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ABSTRACT

This cross-sectional study investigated the problem-solving strategies used by schooled and unschooled Nigerian children to solve simple addition and subtraction problems. The purpose of the study was to: (1) verify with Nigerian children, models of the knowledge and strategies underlying children's solutions to simple word problems; (2) test the influence of children's native language on mathematics performance; and (3) investigate the effects that schooling has on children's solutions of simple addition and subtraction word problems. Individual clinical interviews were used to identify the strategies used by 48 Nigerian schooled children from grades 1 through 4 and 47 Nigerian unschooled children from ages 7- to 14-years-old to solve a broad range of addition and subtraction word problems. Results revealed that the performance of schooled and unschooled children was similar, although unschooled children used the more advanced strategies at older ages than schooled children. As grade or age level increased, solution strategies of both groups of children moved from direct modeling strategies to number of facts learned, both at the recall level and derived from other number facts. Children performed significantly better when problems were presented in their native language than when they were presented in English. (Author/JN)

Program Report 85-17

THE EFFECTS OF LANGUAGE AND SCHOOLING ON THE SOLUTION OF SIMPLE WORD PROBLEMS BY NIGERIAN CHILDREN

BY

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A Report from the Project Using the Microcomputer to Teach Problem-solving Skills

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Abstract

The growing body of research on the processes children use to solve simple addition and subtraction problems has indicated that most children attend to the semantic structure of problems and model with objects the actions or relationships described in different problems. This cross-sectional study investigated the problem-solving strategies used by schooled and unschooled Nigerian children to solve simple addition and subtraction problems. The purpose of the study was threefold: (1) to verify with Nigerian children, models of the knowledge and strategies underlying children's solutions to simple word problems; (2) to test the influence of children's native language on mathematics performance; and (3) to investigate the effects that schooling has on children's solutions of simple addition and subtraction word problems.

The study used individual clinical interviews to identify the strategies used by 48 Nigerian schooled children from grades 1 through 4 and 47 Nigerian unschooled children from ages 7 through 14 years to solve a broad range of addition and subtraction word problems. The results revealed that the performance of schooled and unschooled children was similar, although unschooled children used the more advanced strategies at older ages than schooled children. As grade or age level increased, solution strategies of both groups of children moved from direct modeling strategies to number facts learned, both at the recall level and derived from other number facts. Children performed significantly better when problems were presented in their native language than when they were presented in English.

Children enter school with a great deal of informal knowledge of mathematics (Ginsburg, 1977; Resnick & Ford, 1981). One area in which children's informal or invented strategies demonstrate a remarkable degree of insight is in solving simple word problems (Carpenter & Moser, 1983, 1984; Riley, Greeno, & Heller, 1983). Before they receive any formal instruction in mathematics at school, children can solve a variety of simple mathematics problems by counting and modeling with concrete materials.

These findings suggest that children construct procedures for solving addition and subtraction problems without formal instruction. However, the contribution that schooling makes in the development of strategies for solving addition and subtraction problems has not been investigated. Older children in most prior studies have been in school for several years, so it is not possible to determine whether the acquisition of the more advanced strategies used by older children is dependent on instruction or whether these strategies also would be acquired outside of formal schooling.

This study investigated the strategies used by Nigerian schooled and unschooled children to solve basic addition and subtraction word problems. The purpose of the study was: (1) to verify with Nigerian children models of the knowledge and strategies underlying children's solutions to basic addition and subtraction word problems (Briars & Larkin, 1984; Riley et al. 1983), (2) to test the influence of language on children's ability to solve simple arithmetic word problems, and (3) to study the effect that schooling has on children's solution of basic addition and subtraction word problems.

Background

General Research on Addition and Subtraction

Most of the research on addition and subtraction has dealt with schooled children. Recent studies carried out in different countries, like the United States (Carpenter & Moser, 1983, 1984; Riley, Greeno, & Heller, 1983), Japan (Hatano, 1982), and Israel (Nesher & Katriel, 1982) have investigated the strategies schooled children used to solve addition and subtraction word problems. These studies have revealed the importance of the semantic structure of a problem for the kind of strategies used by children. Four main categories of problems have been identified: Change (Join and Separate), Combine, Compare, and Equalize. Within each of these semantic categories different problems could be formulated by varying the unknown and the nature of relationships in the problem. Twenty distinct problems can be generated from the four semantic categories (Carpenter & Moser, 1983; Riley et al. 1983). Selected problems used in the study are presented in Table 1.

The distinctions between problems illustrated in Table 1 are generally reflected in children's solutions. Children's solution processes tend to model the action or relationships described in a problem. Strategies most frequently used to solve addition problems are summarized in Table 2, and primary subtraction strategies are summarized in Table 3. The relationship between problem structure and children's

Table 1

Representative Word Problems

*1. Addition - Simple Join
Toyin had 9 oranges. Lanre gave her 5 more oranges. How many oranges does Toyin have altogether?

*2. Subtraction - Simple Separate
Toyin had 12 oranges. She gave 3 oranges to Lanre. How many oranges does she have left?

*3. Addition - Combine
Toyin has 9 ripe oranges. She also has 8 green oranges. How many oranges does she have?

4. Subtraction - Compare
Toyin has 13 oranges. Lanre has 9 oranges. How many more oranges does Toyin have than Lanre?

5. Subtraction - Combine
Toyin has 15 oranges. 6 are ripe and the rest are green. How many white oranges does Toyin have?

6. Addition - Compare
Lanre has 8 oranges. Toyin has 5 more oranges than Lanre. How many oranges does Toyin have?

7. Subtraction - Join Start Unknown
Toyin had some oranges. Lanre gave her 7 more oranges. Now she has 15. How many oranges did Toyin have to start with?

*8. Subtraction - Join Change Unknown
Toyin has 8 oranges. How many more oranges does she need to have 14 oranges altogether?

9. Addition - Separate Start Unknown
Toyin had some oranges. She gave 5 to Lanre. Now she has 7 oranges left. How many oranges did Toyin have to start with?

10. Subtraction - Compare
Toyin has 13 oranges. She has 7 more oranges than Lanre. How many oranges does Lanre have?

11. Subtraction - Separate Change Unknown
Toyin had 16 oranges. She gave some to Lanre. Now she has 9 oranges left. How many oranges did she give to Lanre?

*Problems administered both with and without counters.

solution strategies is most clearly illustrated by their solution to subtraction problems. The Separating From strategy directly models the action in the Simple Separate problem (Table 1, problem 2), and it is the strategy that most young children use for that type of problem. Similarly the Adding On strategy is used for Join Change Unknown problems (Table 1, problem 8), and the Matching strategy is used for Compare problems (Table 1, problem 4). Older children tend to use more efficient counting strategies (Counting On From Larger, Counting Up From Given), but problem structure continues to play an important role in their choice of strategy.

Effects of Language

To some degree, children's performance on addition and subtraction problems depends on both the language of the problem and the language in which the problem is presented. The first aspect is concerned with how words used to state a problem may affect the comprehension and solution of the problem. Nesher and Teubal (1975) pointed out that the same words appear in some problems as valid cues and in others as distractors. Studies by Carpenter, Hiebert, and Moser (1981), Hudson (1980), and Lindvall and Ibarra (1980) revealed that some wordings appear to make the semantic structure of the problem clearer than others.

Of particular importance to this study is the second aspect, which relates to children whose native language is not used for instruction. It is conjectured that such children will have problems with the language used in the mathematics classroom in general and with addition and subtraction word problems in particular. Several related studies of the mathematical performances of Hispanics in the United States have lent support to this hypothesis (Cuevas, 1982; Gaarder, 1975; Valvarde, 1984). These studies revealed that mathematics problems presented to children in their native language are easier than similar problems presented in their second language, even though instruction occurred in the second language. Results of Ehindero's (1980) study of Nigerian children were in accordance with these findings.

Effects of Schooling

Ginsburg, Posner, and Russell (1981) considered the effects of schooling on the development of informal mathematical thinking among Dioula and Baoule groups of the Ivory Coast. These researchers found that schooling did not affect Dioula children's performance on simple arithmetic tasks involving concrete objects. That is, both schooled and unschooled Dioula children performed at similar levels, though the unschooled Dioula tended to rely more on regrouping and Number Facts and less on Counting algorithms than their schooled counterparts. A possible explanation for the relatively high performance of the unschooled group was that the Dioula people are predominantly traders. Therefore, the merchantile activities engaged in by these people may have helped the development of mathematical concepts of the unschooled children. The picture is quite different when a neighboring agriculturally oriented group such as the Baoule is considered. Guerry (1975) attributed unschooled Baoule children's poor performance to the fact that mathematics does not play a central role in their culture. These findings suggest that the performance of unschooled children on arithmetic tasks depends on their cultural activities.

Another related study on the effects of schooling was carried out by Saxe (in preparation), in Oksapmin, Papual New Guinea, to investigate the way children's indigenous numerical understandings guide their arithmetic achievements. Children developed calculation skills based on an indigenous number system that involves counting of 27 points defined on the body parts. There is little or no social context in which Oksapmin children engage in arithmetic activities. Nevertheless, these children not only spontaneously used the indigenous system in the context of school arithmetic, but they also created new forms of numerical symbolization and calculation based on the system to deal with school arithmetic problems.

Method

A cross-sectional study was designed to study the processes Nigerian children use to solve simple addition and subtraction problems. Clinical interviews were used to identify these processes.

Subjects

The subjects for the study consisted of 48 schooled children and 47 unschooled children. The schooled subjects were randomly drawn from the

Yoruba speaking groups in grades 1 through 4 of a Nigerian University Staff School in Zaria. Twelve subjects were drawn from each grade level. Story problems are uncommon in this school, as is the case in Nigerian primary schools in general. Much of the time in early elementary school is devoted to the teaching and learning of addition and subtraction number facts. The only meaning of addition taught is "bring together." After children are drilled in this operation, subtraction is introduced. The only definition of subtraction given to the children is "take away." Both these operations are taught with a strong emphasize on drill and practice of arithmetic facts, which is often implemented as classroom chorus drills. The missing numbers in addition and subtraction sentences usually come up for the first graders toward the end of the academic year. These types of problems are also repeated at higher grade levels. No distinction is made between problems of the types A + ? = C and ? + A = C. Both problems involve looking for a number that would be added to A to give C. One way that children solve these types of problems is by Trial and Error.

The 47 unschooled subjects were randomly drawn from the community where the staff school is located. The ages of children in this sample ranged between 7 and 14 years. They could speak Yoruba fluently, and they had at most very limited access to schooling. Most of these children were traders. Their mathematical experiences were probably based on their day-to-day activities in the market. These activities include handling money, which is based on the decimal system, and buying and selling commodities, which are packed in dozens.

Procedures

This study used individual interviews to identify the process that the children used to solve each of the problems. The interviews started on September 26, 1984, and lasted for 6 weeks. During the interviews, the schooled subjects were asked to solve 15 addition and subtraction word problems in English and 15 in Yoruba. The unschooled subjects were asked to solve 15 problems in Yoruba. For 11 of each group of 15 problems, subjects were allowed to use counters (see Table 1). For the remaining four problems, parallel to four of the 11 problems, subjects were not allowed to use counters or fingers. These problems are indicated with an asterisk in Table 1.

Four parallel sets of 11 problems were constructed in English in Yoruba. For each schooled subject, two sets of English language problems were randomly selected. All problems in one of the selected sets were administered with counters; the four problems administered without counters were identified in the second set. The same procedure was followed with the sets of Yoruba language problems, both for the schooled sample and for the unschooled. All problems involved numbers with sums between 10 and 20.

Responses were coded by the interviewer using a coding system developed by Carpenter and Moser (1984). Primary categories of this coding system are summarized in Tables 2 and 3. Several strategies in addition to those listed in Tables 2 and 3 were observed.

For certain problems, Trial and Error is required to directly model the action in the problem. For example, in the Separate Start Unknown

Table 2

Addition Strategies

<u>Modeling strategies</u>	
Counting All	Both sets are represented using physical objects or fingers, and the union of the two sets is counted.
<u>Counting strategies</u>	
Counting On From First	The counting sequence begins with the first number given in the problem and continues the number of units represented by the second number.
Counting On From Larger	The counting sequence begins with the larger of the two numbers given in the problem and continues the number of units represented by the smaller number.
<u>Number Fact strategies</u>	
Recall	The number fact is immediately retrieved from long term memory with no apparent counting.
Derived Facts	The number fact is derived from a recalled number fact.

Table 3

Subtraction Strategies*

Direct modeling strategies	
Separating From	Using objects or fingers, a set of a objects is constructed. b objects are removed. The answer is the number of remaining objects.
Adding On	A set of a elements is constructed. Elements are added to this set until there is a total of b elements. The answer is founded by counting the number of elements added.
Matching	A set of a objects and a set of b objects are matched one to one until one set is exhausted. The answer is the number of objects remaining in the unmatched set.
Counting strategies	
Counting Down From	A backward counting sequence is initiated starting with a. The sequence contains b counting number words. The last number in the counting sequence is the answer.
Counting Up From Given	A forward counting sequence starts with a and continues until b is reached. The answer is the number of counting words in the sequences.
Choice	Either Separating From or Counting Up From Given is used depending upon which is more efficient.

*Strategies for a - b = ? or b + ? = a

problem (Table 1, Problem 9), the initial quantity is unknown so it cannot be represented directly. Some children modeled the action in this problem by putting out some counters, removing a specific number, and counting the remaining counters to determine whether the number left matched the other number given in the problem. If it did not, the initial set was adjusted accordingly. Several trials were generally required to arrive at the correct answer. Variations of Trial and Error were used for other problems.

For Compare problems, children often used a strategy that started out like the Matching strategy but ended with a separating action. To use this strategy, a child modeled the two given numbers. After a long pause, or asking for the problem to be repeated a number of times, the model of the smaller number was discarded. Next the model of the larger number was pulled nearer to the child. Then the smaller number of objects was removed from it. The remainder was given as the answer. Pointing to the discarded set, the child was asked, "Why did you discard it?" The child reported that the discarded model was equivalent to the newly constructed model. For this reason, this strategy was labeled the "Equivalent" strategy. The main difference between the Matching strategy and the Equivalent strategy was that in the Matching strategy, the elements of the model were always used as units to establish a one-to-one correspondence. In the Equivalent strategy, the smaller number was modeled and then discarded.

The Add On/Separate From strategy normally occurred when a child did not keep track of the number of objects added when attempting to Add

On. In the most typical cases, the child counted out counters equivalent to the smaller given number, then paused for some seconds. Counters were then added until the larger number was reached. If children did not keep track of the additional counters, they were forced to remove the smaller given number from the model of the larger given number, which had been constructed by Adding On. The remainder was the answer. Two problems in which this strategy was prominent were the Join Change Unknown and Join Start Unknown problems. As with the Equivalent strategy, the final solution process actually involved Separating From.

Another common response was a variation on the Counting On strategy described in Table 2. In most studies, children who Count On do not directly model the two addends, they simply begin counting with a number representing one of the addends and keep track of the number of steps in the counting sequence. This particular strategy was not observed frequently with Nigerian children. However, a number of children would construct sets representing both addends, but rather than counting the total number of objects in the union of the two sets, they simply started counting with the number of objects in one of the sets and continued the counting sequence with the objects in the second set. This strategy was coded as Counting On.

A number of incorrect strategies were also observed. These include guessing, responding with one of the numbers given in the problem, and choosing the wrong operation. For certain problems in which the unknown was referred to as "some" objects, children gave "some" as their answer.

Results

The performance on selected problems is presented in Table 4. Regardless of the sample (schooled or unschooled) or the language (Yoruba or English) in which the problems were presented, the results indicated that Simple Join, Combine Addition, and Simple Separate were the easiest problems. The Compare problems and the Separate Start Unknown problems were the most difficult.

Strategies used for selected problems are presented in Tables 5-9. Counting All was the primary strategy used for addition problems by the younger children in both samples. Older children used both Counting All and Counting On From Larger strategies. For subtraction problems, Separating From was the dominant strategy. However, other strategies that mirrored the structure of a problem were also used, especially by older children. For example, as indicated in Table 6, appropriate Trial and Error strategies were recorded for Separate Start Unknown problems. Other strategies used were Equivalent strategies for Compare problems and Adding On/Separating From strategies for Join Change Unknown problems. Number facts were commonly used by older children. Except for the three easiest problems, inappropriate strategies were often recorded for younger children.

Effects of Language

Thirty six of the 48 children in the schooled sample performed better when problems were in Yoruba. Only five children performed better when problems were presented in English. Seven children had the

Table 4

Percent Correct on Selected Problems Administered with Counters

Problem Type	Schooled Sample: English Problems				Schooled Sample: Yoruba Problems				Unschooled Sample			
	1[a]	2	3	4	1	2	3	4	7[b]	9	11	13
Simple Join (1)[c]	100	100	100	100	100	100	100	100	72	100	100	100
Simple Separate (2)	84	100	100	100	84	100	100	100	58	92	100	100
Join Change Unknown (8)	8	42	75	100	25	92	100	100	14	75	88	100
Separate Start Unknown (9)	16	50	67	92	34	75	100	100	43	75	82	92
Compare (4)	0	25	67	84	8	25	75	100	0	58	75	92
Mean percent correct for all problems administered	36	61	89	85	48	76	93	99	37	72	85	95

[a]Grade level: N = 12 subjects per grade

[b]Age level: 7-8, N = 7; 9-10, N = 12; 11-12, N = 16; 13-14, N = 12

[c]Indicates problem number in Table 1

Table 5

Percentage of Children Using Various Strategies for Simple Join Problem with Manipulatives (Table 1, problem 1)

	Strategy			
	Count All	Count From Larger	Derived Fact	Number Fact
Schooled Sample (Problems Presented in Yoruba)				
1	92	8	0	0
2	75	16	0	0
3	25	34	0	25
4	16	16	8	58
Unschooled Sample				
7-8	100	0	0	0
9-10	67	8	8	16
11-12	25	12	30	25
13-14	16	8	24	34

Table 6

Percentage of Children Using Various Strategies for Simple Separate Problem with Manipulatives (Table 1, problem 2)

Grade/Age	Strategy			
	Separating From	Derived Fact	Number Fact	Wrong Operation
Schooled Sample (Problems Presented in Yoruba)				
1	100	0	0	0
2	100	0	0	0
3	84	0	16	0
4	42	8	50	0
Unschooled Sample				
7-8	72	0	0	28
9-10	92	0	8	0
11-12	75	0	25	0
13-14	50	0	50	0

Table 7

Percentage of Children Using Various Strategies for Join Change Unknown Problem with Manipulatives (Table 1, problem 8)

Grade/Age	Strategy							
	Separate From	Add On	Add On/ Separate	Trial & Error	Number Fact	Given Number	Guess	Wrong Operation
Schooled Sample (Problems Presented in Yoruba)								
1	0	8	25	8	0	0	34	25
2	8	25	42	25	0	0	0	0
3	25	42	8	16	8	0	0	0
4	8	42	0	0	50	0	0	0
Unschooled Sample								
7-8	0	0	14	0	0	28	43	14
9-10	16	16	50	8	0	0	8	0
11-12	12	25	32	12	12	0	6	0
13-14	16	42	25	0	16	0	0	0

Table 8

Percentage of Children Using Various Strategies
for Separate Start Unknown Problem with Manipulatives (Table 1, problem 9)

Grade/Age	Strategy					
	Count All	Count On	Trial & Error	Number Fact	Guess	Wrong Operation
Schooled Sample (Problems Presented in Yoruba)						
1	34	0	0	0	23	25
2	50	8	25	0	0	8
3	34	16	16	25	0	0
4	16	16	0	50	0	0
Unschooled Sample						
7-8	29	0	14	0	14	29
9-10	34	0	34	8	8	8
11-12	32	12	12	18	18	0
13-14	42	25	0	33	0	0

Table 9

Percentage of Children Using Various Strategies
for Compare Problem with Manipulatives (Table 1, problem 4)

Grade/Age	Strategy						
	Separate From	Equivalent	Matching	Number Fact	Given Number	Guess	Wrong Operation
Schooled Sample (Problems Presented in Yoruba)							
1	8	0	0	0	42	16	34
2	8	16	0	0	34	16	25
3	16	50	0	8	8	8	8
4	25	33	0	42	0	0	0
Unschooled Sample							
7-8	0	0	0	0	58	28	14
9-10	25	33	0	0	33	8	0
11-12	25	44	0	18	6	6	0
13-14	42	25	0	33	0	0	0

same performance in both languages, but five of the seven got all problems correct. Mean levels of performance for each language and each grade are presented in Table 4. Differences at each grade favor problems presented in Yoruba. These differences in performance were significant at the 0.025 level for all four grade levels.

Effects of Schooling

Part of this study addressed the issue of the effects of schooling on solving addition and subtraction word problems. The results indicated that unschooled children were ultimately as successful in solving word problems as schooled children, although the success generally came at an older age. For example, the performance of grade 1 (age 6½) and grade 2 (age 7½) children roughly corresponded to the performance of unschooled children of ages 7 to 10 years. Also most 13- and 14-year-old unschooled children had attained the same levels of success as children of grade 4 (age 9½). With respect to strategies used, there was little difference between the two groups. Unschooled children used the same strategies as schooled children including Number Facts at the older ages. However, there was some difference in the type of Derived Fact strategies used. For example, Derived Facts based on going through 12 strategy was only exhibited by the unschooled subjects. Most children who exhibited this strategy were experienced in selling commodities which were packed in dozens. Generally, the unschooled subjects' ability to solve addition and subtraction word problems demonstrated that children develop a variety of strategies for solving arithmetical problems independent of formal schooling.

Conclusions

Three main conclusions may be drawn from the results of this study. First, Nigerian children develop addition and subtraction problem-solving skills that are not very different from those observed in Western cultures. However, the abstract Counting strategies which Western children use were less pronounced with children in this study. Second, problem-solving skills are not totally a function of schools; the performance (both skills and strategies) of unschooled children on addition and subtraction problems was similar to that of schooled children. Third, the language of problem presentation has an effect on children's performance. Children performed better when problems were presented in their native language, Yoruba, than in their second language, English.

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