INVESTIGATING YOUNG CHILDREN'S STRATEGY USE AND TASK PERFORMANCE IN THE DOMAIN OF SIMPLE ADDITION, USING THE "CHOICE/NO-CHOICE" METHOD

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Abstract. *In this study we investigated young children's strategy use and task performance in the domain of simple addition, using the "choice/no-choice" method. Second-graders, divided in 3 groups according to general mathematical ability, solved 25 problems in 3 different conditions. The results showed use of multiple strategies, adaptive strategy choices, and group differences in strategy choice and strategy execution in parallel with differences in task performance. Furthermore, the use of the "choice/no-choice" method revealed that freedom of choice enhances task performance, and that "retrieval"--although mastered only marginally by children of this age--is a highly efficient strategy to solve simple addition problems up to 20.*

1. Theoretical and empirical background

During the last decades, researchers have intensively studied the strategies people use to solve cognitive tasks, the way people choose between these strategies, and the changes that take place in these processes during lifetime. A major finding of all these studies is that young children, as well as adolescents and adults, make use of, and choose adaptively between, multiple strategies to solve cognitive tasks in diverse domains, including mathematics. The theoretical and methodological ideas of Siegler (1996; see also Lemaire & Siegler, 1995; Siegler & Lemaire, 1997) deepened our understanding about this topic. In his "model of strategic change", Siegler distinguishes among four dimensions of strategic competence and strategic change, namely: (1) strategy repertoire, i.e. the repertoire of strategies a person uses to solve a task, (2) strategy distribution, i.e. the relative frequency with which each strategy is used to solve a task, (3) strategy effectiveness, i.e. the speed and the accuracy with which each strategy is executed, and (4) strategy selection, i.e. the adaptiveness with which each strategy is chosen. According to this model, at the beginning of the learning process, the learner frequently chooses rather primitive "back-up" strategies (like, for instance, counting), which he or she executes rather ineffectively (i.e. slowly and inaccurately). With experience, the learner uses more efficient "back-up" and "retrieval" strategies, which he or she executes ever faster and more accurately, and also more adaptively.

Furthermore, Siegler proposes the use of the "choice/no-choice" method to obtain unbiased information concerning both the efficiency of the strategies an individual uses and the adaptiveness of the strategy choices he or she makes. This method requires testing each subject under two types of conditions. In the “choice” condition, subjects can freely choose which strategy they use to solve a series of problems from a given task domain. In the “no-choice” condition, the experimenter forces them (experimentally) to solve all problems by means of one particular strategy. The number of “no-choice” conditions can vary according to the number of strategies available to the subject, research interests, technical possibilities, etc.

Taking into account Siegler’s theoretical and methodological ideas, we aimed at investigating which strategies 6-7-year-old children with strong, medium, and weak mathematical abilities use to solve simple addition problems up to 20, and how adaptively they choose between these strategies, in relation to task performance. In order to get an accurate picture of both the efficiency of the strategies used and the adaptiveness of the strategy choices, we used the “choice/no-choice” method.

2. Method

Subjects were 77 second-graders from two Flemish schools in the beginning of the school year. Based on their overall scores for mathematics in the first grade and on the second-grade teacher’s judgement, subjects were divided in three groups according to mathematical ability (strong, medium, and weak, further referred to as, respectively, the S-, M-, and W-group).

All children were asked to solve a series of 25 simple addition problems up to 20 in three different conditions. These 25 problems were constructed from the 49 possible pair wise combinations of the integers 3 to 9. The problems belonged to five different problem types (with five problems in each type): one type of easy additions up to 10 (T1; e.g. 3 + 4 = .), and four types of additions up to 20: (1) problems with a large first addend and a small second addend (T2; e.g. 9 + 3 = .), (2) problems with a small first addend and a large second addend (T3; e.g. 3 + 9 = .), (3) “tie sums” (T4; e.g. 7 + 7 = .), and (4) “almost tie sums” (T5; e.g. 7 + 6 = .). Problems were presented on a computer screen and the computer registered the reaction time (RT, with an accuracy of 0.01 sec) as well as the answer.

All children solved the problems in three different conditions. In the first condition, the “choice” condition (= condition CHO), children solved each problem by means of the strategy they preferred. Meanwhile their problem solving behaviour was observed by the experimenter. Immediately after solving each problem, children were asked to report verbally which strategy they had used. In the second condition, children were explicitly instructed to solve all problems with one particular strategy, namely “adding up to 10” (= condition ADD). Note that, as a consequence of the obligatory use of this strategy, the five easy additions up to 10 (T1) were not administered in this condition. To further enhance children to use the strategy “adding up to 10”, the computer presented the problems in the following format: X + Y = X + (. + .) = . In the third condition, the maximum solution time was limited to 2 seconds, to force children as much as possible to solve all problems by "retrieval" (= condition RET). All children first solved the problems in condition CHO (day 1). Half of the children solved the problems in condition ADD on the second day, and ended with solving the problems in condition RET on day 3. For the other half the order of the two "no-choice" conditions was reversed.

Generally spoken, we expected a variation in strategy use in condition CHO, in the sense that all children would use different strategies to solve the problems in this condition (see Siegler, 1996). Next, we expected group differences in strategy choice and in task performance (i.e. accuracy and speed of problem solving), in favour of the S-group (see Geary, 1990). Finally, we expected differences in strategy use and in task performance between the different problem types and between the three conditions (see Siegler & Lemaire, 1997).

3. Results

Strategy use

As expected, all children used multiple strategies to solve the problems in condition CHO. The number of strategies used varied from 2 to 8 different strategies, ranging from counting strategies like "counting all starting from 1" or "counting on starting from smaller/larger" to "adding up to 10" and "retrieval". As shown in the table below, "retrieval" and "adding up to 10" were the two most common strategies (respectively, 42.29% and 37.51% of all strategies used in this condition), followed by the use of a counting strategy (14.60%). As expected, we observed clear group differences in strategy choice ($\chi^2(6)$ = 268.51, p = .001), in the sense that S-children used the "retrieval" strategy more frequently than M- and W-children, whereas W-children solved more problems by means of counting than S- and M-children.

		"Retrieval"	**Adding up to 10**	**Counting**	**Other**	**Total**
S-group	**N**	274	210	11	30	525
	%	52.19	40.00	2.10	5.71	100.00
M-group	**N**	360	383	88	44	875
	%	41.14	43.77	10.06	5.03	100.00
W-group	**N**	180	129	182	34	525
	%	34.29	24.57	34.67	6.48	100.00
Total	**N**	814	722	281	108	1925
	%	42.29	37.51	14.60	5.61	100.00

Accuracy

Scores were analysed using a 3x3x4[1] ANOVA (group x condition x problem type). The scores (maximum score = 5) of the three groups of children on the four different problem types in the three conditions are given in the table below. All differences reported are significant at the 1% level.

As expected, an effect of *group* was found: S-children scored higher than M-children, who scored higher than W-children. We also found an effect of *condition*: As expected, scores in condition CHO and in condition ADD were higher than scores in condition RET, but there was no difference in score between condition CHO and condition ADD. The effect of *problem type* was also significant: Subjects scored highest on T4 problems; the scores on T2 problems were higher than those on T3 and T5 problems, which did not differ mutually. Finally, an interaction between *condition* and *problem type* was found: There was no difference in score on the four problem types in condition CHO and in condition ADD, whereas T4 problems were answered more accurately than T2, T3 and T5 problems in condition RET.

	S-group			**M-group**			**W-group**		
	CHO	**ADD**	**RET**	**CHO**	**ADD**	**RET**	**CHO**	**ADD**	**RET**
T2 (e.g. 9 + 3)	4.81	4.95	1.86	4.80	4.83	1.29	4.52	4.29	0.33
T3 (e.g. 3 + 9)	4.76	4.62	1.38	4.74	4.34	1.23	4.14	3.81	0.05
T4 (e.g. 7 + 7)	4.90	4.95	3.29	4.54	4.91	2.80	3.57	3.90	1.52
T5 (e.g. 7 + 6)	4.86	4.86	1.05	4.63	4.60	1.03	3.76	4.00	0.38

Speed

Reaction times were analysed using a 3x2[2]x4 ANOVA (group x condition x problem type). The reaction times of the three groups of children on the four different problem types in condition CHO and in condition ADD are given in the table below. All differences reported are again significant at the 1% level.

First, an effect of *group* was found: As expected, the S-group answered the problems fastest, whereas the W-group answered the problems slowest. Second, we found an effect of *condition*: As anticipated, lower RTs were observed in condition CHO than in condition ADD. Next, we found an effect of *problem type*: T2 problems were answered as fast as T4 problems; T2 and T4 problems were answered faster than T3 and T5 problems, which did not differ in RT. Furthermore, there was an interaction between *group* and *condition*: The difference in RT between condition CHO and condition ADD was biggest for the M-group, and smallest for the S-group. Finally, we observed an interaction between *condition* and *problem type*: There was no difference in RT between T2, T3 and T4 problems in condition CHO, whereas T5 problems were answered much slower. This pattern was not observed in the ADD condition: In this condition, RTs on T2 and T4 problems, T3 and T5 problems, and T4 and T5 problems did not differ, whereas we did find a difference in RT on T2 and T3 problems, T2 and T5 problems, and T3 and T4 problems.

	S-group		**M-group**		**W-group**	
	CHO	**ADD**	**CHO**	**ADD**	**CHO**	**ADD**
T2 (e.g. 9 + 3)	4.13	5.70	4.27	7.44	6.76	9.86
T3 (e.g. 3 + 9)	4.38	8.02	4.61	11.68	7.99	13.08
T4 (e.g. 7 + 7)	3.90	6.23	4.05	9.41	7.40	11.40
T5 (e.g. 7 + 6)	6.04	7.18	6.62	9.58	10.16	12.56

4. Conclusions

In line with earlier studies concerning young children's strategy use in the domain of simple addition (e.g. Geary, 1990; Siegler, 1996), we observed a rich variation in strategy use (in the "choice" condition) as well as considerable group differences in strategy choice and strategy execution, resulting in group differences in task performance. Furthermore, a first global analysis of the data in the three different conditions revealed, first, that children in general made adaptive strategy choices in the CHO condition: They obviously chose those strategies that allowed them to answer the problems in a relatively fast and accurate way. Second, the overall difference in RT between condition CHO and condition ADD demonstrated that freedom of choice enhances (at least partly) task performance: Forcing children to solve all problems in a standardised and stereotyped way (by means of the "adding up to 10"-strategy) influenced their response time negatively (although it did not influence their accuracy). Finally, the data obtained in condition RET indicate that children of this age are typically not (yet) able to solve simple addition problems up to 20 by means of "retrieval" (except for the "tie-sums"). Nevertheless, when a child succeeded in responding by "retrieval" in the RET condition, the answer was mostly correct. Ongoing more fine-grained and individualised comparative analyses of the nature and the efficiency of the strategies used in the different conditions will shed further light on the adaptiveness of children's strategy choices.

References

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[1] Taking the central topic of the study into account, namely second-graders' strategy use and task performance on simple addition problems up to 20, data concerning *problem type* 1 were not included in the analysis.

[2] Because of the strict time limit in *condition* RET, data concerning condition RET were not included in the analysis.