1 + 1 + 1 =$	7		
76	$7 - 1 + 1 + 1 =$	8	6	3, 4, 7, 9, 9, 10
77	$6 + 1 + 1 + 0 =$	11	1	0
78	$9 - 1 + 0 + 0 =$	6	5	5, 6, 7, 7, 9
79	$8 - 1 + 1 + 0 =$			
80	$8 + 1 =$	9		
81	$9 - 0 =$	11	1	8
82	$9 + 0 =$	7		
83	$10 - 1 =$	9	2	1, 1
84	$7 + 1 + 1 =$	3		
85	$9 - 1 + 1 =$	2	1	10
86	$9 + 1 - 1 =$	2	1	10
87	$8 + 0 + 1 =$	1		
88	$8 + 1 + 0 =$	1		
89	$6 + 1 + 1 + 1 =$	7		
90	$7 + 1 + 1 + 0 =$	8	1	8
91	$8 + 1 + 0 + 0 =$	14		
92	$7 + 0 + 1 + 1 =$	6		

Year 6 (mean age = 10;10; n = 20)

No.	Operation	Correct	Incorrect	List of incorrect solutions
1	$2 + 1 =$	18		
2	$3 + 0 =$	13		
3	$4 - 1 =$	13		
4	$3 - 0 =$	17	1	2
5	$1 + 1 + 1 =$	4		

No.	Operation	Correct	Incorrect	List of incorrect solutions
6	$3 + 1 - 1 =$	1	2	4, 4
7	$3 + 0 + 0 =$	5		
8	$3 - 1 + 1 =$	4		
9	$2 + 1 + 0 =$	3		
10	$1 + 1 + 1 + 0 =$	24		
11	$2 + 1 + 1 - 1 =$	9	4	4, 4, 4, 5
12	$2 - 1 + 1 + 1 =$	16	4	4, 4, 4, 4
13	$1 + 0 + 1 + 1 =$	15		
14	$3 + 1 =$	20		
15	$4 + 0 =$	19		
16	$5 - 1 =$	26	1	7
17	$4 - 0 =$	25	1	3
18	$2 + 1 + 1 =$	5	1	5
19	$3 + 0 + 1 =$	1		
20	$4 + 1 - 1 =$	5	3	5, 5, 6
21	$4 - 1 + 1 =$	2	1	5
22	$3 + 1 + 0 =$	6		
23	$2 + 0 + 1 + 1 =$	15		
24	$1 + 1 + 1 + 1 =$	28		
25	$3 - 1 + 1 + 1 =$	19	3	3, 5, 5
26	$2 + 1 + 1 + 0 =$	20		
27	$4 + 1 =$	24		
28	$5 + 0 =$	22		
29	$6 - 1 =$	14	2	7, 7
30	$5 - 0 =$	23		
31	$3 + 1 + 1 =$	6		
32	$4 + 1 + 0 =$	6		
33	$4 + 0 + 1 =$	8	1	3
34	$5 + 1 - 1 =$	6	4	6, 6, 6, 6
35	$5 - 1 + 1 =$	7	3	3, 6, 6
36	$2 + 1 + 1 + 1 =$	23		
37	$4 - 1 + 1 + 1 =$	11	1	7
38	$3 + 0 + 1 + 1 =$	24	1	4
39	$3 - 0 + 1 + 1 =$	12	3	2, 4, 4
40	$5 + 1 =$	23		
41	$6 + 0 =$	19		
42	$7 - 1 =$	22	4	8, 8, 8, 8
43	$6 - 0 =$	16		
44	$4 + 1 + 1 =$	3		
45	$5 + 1 + 0 =$	3		
46	$6 + 1 - 1 =$	3		
47	$7 + 0 - 1 =$	4	3	7, 7, 8
48	$8 - 1 - 1 =$	6		
49	$3 + 1 + 1 + 1 =$	24	1	5
50	$5 - 1 + 1 + 1 =$	15	2	2, 7

No.	Operation	Correct	Incorrect	List of incorrect solutions
51	$7 - 1 - 1 + 1 =$	14	7	4, 4, 5, 7, 8, 8, 8
52	$6 + 0 + 1 - 1 =$	13	6	4, 5, 7, 8, 8, 8
53	$6 + 1 =$	17		
54	$7 + 0 =$	14		
55	$8 - 1 =$	14		
56	$7 - 0 =$	21	1	6
57	$5 + 1 + 1 =$	7	3	8, 8, 9
58	$6 + 1 + 0 =$	1		
59	$6 + 0 + 1 =$	4		
60	$7 + 1 - 1 =$	2	1	8
61	$6 + 1 + 1 - 1 =$	6	4	6, 7, 9, 9
62	$5 + 1 + 1 + 0 =$	19		
63	$4 + 1 + 1 + 1 =$	16	1	8
64	$8 - 1 - 1 + 1 =$	11	4	6, 9, 9, 9
65	$8 - 1 + 0 + 0 =$	15		
66	$7 + 1 =$			
67	$8 + 0 =$	19		
68	$9 - 1 =$	14	2	10, 10
69	$8 - 0 =$	15	1	7
70	$6 + 1 + 1 =$	7		
71	$7 + 1 + 0 =$	10		
72	$7 + 1 - 0 =$	4		
73	$8 + 1 - 1 =$	7	2	9, 9
74	$7 + 0 + 1 =$	6		
75	$5 + 1 + 1 + 1 =$	17		
76	$7 - 1 + 1 + 1 =$	13	2	6, 9
77	$6 + 1 + 1 + 0 =$	12		
78	$9 - 1 + 0 + 0 =$	14	3	6, 7, 9
79	$8 - 1 + 1 + 0 =$	15		
80	$8 + 1 =$			
81	$9 - 0 =$	7		
82	$9 + 0 =$	10		
83	$10 - 1 =$	23		
84	$7 + 1 + 1 =$	6		
85	$9 - 1 + 1 =$	6	2	7, 7
86	$9 + 1 - 1 =$	9		
87	$8 + 0 + 1 =$	4		
88	$8 + 1 + 0 =$	12		
89	$6 + 1 + 1 + 1 =$	17	1	8
90	$7 + 1 + 1 + 0 =$	16	1	8
91	$8 + 1 + 0 + 0 =$	11		
92	$7 + 0 + 1 + 1 =$	10		

School 2

Year 3 (mean age = 8;4; n = 18)

No.	Operation	Correct	Incorrect	List of incorrect solutions
1	$2 + 1 =$	20		
2	$3 + 0 =$	23	1	2
3	$4 - 1 =$	11	6	0, 5, 5, 5, 5, 5
4	$3 - 0 =$			
5	$1 + 1 + 1 =$	4		
6	$3 + 1 - 1 =$	1	1	5
7	$3 + 0 + 0 =$			
8	$3 - 1 + 1 =$	1	2	4, 4
9	$2 + 1 + 0 =$			
10	$1 + 1 + 1 + 0 =$	14		
11	$2 + 1 + 1 - 1 =$	10	10	4, 4, 5, 5, 5, 5, 5, 5, 5, 5
12	$2 - 1 + 1 + 1 =$	9	6	2, 4, 4, 5, 5, 5, 5
13	$1 + 0 + 1 + 1 =$	8		
14	$3 + 1 =$	13	1	3
15	$4 + 0 =$	10	1	3
16	$5 - 1 =$	12	3	6, 6, 6
17	$4 - 0 =$	14		
18	$2 + 1 + 1 =$	3		
19	$3 + 0 + 1 =$	1	1	3
20	$4 + 1 - 1 =$	3	3	5, 6, 6
21	$4 - 1 + 1 =$	0	1	5
22	$3 + 1 + 0 =$			
23	$2 + 0 + 1 + 1 =$	13	2	2, 3
24	$1 + 1 + 1 + 1 =$	14		
25	$3 - 1 + 1 + 1 =$	13	15	3, 3, 3, 3, 3, 3, 5, 5, 5, 5, 6, 6, 6, 6, 7
26	$2 + 1 + 1 + 0 =$	15	1	3
27	$4 + 1 =$	19	1	3
28	$5 + 0 =$	16		
29	$6 - 1 =$	11	9	1, 1, 1, 7, 7, 7, 7, 7, 7
30	$5 - 0 =$	20		
31	$3 + 1 + 1 =$	4		
32	$4 + 1 + 0 =$	6	1	8
33	$4 + 0 + 1 =$	7		
34	$5 + 1 - 1 =$	3	3	4, 7, 7
35	$5 - 1 + 1 =$			
36	$2 + 1 + 1 + 1 =$	10		
37	$4 - 1 + 1 + 1 =$	4	5	1, 3, 6, 7, 7

No.	Operation	Correct	Incorrect	List of incorrect solutions
38	$3 + 0 + 1 + 1 =$	12	1	6
39	$3 - 0 + 1 + 1 =$	11	3	2, 2, 4
40	$5 + 1 =$	15		
41	$6 + 0 =$	11		
42	$7 - 1 =$	7	6	7, 8, 8, 8, 8, 8
43	$6 - 0 =$	17	1	0
44	$4 + 1 + 1 =$	3		
45	$5 + 1 + 0 =$	3		
46	$6 + 1 - 1 =$	1	1	8
47	$7 + 0 - 1 =$			
48	$8 - 1 - 1 =$	11		
49	$3 + 1 + 1 + 1 =$	9	6	3, 3, 7, 7, 8, 8
50	$5 - 1 + 1 + 1 =$	4	8	2, 2, 2, 5, 5, 8, 10, 10, 10
51	$7 - 1 - 1 + 1 =$	7	12	4, 7, 8, 8, 8, 8, 8, 8, 8, 8
52	$6 + 0 + 1 - 1 =$	2	2	10, 10
53	$6 + 1 =$	7	1	5
54	$7 + 0 =$	8	1	6
55	$8 - 1 =$	6	5	1, 9, 9, 9, 9
56	$7 - 0 =$	9		
57	$5 + 1 + 1 =$	5		
58	$6 + 1 + 0 =$	1	1	5
59	$6 + 0 + 1 =$			
60	$7 + 1 - 1 =$	1	1	5
61	$6 + 1 + 1 - 1 =$	3	5	9, 9, 9, 9, 9
62	$5 + 1 + 1 + 0 =$	13		
63	$4 + 1 + 1 + 1 =$	7	1	9
64	$8 - 1 - 1 + 1 =$	2		
65	$8 - 1 + 0 + 0 =$	4	3	9, 10, 10
66	$7 + 1 =$	17		
67	$8 + 0 =$	9		
68	$9 - 1 =$	9	2	10, 10
69	$8 - 0 =$	6		
70	$6 + 1 + 1 =$	2		
71	$7 + 1 + 0 =$	4		
72	$7 + 1 - 0 =$	2	1	7
73	$8 + 1 - 1 =$	2	3	10, 10, 10
74	$7 + 0 + 1 =$			
75	$5 + 1 + 1 + 1 =$	8		
76	$7 - 1 + 1 + 1 =$	4	6	3, 4, 7, 9, 10, 10
77	$6 + 1 + 1 + 0 =$	11		
78	$9 - 1 + 0 + 0 =$			
79	$8 - 1 + 1 + 0 =$	4	4	9, 10, 10, 10
80	$8 + 1 =$	10		

No.	Operation	Correct	Incorrect	List of incorrect solutions
81	$9 - 0 =$	14		
82	$9 + 0 =$	4		
83	$10 - 1 =$	7	3	1, 1, 10
84	$7 + 1 + 1 =$	2		
85	$9 - 1 + 1 =$	2	2	2, 10
86	$9 + 1 - 1 =$	1		
87	$8 + 0 + 1 =$	2		
88	$8 + 1 + 0 =$			
89	$6 + 1 + 1 + 1 =$	7		
90	$7 + 1 + 1 + 0 =$	6	1	7
91	$8 + 1 + 0 + 0 =$	4	1	7
92	$7 + 0 + 1 + 1 =$	5	1	8

Year 5 (mean age = 9;2; n = 27)

No.	Operation	Correct	Incorrect	List of incorrect solutions
1	$2 + 1 =$	23		
2	$3 + 0 =$	46		
3	$4 - 1 =$	23	4	1, 4, 4, 5
4	$3 - 0 =$			
5	$1 + 1 + 1 =$	5		
6	$3 + 1 - 1 =$	4		
7	$3 + 0 + 0 =$	5		
8	$3 - 1 + 1 =$	1	3	2, 4, 4
9	$2 + 1 + 0 =$			
10	$1 + 1 + 1 + 0 =$	30		
11	$2 + 1 + 1 - 1 =$	16	6	1, 2, 4, 5, 5, 7
12	$2 - 1 + 1 + 1 =$	23	7	1, 1, 2, 2, 4, 4, 5
13	$1 + 0 + 1 + 1 =$	24	5	2, 2, 3, 5, 7
14	$3 + 1 =$	35	3	2, 2, 2
15	$4 + 0 =$	30		
16	$5 - 1 =$	27	2	5, 6
17	$4 - 0 =$	36	1	5
18	$2 + 1 + 1 =$	4		
19	$3 + 0 + 1 =$	6		
20	$4 + 1 - 1 =$	4		
21	$4 - 1 + 1 =$	5	2	2, 3
22	$3 + 1 + 0 =$			
23	$2 + 0 + 1 + 1 =$	32	3	2, 2, 2
24	$1 + 1 + 1 + 1 =$	19	1	2
25	$3 - 1 + 1 + 1 =$	18	4	2, 3, 4, 5
26	$2 + 1 + 1 + 0 =$	23	3	3, 3, 5

No.	Operation	Correct	Incorrect	List of incorrect solutions
27	$4 + 1 =$	24		
28	$5 + 0 =$	32		
29	$6 - 1 =$	30	4	5, 7, 7, 7
30	$5 - 0 =$	27		
31	$3 + 1 + 1 =$	10	1	9
32	$4 + 1 + 0 =$	9		
33	$4 + 0 + 1 =$	10	1	6
34	$5 + 1 - 1 =$	11	1	6
35	$5 - 1 + 1 =$			
36	$2 + 1 + 1 + 1 =$	32	1	6
37	$4 - 1 + 1 + 1 =$	15	11	0, 1, 1, 3, 3, 3, 4, 6, 6, 7, 7
38	$3 + 0 + 1 + 1 =$	19		
39	$3 - 0 + 1 + 1 =$	39	6	2, 2, 2, 2, 6, 6
40	$5 + 1 =$	23	1	4
41	$6 + 0 =$	30	1	1
42	$7 - 1 =$	26	1	8
43	$6 - 0 =$	28		
44	$4 + 1 + 1 =$	5		
45	$5 + 1 + 0 =$	5		
46	$6 + 1 - 1 =$	3		
47	$7 + 0 - 1 =$			
48	$8 - 1 - 1 =$	7	1	10
49	$3 + 1 + 1 + 1 =$	22	3	3, 4, 8
50	$5 - 1 + 1 + 1 =$	27	8	0, 0, 2, 3, 7, 7, 8, 8
51	$7 - 1 - 1 + 1 =$	23	6	2, 2, 5, 5, 8
52	$6 + 0 + 1 - 1 =$	14	7	5, 5, 7, 7, 7, 8, 8
53	$6 + 1 =$	11		
54	$7 + 0 =$	19		
55	$8 - 1 =$	22	1	9
56	$7 - 0 =$	21		
57	$5 + 1 + 1 =$	1	1	2
58	$6 + 1 + 0 =$	6	1	6
59	$6 + 0 + 1 =$	6		
60	$7 + 1 - 1 =$	6		
61	$6 + 1 + 1 - 1 =$	11	2	8, 9
62	$5 + 1 + 1 + 0 =$	23		
63	$4 + 1 + 1 + 1 =$	18	2	5, 8
64	$8 - 1 - 1 + 1 =$	14	3	5, 5, 9
65	$8 - 1 + 0 + 0 =$	3	1	7
66	$7 + 1 =$	21	1	6
67	$8 + 0 =$	25		
68	$9 - 1 =$	24		
69	$8 - 0 =$	19		
70	$6 + 1 + 1 =$	12		
71	$7 + 1 + 0 =$	7		

No.	Operation	Correct	Incorrect	List of incorrect solutions
72	$7 + 1 - 0 =$	6	1	6
73	$8 + 1 - 1 =$	7	1	7
74	$7 + 0 + 1 =$			
75	$5 + 1 + 1 + 1 =$	16	2	2, 9
76	$7 - 1 + 1 + 1 =$	17	3	3, 4, 9
77	$6 + 1 + 1 + 0 =$	13	1	7
78	$9 - 1 + 0 + 0 =$	1		
79	$8 - 1 + 1 + 0 =$	15	2	9, 10
80	$8 + 1 =$	17	1	7
81	$9 - 0 =$	27		
82	$9 + 0 =$	19		
83	$10 - 1 =$	15	1	10
84	$7 + 1 + 1 =$	2		
85	$9 - 1 + 1 =$	2	1	8
86	$9 + 1 - 1 =$	6	4	10, 10, 10, 10
87	$8 + 0 + 1 =$	4		
88	$8 + 1 + 0 =$			
89	$6 + 1 + 1 + 1 =$	16	1	10
90	$7 + 1 + 1 + 0 =$	11	3	8, 8, 10
91	$8 + 1 + 0 + 0 =$	15	2	7, 9
92	$7 + 0 + 1 + 1 =$	16		

Year 6 (mean age = 10;3; n = 20)

No.	Operation	Correct	Incorrect	List of incorrect solutions
1	$2 + 1 =$	19		
2	$3 + 0 =$	33		
3	$4 - 1 =$	19	1	5
4	$3 - 0 =$			
5	$1 + 1 + 1 =$	4		
6	$3 + 1 - 1 =$	3		
7	$3 + 0 + 0 =$	6		
8	$3 - 1 + 1 =$	2	2	4, 4
9	$2 + 1 + 0 =$			
10	$1 + 1 + 1 + 0 =$	14		
11	$2 + 1 + 1 - 1 =$	18	1	4
12	$2 - 1 + 1 + 1 =$	15	2	1, 2
13	$1 + 0 + 1 + 1 =$	17		
14	$3 + 1 =$	21	1	2
15	$4 + 0 =$	17		
16	$5 - 1 =$	24	1	6
17	$4 - 0 =$	15	1	0
18	$2 + 1 + 1 =$			

No.	Operation	Correct	Incorrect	List of incorrect solutions
19	$3 + 0 + 1 =$	7		
20	$4 + 1 - 1 =$	2		
21	$4 - 1 + 1 =$	1		
22	$3 + 1 + 0 =$			
23	$2 + 0 + 1 + 1 =$	27		
24	$1 + 1 + 1 + 1 =$	27		
25	$3 - 1 + 1 + 1 =$	22	5	0, 0, 5, 6, 6
26	$2 + 1 + 1 + 0 =$	14		
27	$4 + 1 =$	17	1	3
28	$5 + 0 =$	23	2	0, 0
29	$6 - 1 =$	23		
30	$5 - 0 =$	20	1	0
31	$3 + 1 + 1 =$	14		
32	$4 + 1 + 0 =$	6		
33	$4 + 0 + 1 =$	10		
34	$5 + 1 - 1 =$	7	2	6, 6
35	$5 - 1 + 1 =$			
36	$2 + 1 + 1 + 1 =$	23		
37	$4 - 1 + 1 + 1 =$	12	3	0, 6, 7
38	$3 + 0 + 1 + 1 =$	15	1	4
39	$3 - 0 + 1 + 1 =$	12	1	3
40	$5 + 1 =$	19	2	4, 4
41	$6 + 0 =$	16		
42	$7 - 1 =$	15	3	0, 5, 5
43	$6 - 0 =$	18		
44	$4 + 1 + 1 =$	7		
45	$5 + 1 + 0 =$	4	2	5, 7
46	$6 + 1 - 1 =$	5	2	1, 7
47	$7 + 0 - 1 =$			
48	$8 - 1 - 1 =$	5	2	7, 10
49	$3 + 1 + 1 + 1 =$	12	5	0, 7, 8, 8, 8
50	$5 - 1 + 1 + 1 =$	22	2	4, 4
51	$7 - 1 - 1 + 1 =$	14	2	8, 8
52	$6 + 0 + 1 - 1 =$	1		
53	$6 + 1 =$	13		
54	$7 + 0 =$	11		
55	$8 - 1 =$	13	1	9
56	$7 - 0 =$	15	3	0, 0, 6
57	$5 + 1 + 1 =$	5		
58	$6 + 1 + 0 =$	1		
59	$6 + 0 + 1 =$	4		
60	$7 + 1 - 1 =$	4	1	9
61	$6 + 1 + 1 - 1 =$	8	4	8, 9, 9, 9

No.	Operation	Correct	Incorrect	List of incorrect solutions
62	$5 + 1 + 1 + 0 =$	14		
63	$4 + 1 + 1 + 1 =$	13	1	9
64	$8 - 1 - 1 + 1 =$	14		
65	$8 - 1 + 0 + 0 =$	3		
66	$7 + 1 =$	18		
67	$8 + 0 =$	17		
68	$9 - 1 =$	17		
69	$8 - 0 =$	8	1	0
70	$6 + 1 + 1 =$	7	1	7
71	$7 + 1 + 0 =$	6		
72	$7 + 1 - 0 =$	7		
73	$8 + 1 - 1 =$	2		
74	$7 + 0 + 1 =$			
75	$5 + 1 + 1 + 1 =$	13		
76	$7 - 1 + 1 + 1 =$	11	3	4, 9, 9
77	$6 + 1 + 1 + 0 =$	13	2	6, 7
78	$9 - 1 + 0 + 0 =$			
79	$8 - 1 + 1 + 0 =$	9		
80	$8 + 1 =$	6	1	7
81	$9 - 0 =$	9	1	8
82	$9 + 0 =$	11		
83	$10 - 1 =$	15	1	1
84	$7 + 1 + 1 =$	6		
85	$9 - 1 + 1 =$	7	2	7, 7
86	$9 + 1 - 1 =$	5		
87	$8 + 0 + 1 =$	6	1	7
88	$8 + 1 + 0 =$			
89	$6 + 1 + 1 + 1 =$	10		
90	$7 + 1 + 1 + 0 =$	10		
91	$8 + 1 + 0 + 0 =$	10		
92	$7 + 0 + 1 + 1 =$	10		

Table 3: Arithmetic operations organised into groups of varying difficulty for each year group (both schools)²

Accuracy Range (% correct)	OPERATIONS	
	YR 3	YR 6
>90	<p>2+1, 3+0, 3+1, 4+0, 4-0, 5+0, 5+1, 7+1, 4+1, 5-0, 6-0, 6+1, 8+0, 8-0, 9-1, 8+1, 9+0</p> <p>1+1+1, 3+0+0, 3+1+0, 4+1+0, 3+1+1, 5+1-1, 4+1+1, 6+1+0, 6+0+1, 7+1-1, 6+1+1, 7+1+1, 9+1-1, 8+0+1, 8+1+0</p> <p>1+1+1+0, 1+0+1+1, 1+1+1+1, 2+0+1+1, 3-0+1+1, 6+1+1-1, 6+1+1+0, 8-1+0+0, 8-1+1+0, 7-1+1+1,</p>	<p>2+1, 4-1, 3-0, 3+0, 4+0, 3+1, 5-1, 4-0, 4+1, 5+0, 6-1, 5-0, 5+1, 6+0, 6-0, 6+1, 7+0, 8-1, 7+1, 8+0, 9-1, 8-0, 8+1, 9-0, 9+0, 10-1</p> <p>1+1+1, 3+0+0, 2+1+0, 3+0+1, 3+1+0, 3+1+1, 4+1+0, 4+0+1, 4+1+1, 6+1+0, 6+0+1, 6+1+1, 7+1-0, 7+0+1, 7+1+0 7+1+1, 8+0+1, 9+1-1, 7+1+1, 8+1+0, 1+1+1+0, 1+0+1+1, 2+0+1+1, 1+1+1+1, 2+1+1+0, 2+1+1+1, 3+0+1+1, 6+1+1-1, 4+1+1+1, 5+1+1+0, 8-1+0+0, 6+1+1+0, 5+1+1+1, 9-0+0+0</p>
80-90	<p>7-1, 8-1, 9-0</p> <p>2+1+1, 5-1+1, 7+1+0</p> <p>2-1+1+1, 2+1+1+0, 3+0+1+1, 5+1+1+0</p>	<p>7-1, 7-0</p> <p>2+1+1, 4+1-1, 4-1+1, 5+1+0, 6+1-1, 8-1-1, 5+1+1</p> <p>8-1-1+1, 8-1+1+0, 7-1+1+1</p>
70-80	<p>4-1, 3-0, 5-1, 6-1, 6+0, 7+0, 10-1</p> <p>3+1+0, 3+0+1, 4+1-1, 5+1+0, 7+0-1, 9-1+1, 4+0+1, 5+1+0, 7+0-1</p> <p>2+1+1+1, 4-1+1+1, 3+1+1+1, 3+1+1+1, 6+0+1-1, 8-1-1+1, 5+1+1+1</p>	<p>3-1+1, 5-1+1, 7+1-1, 9-1+1</p> <p>7-1-1+1</p>
< 70	<p>7-1, 7-0,</p> <p>3-1+1, 8-1-1, 5+1+1, 7+1-0, 7+0+1</p> <p>2+1+1-1, 3-1+1+1, 5-1+1+1, 7-1-1+1, 4+1+1+1</p>	<p>3+1-1, 5+1-1, 7+0-1</p>

² Operations which were presented on only 3 or fewer occasions and which were never answered correctly are not included in this table.