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Age and Memory as Factors in Problem Solving.
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In a 1964 investigation of the effects of age and memory on problem solving, using subjects from age three to age nineteen, it was found that the youngest and oldest subjects performed a three-choice probabilistic task significantly different from the "middle-age" children (7 to 9 years old). The three-choice task was an apparatus with a signal light, three buttons, and a container into which marbles were dispensed for "correct" responses. Only one button was set up to release a marble, and even it was on a partial reinforcement schedule. The younger and older subjects tended to maximize their choice of the "pay-off" button. The middle-age children tended to respond in simple patterns regardless of the fact that such patterns did not increase the pay-off. It was thought that this result interfered with their memory in regard to which button was paying off. A later study, in which a memory aid was used for half of the subjects, was conducted. It was found that the younger and older subjects performed about the same as before, regardless of the existence of the memory aid. The 7- and 9-year-olds who used the aid performed significantly better than those who did not. A third study, similar to the previous studies except that four different reinforcement schedules were used, indicated that responses become more complex with age. (WD)

Age and Memory as Factors in Problem Solving[1]

Morton W. Weir

In a recent paper (Weir, 1964), I examined the behavior of subjects ranging in age from three years to adult in a three-choice probabilistic task. The apparatus which was used is shown in Fig. 1. It consisted of a signal light centered above three push buttons, and a delivery hole for marbles centered below the three buttons. The marbles fell into an enclosed, clear plastic container. The subject was told that when the light went on, he was to press one of the three buttons. He was also told that if he pressed the "correct" button, a marble would fall into the container, and that the object of the game was to win as many marbles as possible. One of the knobs paid off part of the times it was chosen (33% or 66%), while the other two were dummies and never paid off. This constituted a partial-zero-zero reinforcement schedule, with the partial reinforcement being delivered randomly.

As was pointed out in the earlier study (Weir, 1964), it appears that subjects of all ages, with the possible exception of children below five years of age, regard this task as a problem solving situation. They generate hypotheses and employ strategies aimed at solution of the problem. The solution expected by them is almost always of a pattern-of-response nature, and subjects generally believe that if they achieve solution they will be able to win a marble on every trial, or at least predict accurately when a marble will be delivered and when it will not. Since the reinforcement schedule is random, neither of these solutions is possible.

I should like to review briefly some of the findings and conclusions of the earlier study (which I shall subsequently refer to as the "1964 study"), and to tell you of some further research on this problem which I believe demonstrates the importance of the role of memory in determining performance in this type of task.

Figure 2 presents the proportion of correct responses during the last 20 trials of this task plotted as a function of age. A correct response is defined as any time the subject chooses the only button that pays off, regardless of whether or not it actually

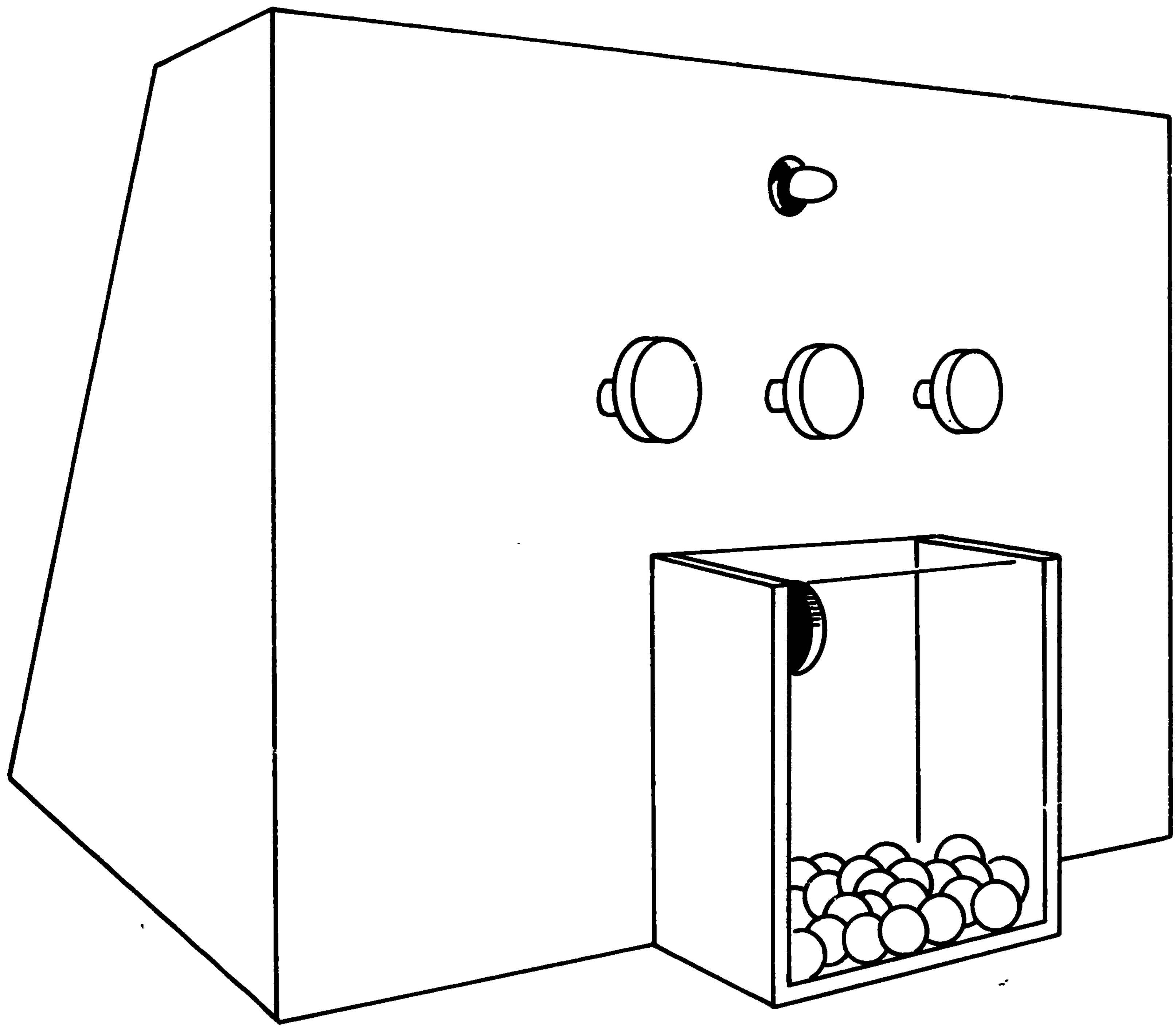
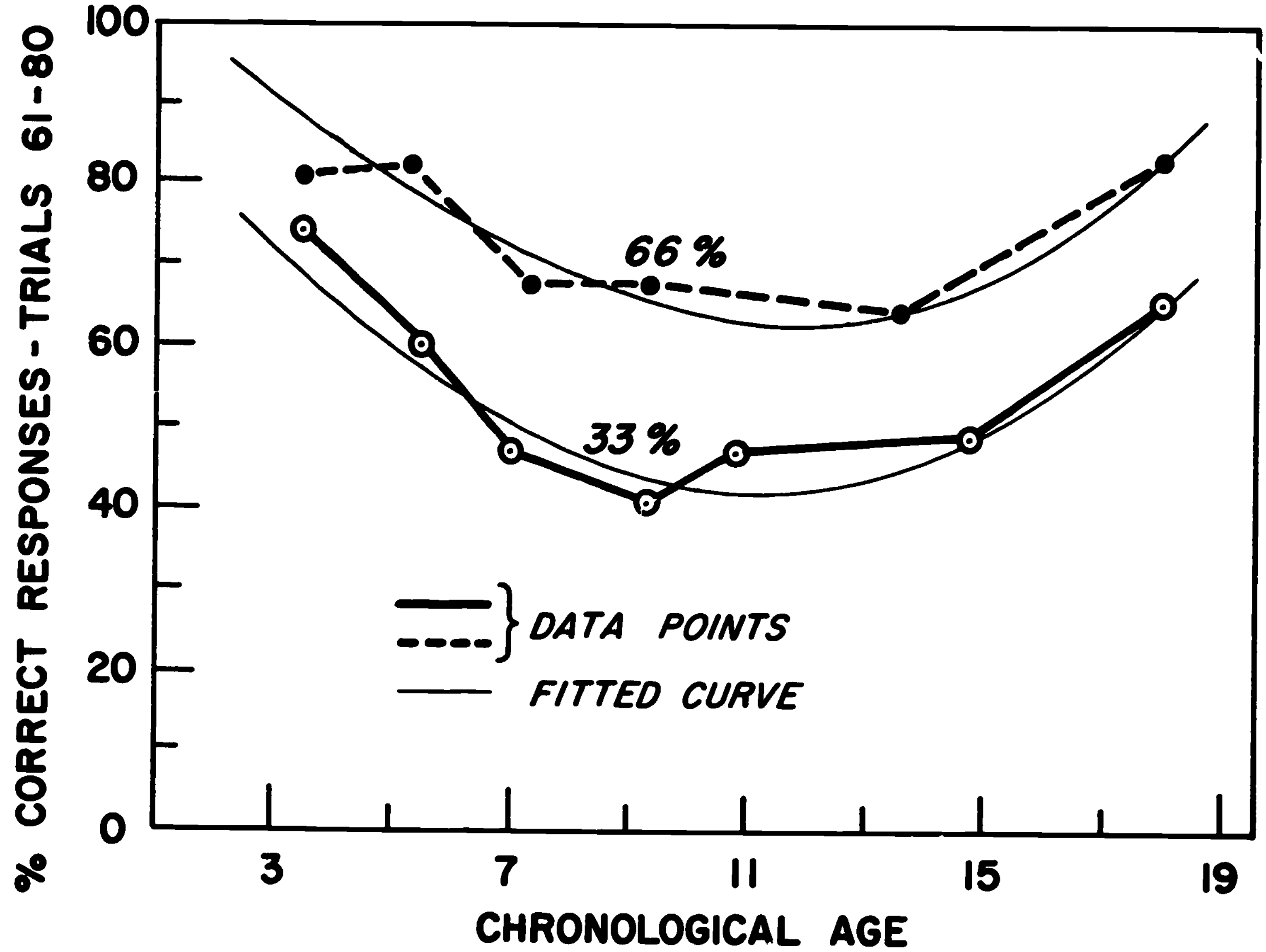
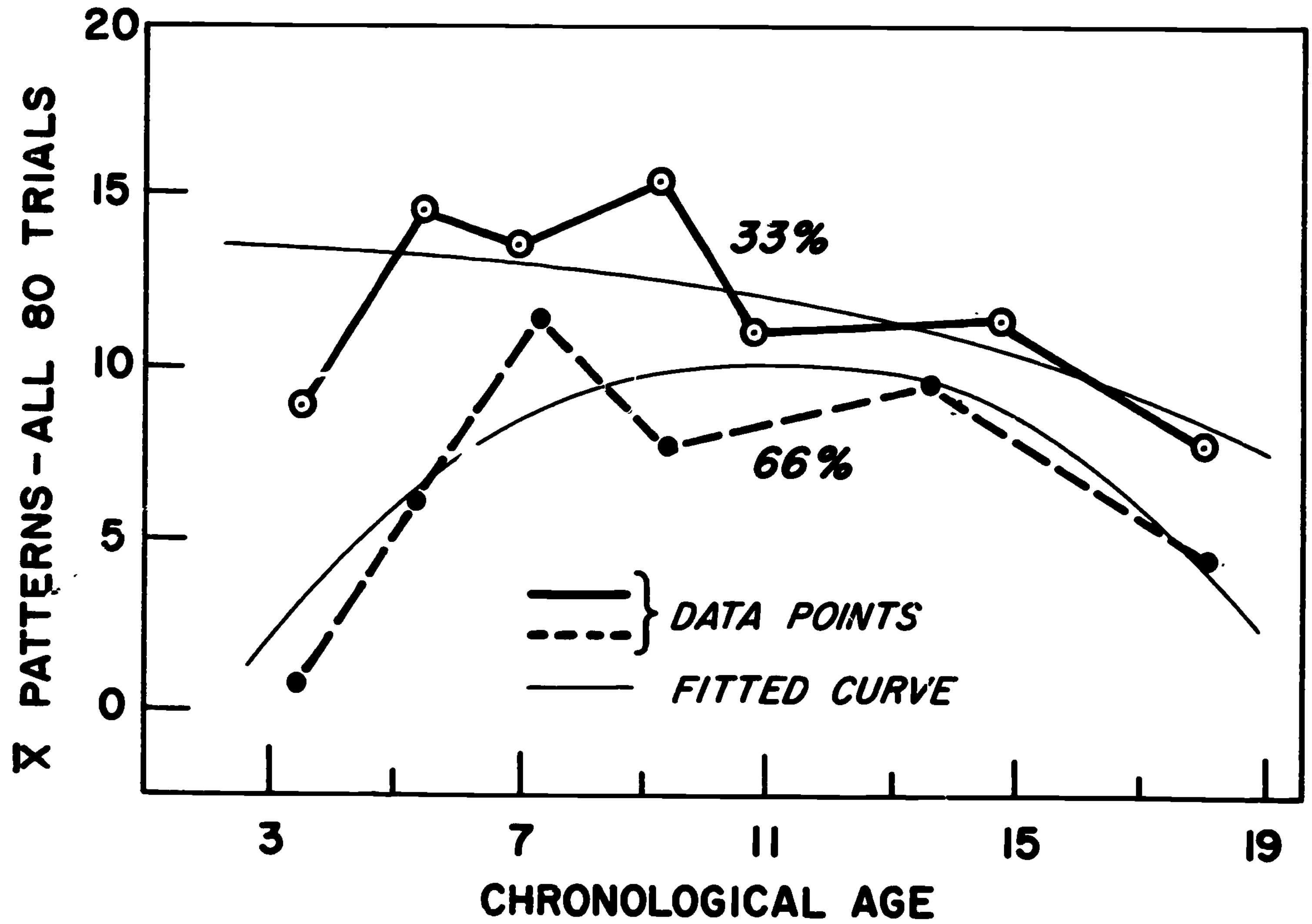


FIG. 1


% CORRECT RESPONSES - TRIALS 61-80
100
80
60
40
20
0
66 %
33 %
DATA POINTS
FITTED CURVE
3
7
11
15
19
CHRONOLOGICAL AGE

F I G. 2


X̄ PATTERNS - ALL 80 TRIALS
20
15
10
5
0
33%
66%
DATA POINTS
FITTED CURVE
3
7
11
15
19
CHRONOLOGICAL AGE

F I G. 3

paid off on that particular trial. Note the curvilinearity of these data for both 33% and 66% reinforcement schedules. Note also that the nine to 11-year-old age range represents the lowest portion of this curve. The younger children (three to five-year-olds) tend toward maximization of their choices of the pay-off button; the same is true of adults, although learning curve data make it clear that the adults reach this high terminal level much more slowly than do three- and five-year-olds.

If the nine to 11-year-olds are not choosing the pay-off button, what are they doing? Examination of the frequency of simple patterns of response supplies at least a partial answer. Plotted in Fig. 3 are the mean number of response patterns of a left, middle, right (LMR), or a right, middle, left (RML) nature as a function of age for the two reinforcement schedules. Although these data are quite variable, it appears that children in the "middle-age" range display more of these simple patterns than do younger or older children. This is especially true of the 66% condition.

The nine to 11-year-old child, then, is certainly not responding randomly. The relatively few choices of the pay-off button which he displays occurs because he is apparently instead making a large number of these simple response patterns. As tentative explanation of these data, consider the following line of reasoning. Given a spatial task of this level of complexity, a child of age nine to 11 might very well be far enough along in his cognitive development to enable him to generate some hypotheses involving patterns of response, while a younger child might not be able to do so. It is interesting to note, however, that the nine to 11-year-old child continues to make these simple response patterns throughout the task, even though they do not consistently pay off. It is as if it is very difficult for him to reject this simple strategy, even though it does not work. In order to explain this response stereotypy, it appeared possible that although the nine to 11-year-old child may be far enough advanced in his development to generate such patterns, he may not be far enough advanced to process the information available from the results of his own responding. He may be, at this age, fairly sophisticated hypothesizer, but a poor information processer. If so, he perhaps would not be able to compile sufficient information to enable him to discard these ineffective simple strategies, and as a consequence he would try them often throughout the task.

In considering this hypothesis, it appeared possible that the poor information processing of the "middle-age" child, at least when compared with his ability to generate hypotheses, might be the result of an inadequate memory. He might be capable of generating LMR or RML patterns, but not be able to remember his reponses and and their outcomes more than a few trials back, get confused, and start over. If an insufficient memory is a crucial factor, then supplying a nine-year-old with a memory comparable to that of an adult should change the child's performance considerably in the direction of that displayed by older subjects. That is, the nine-year-old with a memory aid should show more frequent choice of the pay-off alternative and fewer simple patterns of response than should a nine-year-old with no aid to memory provided. In order to test this idea, a simple, but infallible memory was designed for the use of the nine-year-old. It consisted of a pe rd with many rows of three holes each. The children who were given this memory aid were instructed that each time they pressed a button, they were to put a peg in one of the three holes corresponding to the position of the button they had just pressed. On the next trial, they were to drop down a row and do the same thing. If they won a marble, they were told to place a black peg in the hole; if they did not win, a pink peg was inserted. If a subject understood the use of the peg board, he could look back over his past responses and determine exactly which patterns he had been using and what their outcomes had been. Five-year-olds, nine-year-olds, and college adults participated in this experiment. Within each age group, one-half of the subjects used the memory aid and one-half did not. Other than this, the task and instructions were the same as in the 1964 study. The same 66% reinforcment schedule was used, subjects were run for 120 trials, and of course only one button ever paid off.

The proportion of choices of the pay-off button for the memory and non-memory groups of nine-year-olds is shown in Figure 4. The result with this age group was as expected, with the memory aid condition exceeding the non-memory condition. This difference is significant at beyond the .01 level. Also note the "X" which is labeled "64-9". This represents performance of nine-year-olds as predicted from the fitted age curves derived from the 1964 study. The purpose in placing this marker on the graph is to provide some rough indication of the reliability of these data.

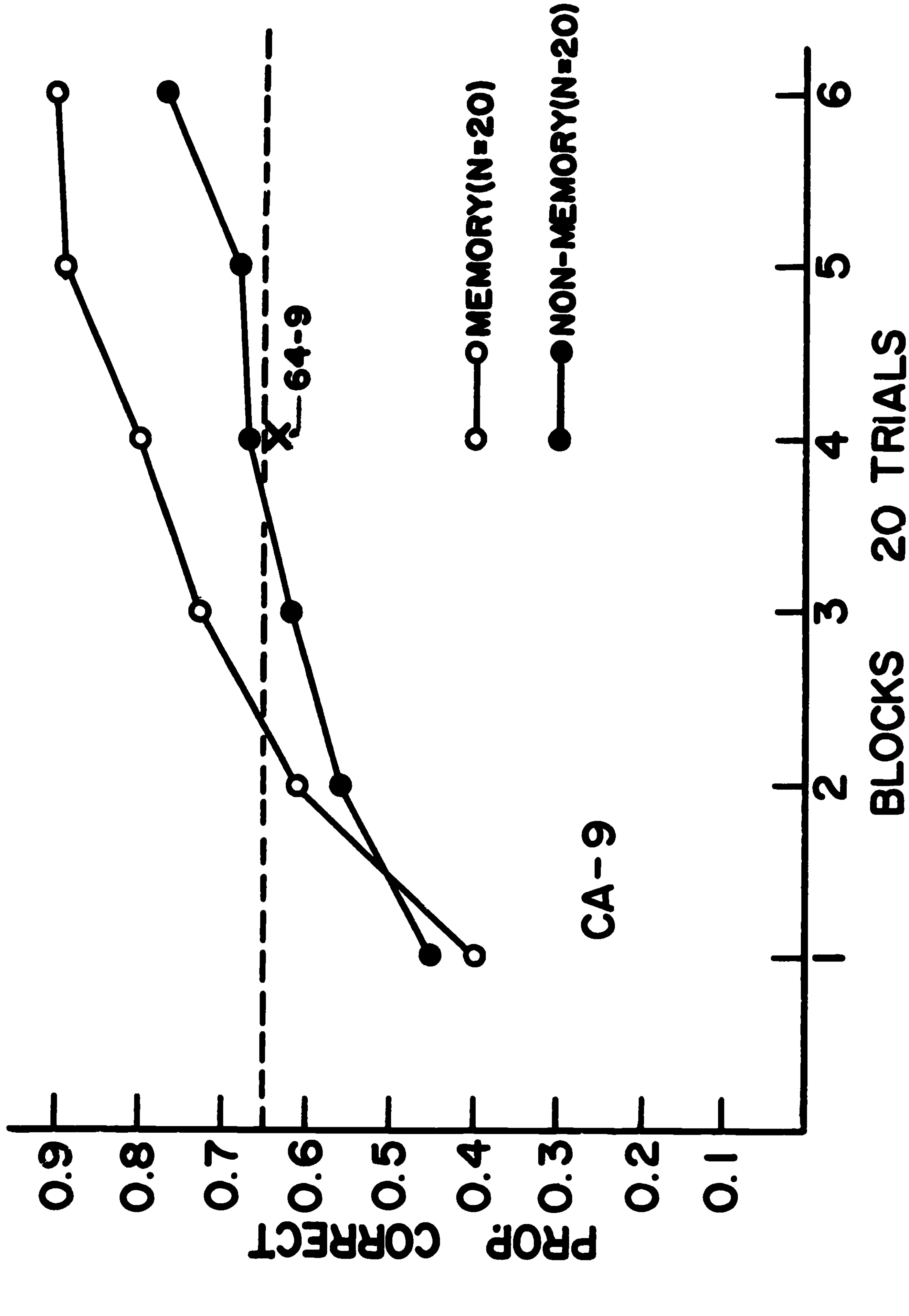

PROP CORRECT
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
BLOCKS 20 TRIALS
1
2
3
4
5
6
CA-9
64-9
MEMORY(N=20)
NON-MEMORY(N=20)

FIG. 4

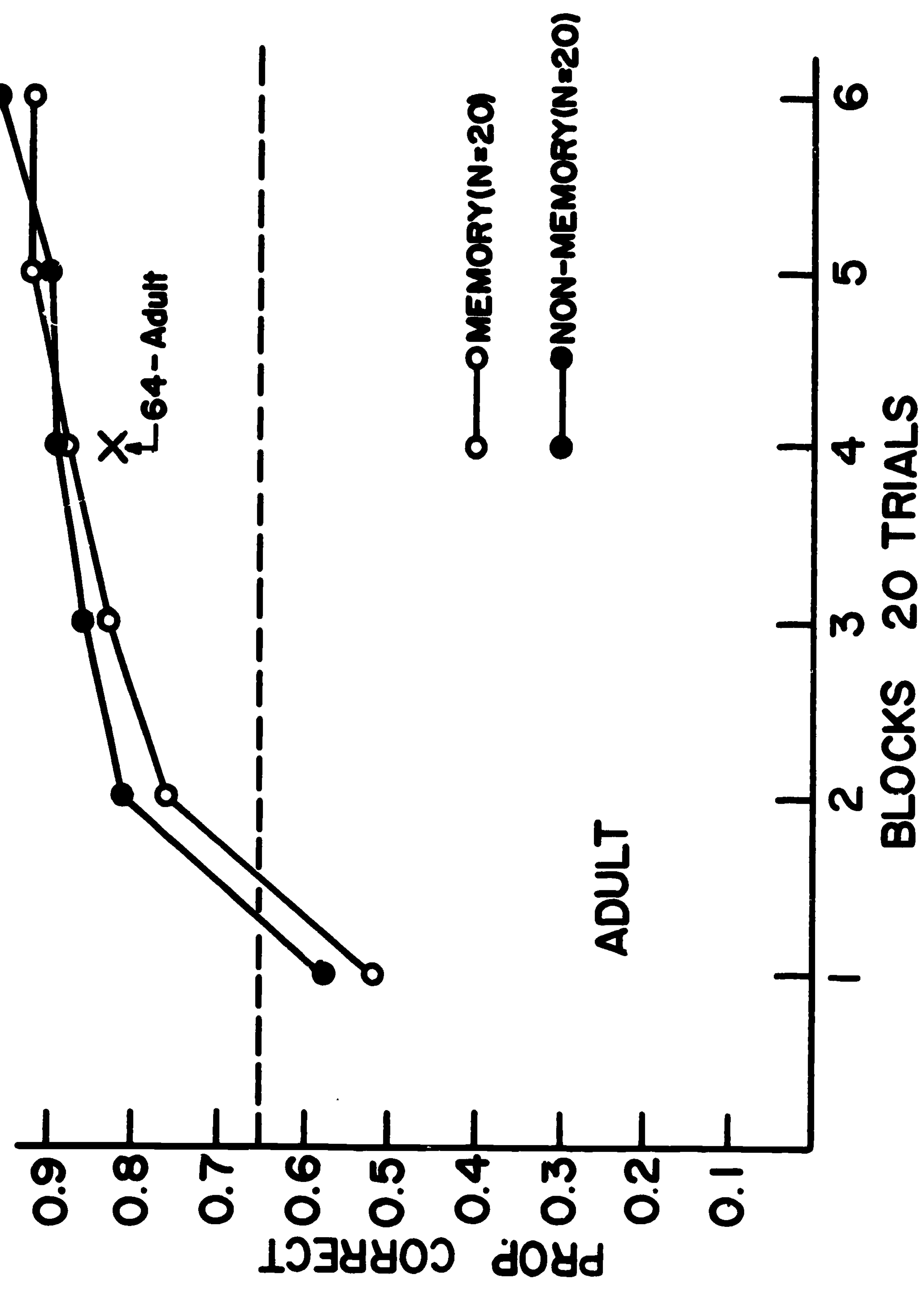

PROP. CORRECT
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
BLOCKS 20 TRIALS
ADULT
X 64-Adult
MEMORY (N=20)
NON-MEMORY (N=20)

FIG. 5

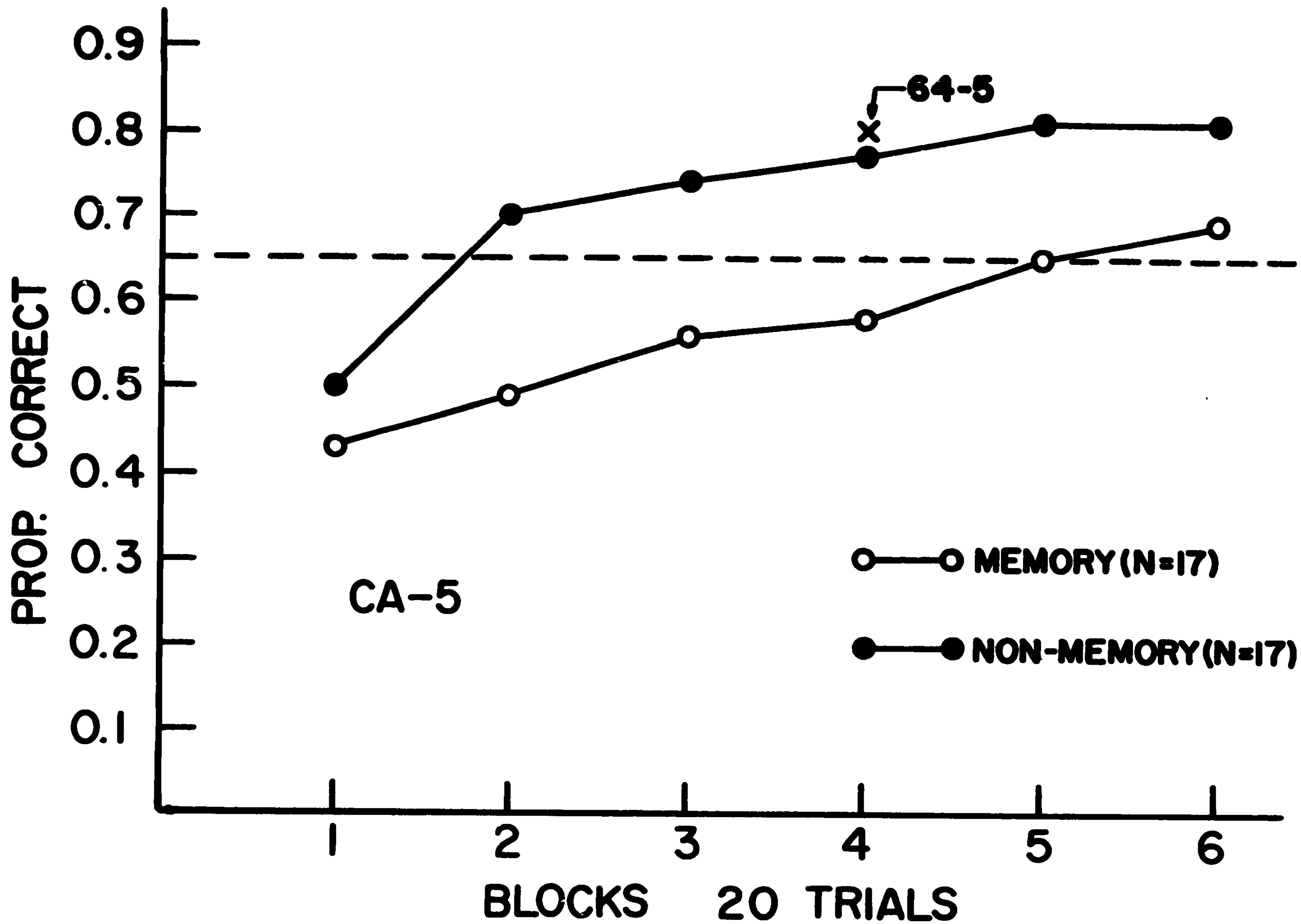

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
PROP. CORRECT
64-5
CA-5
MEMORY (N=17)
NON-MEMORY (N=17)
1
2
3
4
5
6
BLOCKS 20 TRIALS

FIG. 6

In Figure 5, the same data are plotted for the adult group. There is no difference between the memory and non-memory conditions, and the terminal proportion of the adult data predicted from the age curves in the 1964 study is very close to both these curves. No difference had been predicted here, as it was thought that the adults would not need the aid of this device in recalling fairly long series of trials and their outcomes, and it would therefore change their behavior little, if any, during the task.

The five-year-olds present a completely different picture. As Fig. 6 indicates, the memory aid had an effect <u>opposite</u> to that noted with the nine-year-olds. This difference is also significant at beyond the .01 level. In addition, the prediction from the fitted curves of the 1964 study agrees closely with that of the equivalent (non-memory) condition in this experiment. In watching these five-year-olds perform in this task, the source of this effect seemed clear. Many of the five-year-olds did not understand the relationship between the memory device and the probability task. They frequently made errors in peg placement, and often could not remember which button they had just pressed. In anticipation of this problem, all subjects in this study had a second experimenter present who sat beside and slightly behind the subject. The function of this second experimenter was to aid the subject in peg placement if he had trouble. Thus, all subjects had before them an accurate representation of past responses and their outcomes. The five-year-olds frequently needed help from this second experimenter, and it appeared as if the memory board was a completely irrelevant task interposed between trials which served to disrupt performance in the probabilistic task.

LMR and RML patterns were also examined for the three age groups, and a significant reduction in the number of such patterns occurred in the nine-year-old group, as had been predicted. There was no significant change in the number of these patterns for either the five-year-olds or the adults.

These data appear to support the original hypothesis. However, the nine-year-olds could be making another use of the memory aid besides keeping track of past response patterns and their outcomes. After 15-20 trials, it becomes obvious from examination of the pegboard that all the black pegs occur in only one column. This provides the nine-year-old with information about something which he might otherwise be confused--that only one button pays off. In fact, in questioning nine-year-olds after the task, those without a memory aid occasionally volunteered the information that the other two knobs sometimes paid off, when of course, they actually had not.

In order to assess the role of the information conveyed by the columns of the memory board, a small change was made in the apparatus. Instead of a single center delivery box for marbles, the apparatus was converted to provide three receptacles, one associated with each knob. This change should provide the same information that all the black pegs in one column of the memory board provides--that is, that only one knob pays off. With the converte apparatus, this information is conveyed to the subject by the fact that marbles only fall into one box, or, as the children put it, "out of one knob." In this task we again ran five-year-olds, nine-year-olds, and college adults, using the same 66% reinforcement schedule and a task length of 120 trials.

The results for the nine-year-olds are presented in Fig. 7. If the critical feature of the memory aid was the information in conveyed concerning the fact that only one knob ever paid off, it might be expected that subjects in the three-box condition would show an increase in performance similar to that shown by subjects in the memory board condition. As can be seen in Fig. 7, there is no difference between the three-box and one-box conditions and both of these are very similar to the non-memory condition of the previous study. The data from the nine-year-olds in the memory board study are also shown in Fig. 7 for compariso purposes.

The picture is the same for the adults, as well as the five-year-olds. The three-box condition has no effect upon performance. The results are so similar in that regard to those of the nine-year-olds, that no graphical representation seems necessary.

It therefore appears that the memory board functions as it was designed--it allows the nine-year-old to look back over a series of responses and their outcomes, perhaps as an older child or an adult would use his own memory in a task such as this. He is able to make use of this information by rejecting simple patterned strategies when they do not work (that is, do not end in a black peg), and eventually show a tendency toward maximization of choices of the only alternative which pays off. This behavior is much more adult-like

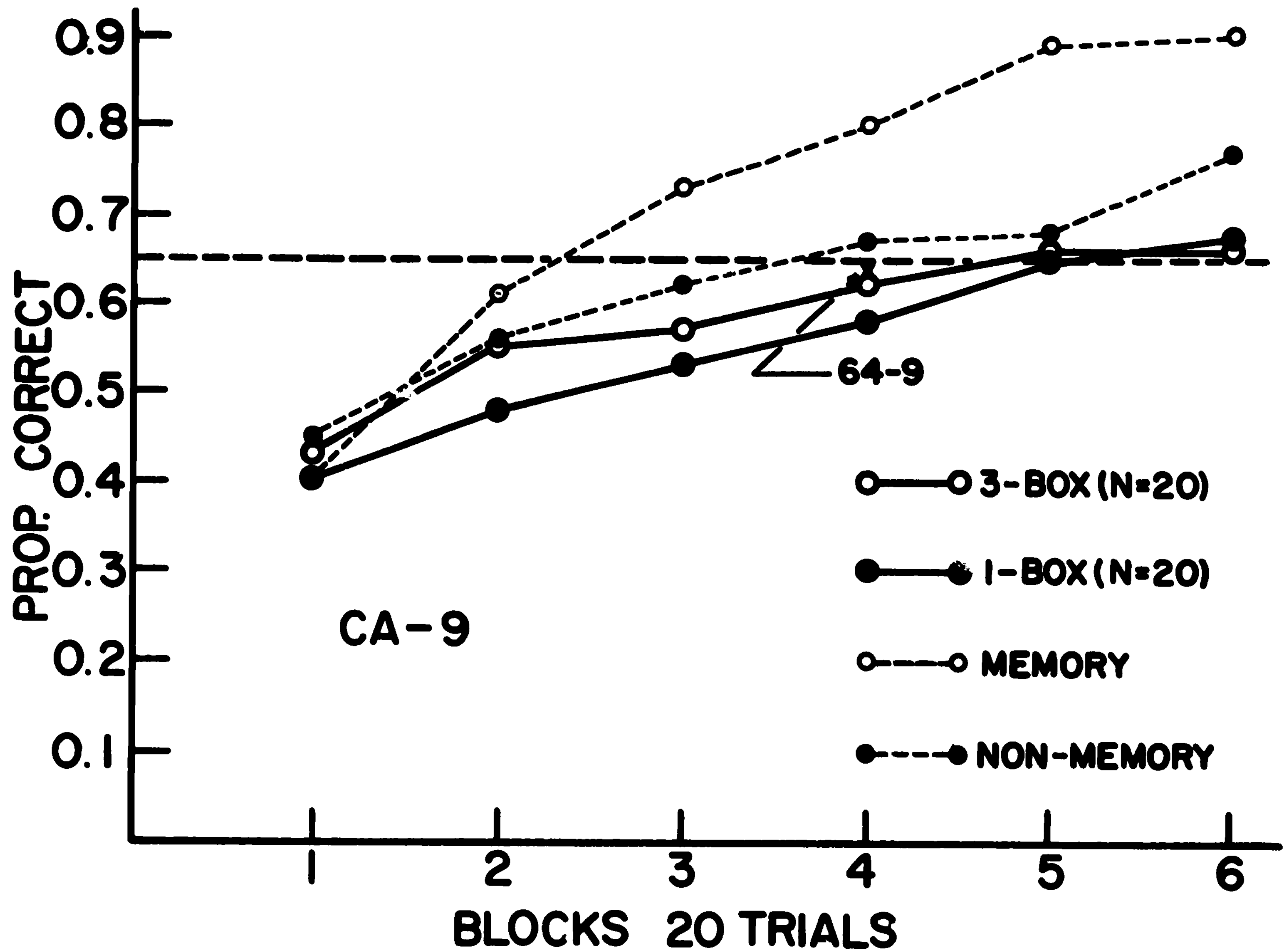

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
PROP. CORRECT
64-9
CA-9
3-BOX (N=20)
1-BOX (N=20)
MEMORY
NON-MEMORY
1
2
3
4
5
6
BLOCKS 20 TRIALS

FIG. 7

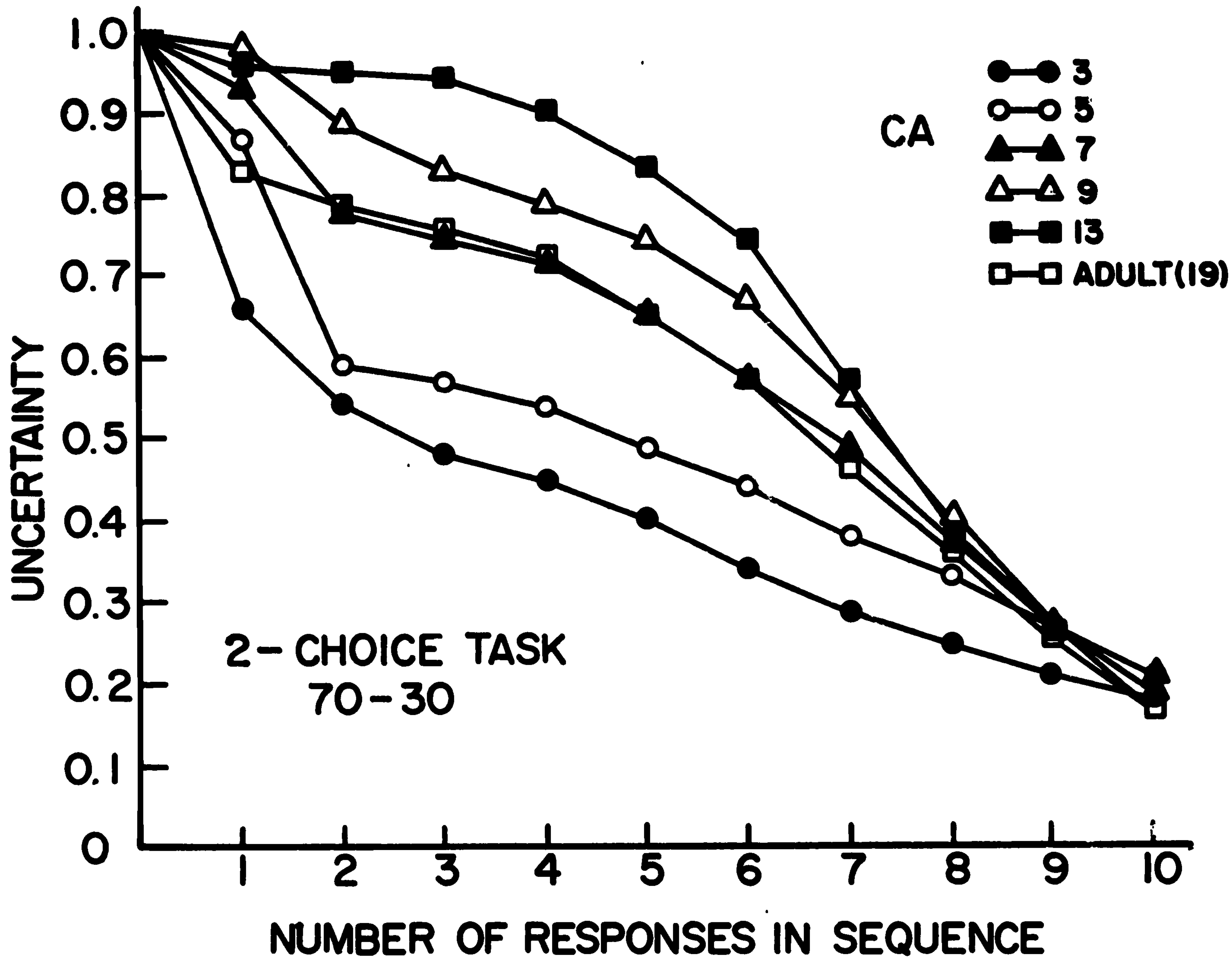
than is that of nine-year-olds without a memory aid. It thus appears that the hypothesis that the continued use of simple patterns of response seen in the nine-year-olds in the 1964 study might have been due in part to an insufficient memory gains support from these data.

The experiments which I have just described have, I believe, a direct bearing upon memory as it relates to developmental changes in problem solving strategies. I should now like to present some data which may or may not relate to memory, but which I believe are sufficiently orderly and interesting to warrant close consideration. I have a tentative interpretation of the data, but I am most interested in the reactions of the rest of the symposium members as to their interpretation.

In these studies, an apparatus was used which was very similar to that used in the probabilistic task which I have just described. The major difference was that the number of alternatives was varied, as was the reinforcement schedule. Subjects were assigned to either a two- or a four-choice condition. For some subjects, one of the two (or four) knobs paid off 70% of the times it was chosen and the other one (or three) never paid off. For other subjects, one of the alternatives paid off 70% of the times it was chosen, while the other one (or three) paid off 30% each. This resulted in the formation of four conditions, with two levels of number of alternatives, and two reinforcement schedules (i.e., 70:0, 70:0:0:0, 70:30, and 70:30:30:30). In the two conditions in which only one knob paid off, five age levels were used (4, 6, 9, 12 and adult); in the two conditions in which all alternatives paid off at least part of the time, six age levels were used (4, 5, 7, 9, 13 and adult). All subjects were run for a total of 120 trials.

The choice behavior of these subjects was then analyzed for response patterning. Rather than pick only one type of pattern, as was done in the study just described, an information analysis of response sequences was performed. In this type of analysis, a computer examines <u>all possible</u> patterns of run lengths of up to 10 in the two-choice task and up to six in the four-choice task, and provides a measure of the degree to which subjects are using repeated response patterns of various lengths.

Figure 8 shows the outcome of this analysis for the two-choice, 70:30 task. In this figure, uncertainty is plotted as a function of the number of responses in sequence for the



1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
UNCERTAINTY
1
2
3
4
5
6
7
8
9
10
NUMBER OF RESPONSES IN SEQUENCE
CA
3
5
7
9
13
ADULT(19)
2-CHOICE TASK
70-30

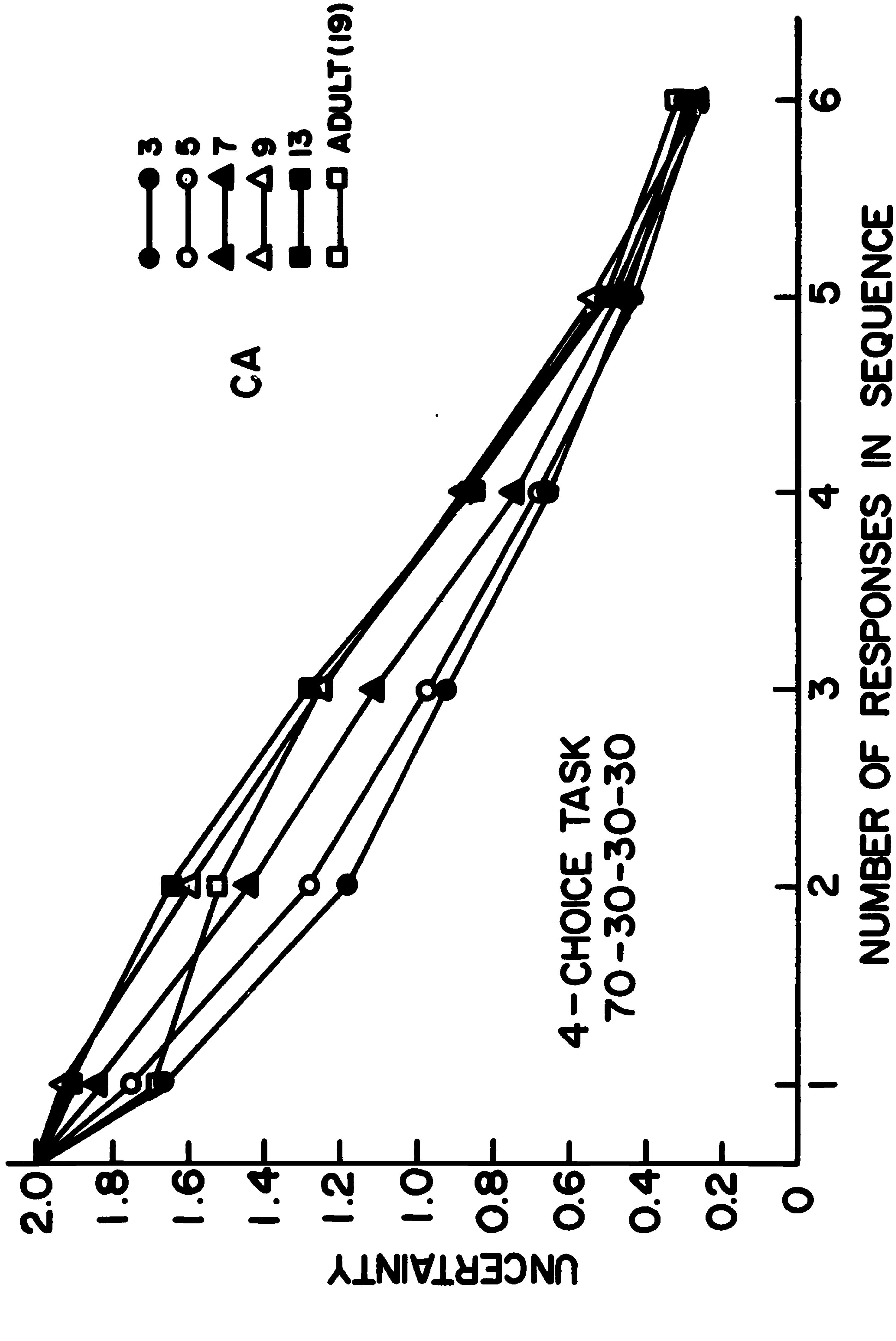
FIG. 8

six age groups. The result is a perfect developmental ordering except for the adult data. In order to clarify the meaning of this figure, it should be pointed out that the sooner a curve begins its downward deflection (e.g., the curve of the four-year-olds), the simpler are the response patterns being used repeatedly by the subjects. The further a curve progresses along the abscissa before making its major downward deflection (e.g., the curve representing the performance of the 13-year-olds), the more complex is the response sequencin In other words, this figure simply indicates the increasing complexity of responding in this task as age increases.

Figure 9 presents the same type of data for the four-choice, 70:30:30:30 task. Note that the abscissa includes only run lengths of up to six, as that is the limit of the memory of the computer used to analyze these four-choice data. Again, the developmental ordering is perfect, except for the adults.

When my colleague, Harry Munsinger, saw these two graphs, he suggested another way to examine these data. The idea is as follows: Assume there is a limit to a child's information processing capability, and, in both the two- and four-choice tasks, he works close to this processing limit. If it were possible to somehow equate these two tasks for difficulty level, the uncertainty reduction curves should be identical. We attempted to do this in the following manner: Each decision in the four-alternative task is, in informational terms, a two-bit decision, while each one in the two-alternative task is a one-bit decision. Perhaps the comparison we want could come from examining the amout of information reduction in the two-choice task following every <u>second</u> response in the sequence. Thus, each point plotted on the abscissa would represent 2 one-bit decisions in the two alternative task, and this curve could then be plotted on the same set of axes as is the curve for the four-alternative task.

Figure 10 presents such curves for the six age groups studied. Note the disparity between the four-choice and the converted two-choice curves for the younger children; note also that the degree of disparity decreases systematically as age increases. The young child (e.g., four to six years old) appears to behave in a fairly complex fashion in this task <u>if</u> the task itself is complex. If the task is simpler, then his response



CA
3
5
7
9
13
ADULT (19)
4-CHOICE TASK
70-30-30-30
UNCERTAINTY
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
NUMBER OF RESPONSES IN SEQUENCE

FIG. 9

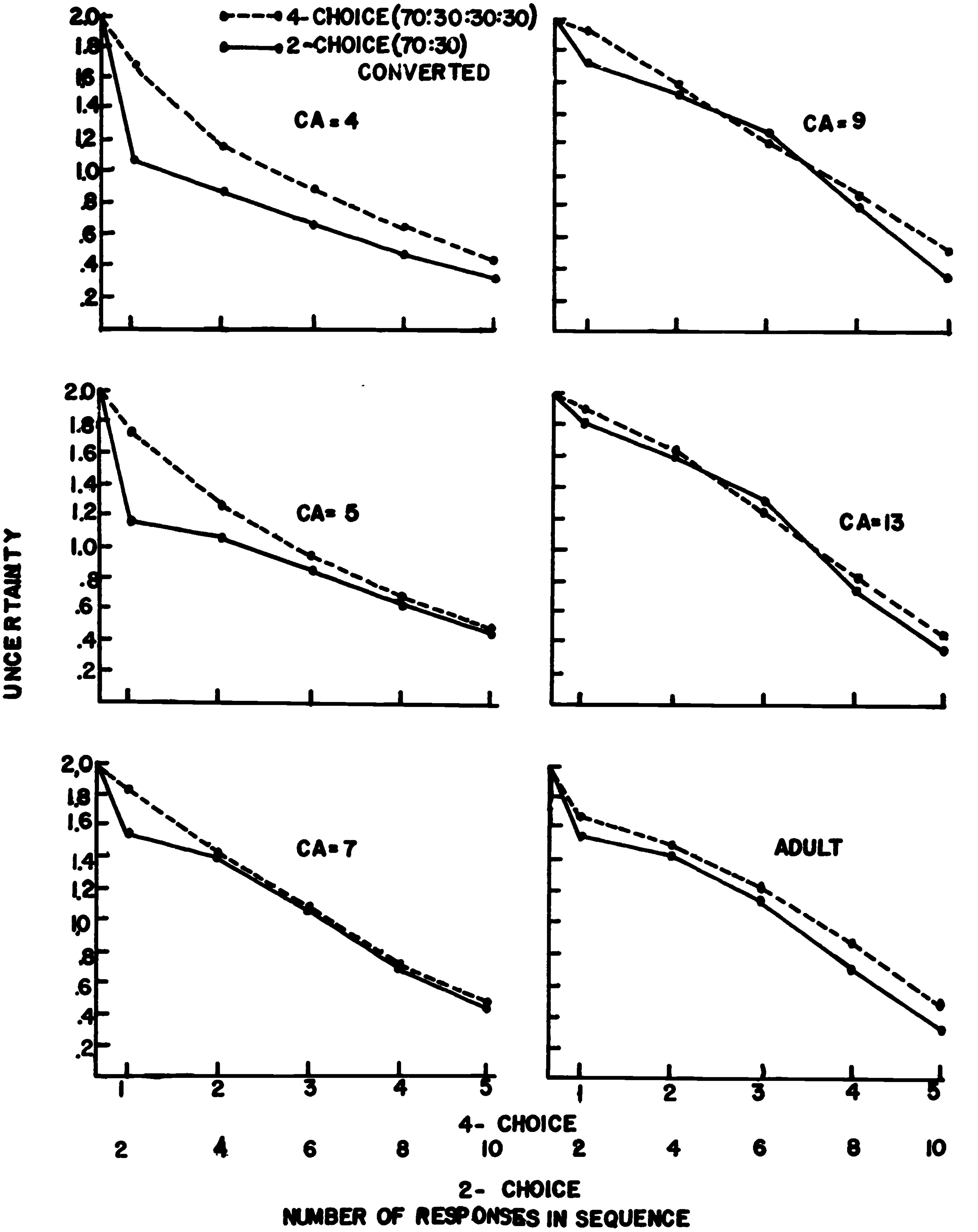

4-CHOICE(70:30:30:30)
2-CHOICE(70:30)
CONVERTED
CA=4
CA=9
CA=5
CA=13
CA=7
ADULT
UNCERTAINTY
4- CHOICE
2- CHOICE
NUMBER OF RESPONSES IN SEQUENCE

FIG. 10

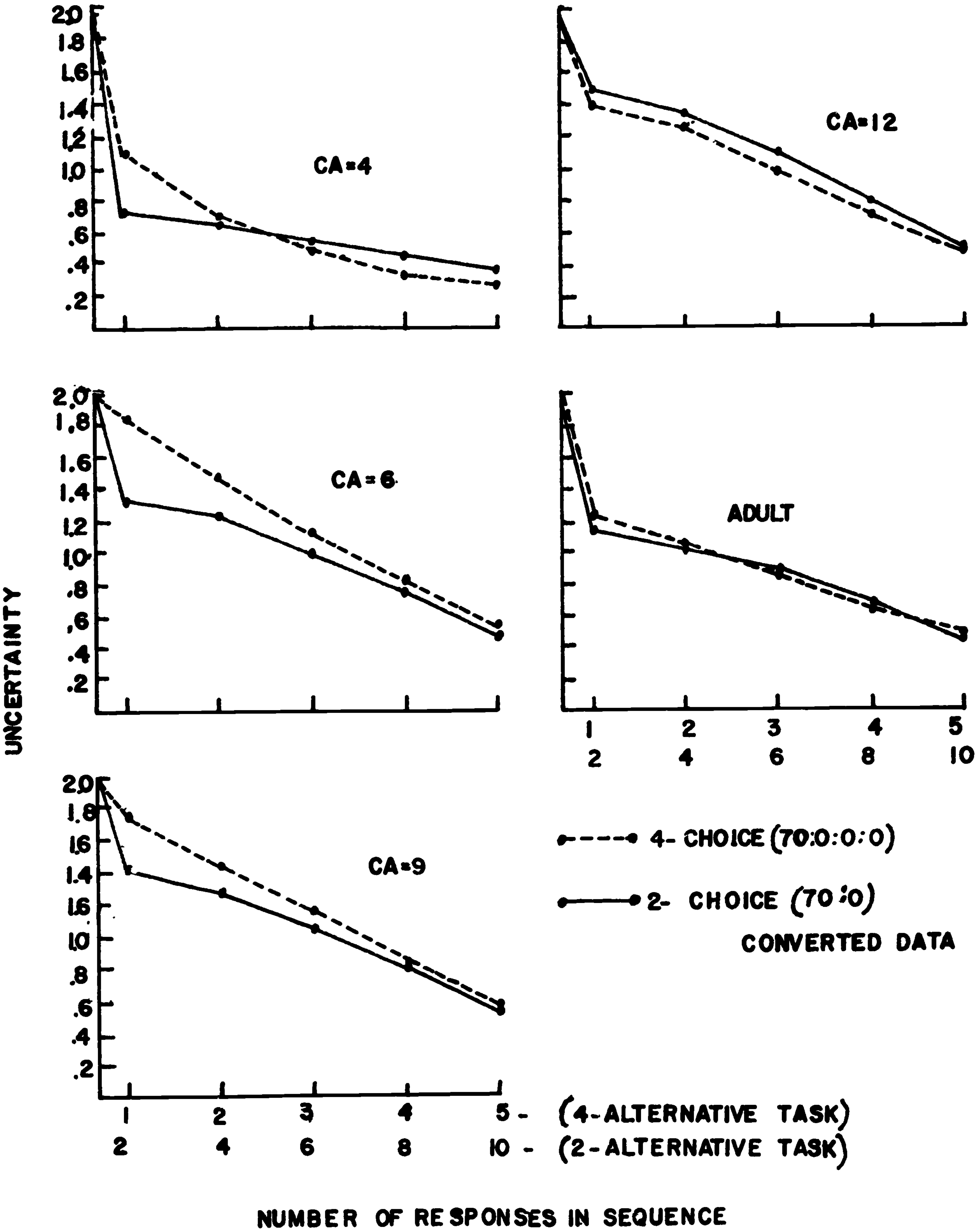

CA=4
CA=12
CA=6
ADULT
CA=9
UNCERTAINTY
4- CHOICE (70:0:0:0)
2- CHOICE (70:0)
CONVERTED DATA
1 2 3 4 5 - (4-ALTERNATIVE TASK)
2 4 6 8 10 - (2-ALTERNATIVE TASK)
NUMBER OF RESPONSES IN SEQUENCE

FIG. 11

sequencing is also simpler. This does not appear to be true of the older child--in terms of information processing, and the conversion used here, he behaves the same regardless of the complexity of the task, at least within the limits of complexity represented by this experiment. I have little doubt that the older child would show differences in information processing as a function of task complexity if the complexity were greater than it was in these studies.

Thus far I have not mentioned the 70:0 and 70:0:0:0 tasks. The converted curves for the 70:0 schedule are presented in Fig. 11 along with the data from the 70:0:0:0 condition. With the exception of the four-year-olds, this picture is about the same as that presented in Fig. 10. What is the explanation of the performance of these youngest children when compared with their performance shown in Fig. 10? Two possibilities have occurred to us. First, the data plotted in Fig. 11 for the four-year-olds represents only about half as many subjects as the rest of the curves in Figs. 10 and 11. The discrepancy may then be a sampling error. Second, in a 70:0 or a 70:0:0:0 task, children this young tend to maximize their choices of the pay-off alternative very early in the task. The same thing is true of children this age in a three-choice, 70:0:0 task. It may simply be that these children, lacking patterned strategies, are drawn to the only button that pays off solely on the basis of the absence of pay-off on the other alternatives and the large discrepancy between the percentage of pay-off between the reinforced alternative and the other alternatives. The result of this may be to destroy most of the effect that variation in task complexity might have for these children.

In general, it appears that the developmental ordering of these curves in consistent with the notion that the older child and adult can manufacture a complex set of responses, even when presented with a relatively simple task. The younger child, on the other hand, does not appear to be able to do so, and greater response complexity is seen to be associated with greater task complexity. In deference to the title of my presentation, which mentions children's memory, I am suggesting that one reason a young child's performance varies as a function of task complexity is that in order to produce complex response sequences in a relatively simple task, the child, not having complexity represented in front of him in the stimulus situation, must rely to a greater degree upon his own recall for information concerning responses which he has just made. Since the young child is less well able to do this than is an older child, his response patterning is less complex in a two-choice tha in a four-choice task. The older child, on the other hand can remember, in the two-choice task, several preceding responses and their outcomes. Using this recall, he is able to manufacture as complex a string of responses as he is when greater complexity is actually coded for him in the task. Perhaps what I am saying is simply that the younger child is more "stimulus bound" than is the older child, and can produce complex response patterns only when the complexity is coded for him in the stimulus situation.

Reference

Weir, M. W. Developmental changes in problem solving strategies. Psychol. Rev., 1964, 71, 473-490.

Footnote

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