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ABSTRACT

This study examined the relationship between knowledge of sequence relations and the process of mental rotation in four-year-olds. Subjects were 12 preschool children who were tested individually. They were given a State Comparison Task (SCT) in which they were shown pairs of animal pictures, half identical and half mirror images of one another, and asked to decide if the figures were the same or different. The Sequential Ordering Task (SOT) involved showing animal shapes rotated from zero to 180 degrees in increments of 45 degrees. Children were shown either the first or last card of the sequence and the remaining 4 cards in random order; their task was to place the cards in the correct sequence showing a rotation from upright to 180 degrees. Responses were timed to one-thousandth of a second. Findings indicated that there was a significant positive correlation between the number of correctly placed cards in the SOT and the number of correct trials in the SCT. Some four-year-olds understood sequence relations; most performed at better than chance levels on the SOT. Some four-year-olds used mental rotation. However, Rotators did not perform the SCT better or more quickly than did Non-Rotators, suggesting that mental rotation was not essential to this task. (KDFB)

Mental Rotation and Sequential Ordering in Preschoolers

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Introduction

Since the work of Shepard and Metzler (1971), numerous researchers have replicated their finding of a linear relationship between response time in a state comparison task involving rotated forms and the angular disparity of the two forms to be compared. Although some theorists (e.g., Pylyshyn, 1979) disagree, this linear function is generally taken as evidence that such tasks are performed through a process of mental rotation, i.e., the mental reorientation of one of the forms in order to compare it to the other form. However, relatively few researchers (e.g., Dean, Scherzer & Chabaud, 1986; Marmor, 1975) have looked at mental rotation in children younger than 8 years old.

Piaget and Inhelder (1971) suggest that preoperational children are unable to understand the concept of sequence and thus lack the ability to perform a mental rotation task and their research supports this position. However, Marmor (1975) found that data for each of her 5-year-old subjects showed a linear relationship between response time and angular displacement on a state comparison task and all subjects performed well above chance. These results suggest that at least some 5-year-olds do understand sequence relations. In contrast, Dean, Scherzer & Chabaud (1986) argue that children can perform a mental rotation task without understanding sequence relations. Although 35% of their 5 year old subjects appeared to be using mental rotation in a state comparison task comparable to Marmor's, none of these subjects could order correctly a 7-card series of pictures depicting a figure rotating from upright to upside down.

The present study addresses some methodological issues in Dean et al. (1986) that may have influenced their results. First, the 7-card sequence used for the ordering task may have been beyond the short-term memory capacity of the subjects (Kail, 1977); this may have obscured their sequential ordering ability. In addition, using 7 cards reduces the angular disparity between each card and the next to only 30 degrees; this may have made them difficult to distinguish from one another. Finally, subjects in the Dean et al. study received training in the state comparison task that focused specifically on the same-or-different judgment while there was no comparable training in the sequential

ordering of rotated forms; instead, subjects watched a form rotated from 0 to 180 degrees. In this study we used a modified sequential ordering task. By reducing the sequence to 5 items, we simultaneously increase the angular disparity between them to 45 degrees and reduce the number of items to be remembered. In addition, training for the sequential ordering task focused specifically on learning to manipulate the degree of rotation of elements in a sequence.

Method

Subjects. Twelve children (6F, 6M) from a college-sponsored preschool participated in this research. Their mean age was 4.25 years old.

Materials. Animal shapes attached to poster board were used for both tasks. The State Comparison Task (SCT) used 10 pairs of animals, half identical and the other half mirror images of one another. Each pair contained 1 figure upright and the other either upright or rotated clockwise in the picture plane; 2 pairs (1 same, 1 different) were shown at each of 5 angles of rotation: 0, 45, 90, 135, and 180 degrees. Figure 1 shows a 180 degree rotation. The Sequential Ordering Task (SOT) used 8 sets of 5 cards; each set showed an animal shape rotated from 0 to 180 degrees in increments of 45 degrees (Figure 2). A stopwatch accurate to one-thousandth of a second was used to time responses.

Procedure. Each subject was tested individually in two separate sessions by the same experimenter; order of task was counterbalanced across subjects. Subjects were trained in each task prior to the test trials. For the SCT, each pair of figures was shown simultaneously; the subjects' task was to decide as quickly and accurately as possible whether the 2 shapes were the same or different. For the SOT, subjects were given either the first or the last card of the sequence and shown the remaining 4 cards in random order; half the trials began with the first card. The subjects' task was to place the remaining 4 cards in the correct sequence showing a rotation from upright to 180 degrees.

Results

* There was a significant positive correlation between the number of correctly placed cards in the Sequential Ordering Task and the number of correct trials in the State Comparison Task ($r(10) = .54$, $p < .05$, one-tailed).

* Each subject's data from the Sequential Ordering Task were analyzed separately to determine whether there was a linear relationship between angle of rotation and response time. Data from 5 subjects (45%) show this pattern. Sample regression lines are shown in Figures 3 and 4.

* There was no significant difference between Rotators and Non-Rotators in performance ($t(10) = 0.374$) or response time for correct trials ($t(10) = 1.175$) on the State Comparison Task.

* There was a significant difference between Rotators and Non-Rotators in performance on the Sequential Ordering Task. Although there was only a weak tendency for Rotators to do better when scored by percent of cards placed correctly ($t(10) = 1.788$, $p = .104$), Rotators had significantly more correct sequences ($t(10) = 3.53$, $p < .01$, two-tailed). (See Figure 5.)

* There was a marginally significant difference in the proportion of males and females who used mental rotation in the State Comparison Task ($X^2 = 3.086$, $df = 1$, $p = .079$). Four of the five Rotators were female.

Discussion

These data support the position that there is a formal relationship between the knowledge of sequence relations and the seemingly automatic process of mental rotation. However, in contrast to the results Dean et al. (1986) with 5-year-olds, we find that at least some 4-year-olds are capable of understanding sequence relations. Most of our subjects performed the task at better-than-chance levels and one subject correctly placed 37 of the 40 stimulus cards. This suggests that the understanding of sequence relations may occur much earlier in development than Piaget and Inhelder (1971) propose. In addition, some preschoolers can use mental rotation. On the other hand, Rotators did not perform the State Comparison Task significantly better, or more quickly, than did Non-Rotators; this suggests that mental rotation is not essential to the performance of this task.

These results show that 4-year-olds vary in their cognitive sophistication, as Piaget said they did, but that many of them possess abilities that Piaget believed were beyond them. Piaget's belief that children of this age could not manipulate mental images was based on the results of a task in which children were asked to draw how a pencil would look as it rotated from upright to a horizontal position (Piaget & Inhelder, 1971). As Marmor (1975) has suggested, it is likely that his subjects were simply unskilled in the drawing task rather than unable to carry out the mental rotation. However, none of our subjects were tested using Piaget's measures of reversibility and transformation so that no direct comparison can be made. Further research in our laboratory will look at the relationship between sequential ordering and state comparison tasks and performance on Piagetian tasks within the same sample.

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Table 1
Scores on the Sequential Ordering and State Comparison Tasks

		Rotators	Non-Rotators
State Comparison Task			
Response Time for Correct Trials (Sec.)	Mean	4.850	5.773
	sd	0.722	1.628
Percent Correct	Mean	76.000	72.857
	sd	11.402	16.036
Sequential Ordering Task			
Percent of Items Correct	Mean	76.500	57.500
	sd	8.404	22.407
# of Correct Sequences	Mean	3.80	2.14
	sd	1.10	2.54

Figure 1
Sample Stimulus: State Comparison Task

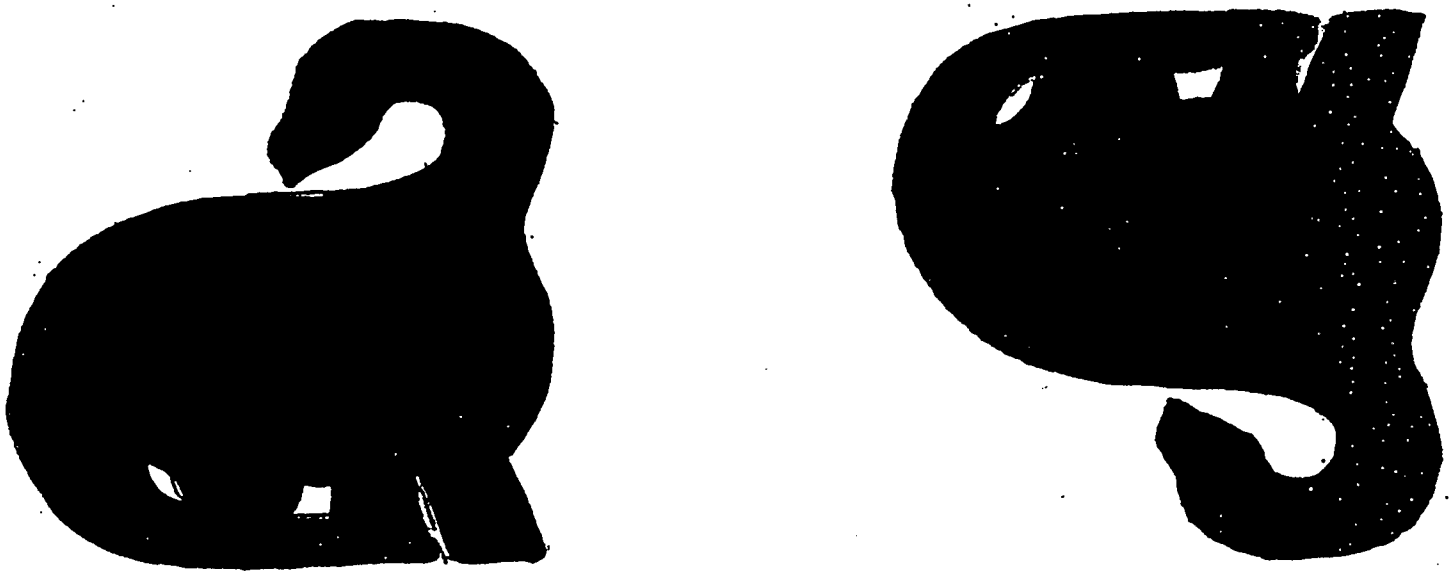


Figure 2
Sample Stimulus: Sequential Ordering Task

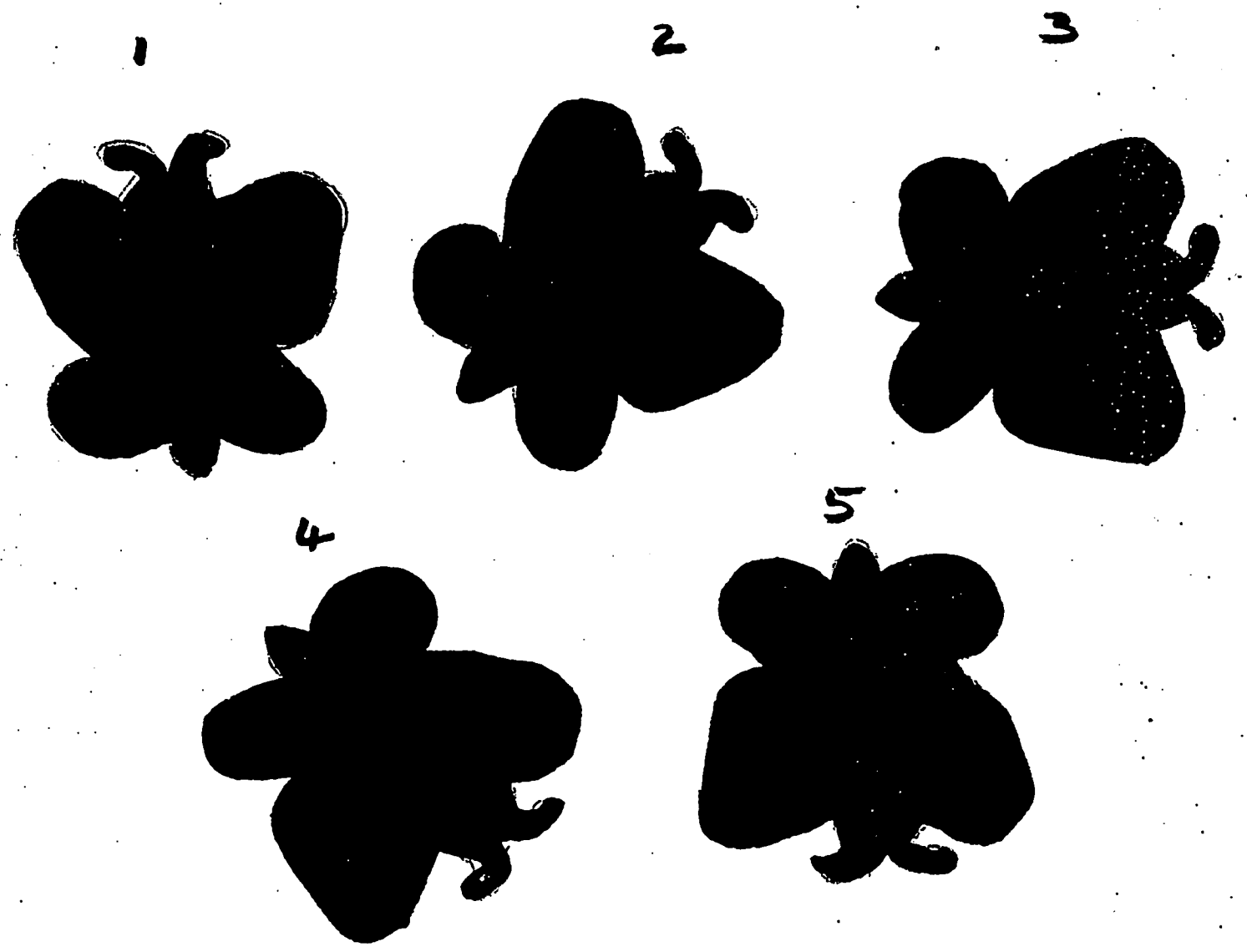


Figure 3

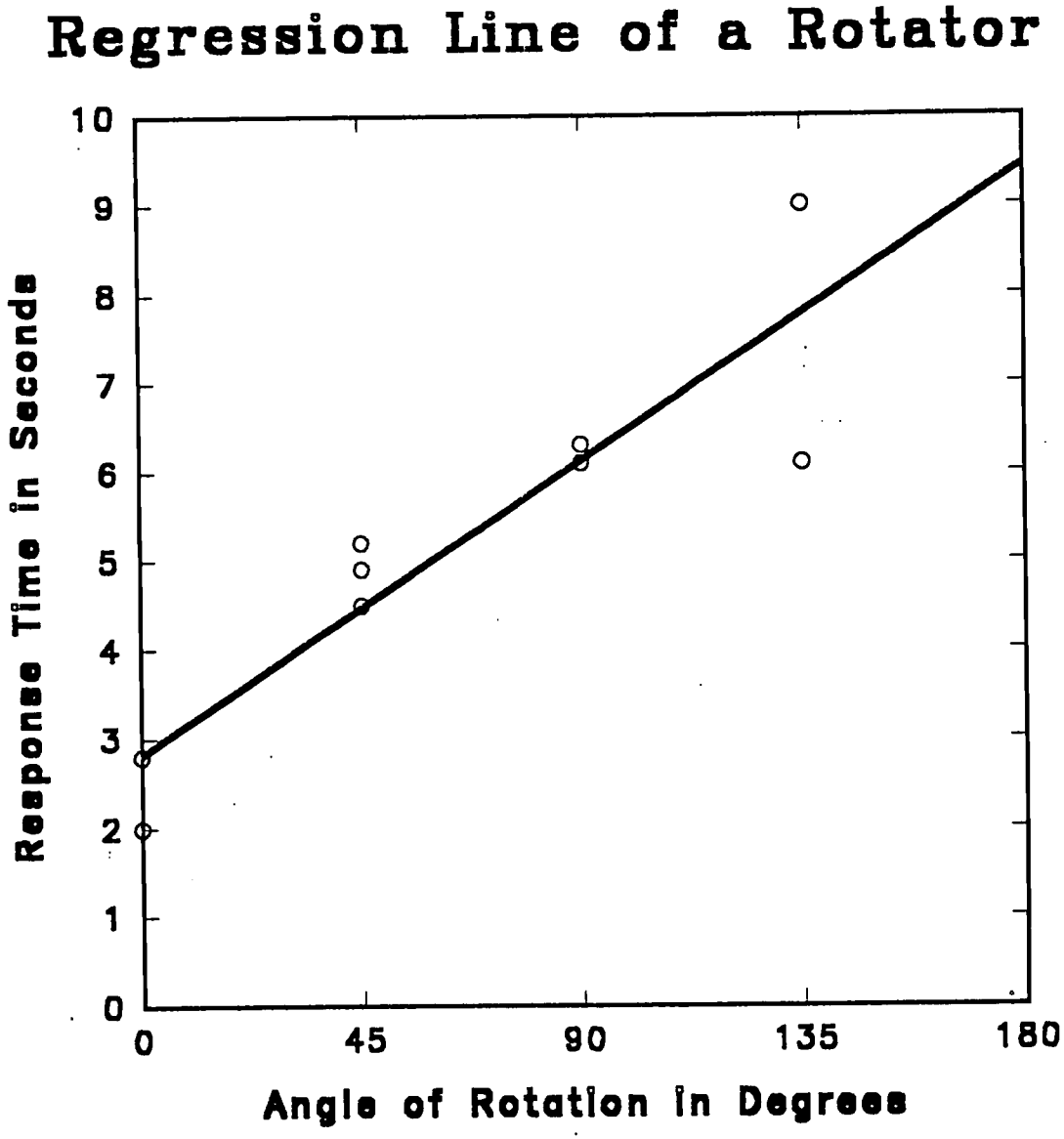

Regression Line of a Rotator
Response Time in Seconds
0
1
2
3
4
5
6
7
8
9
10
0
45
90
135
180
Angle of Rotation in Degrees

Figure 4

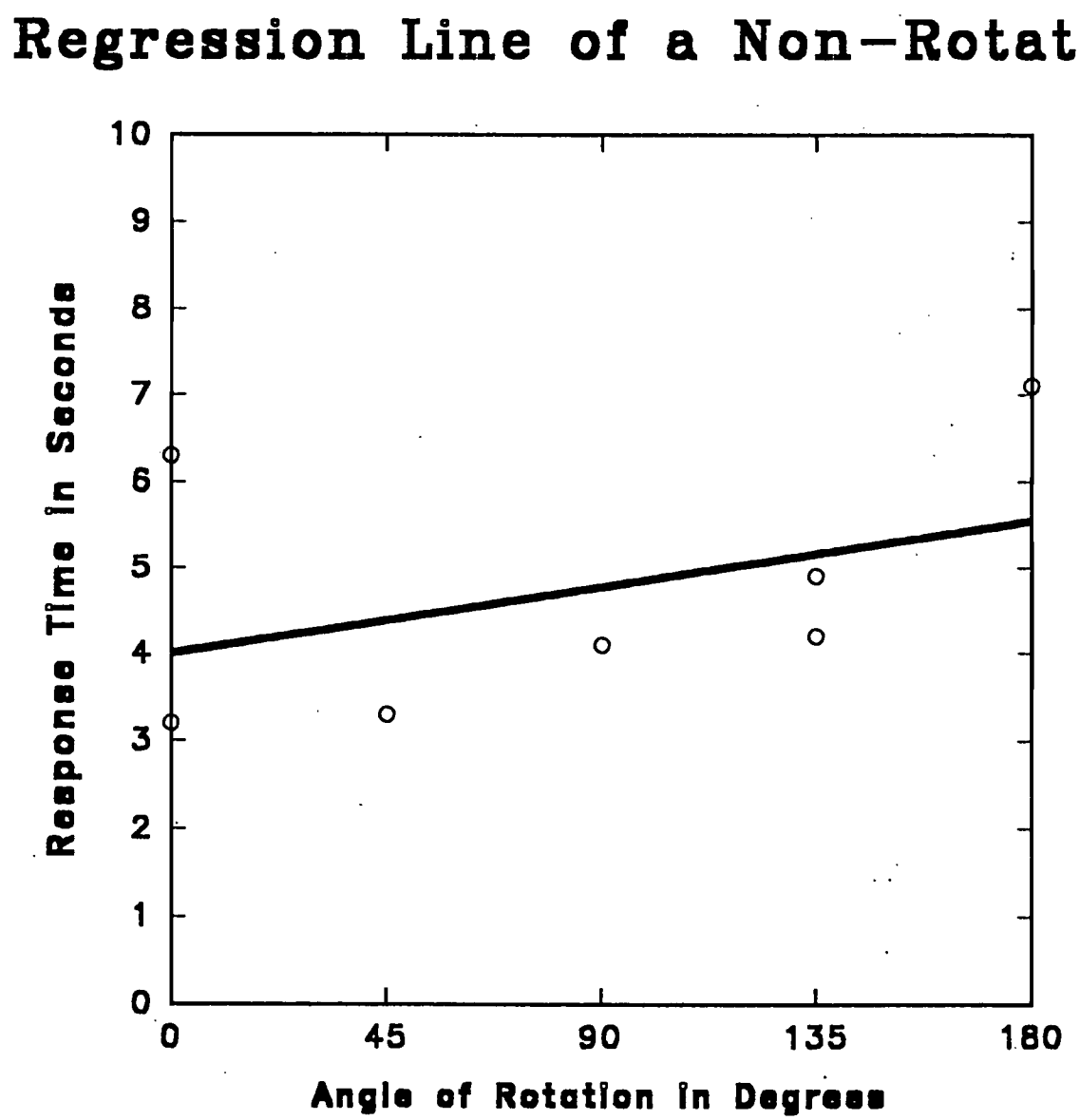
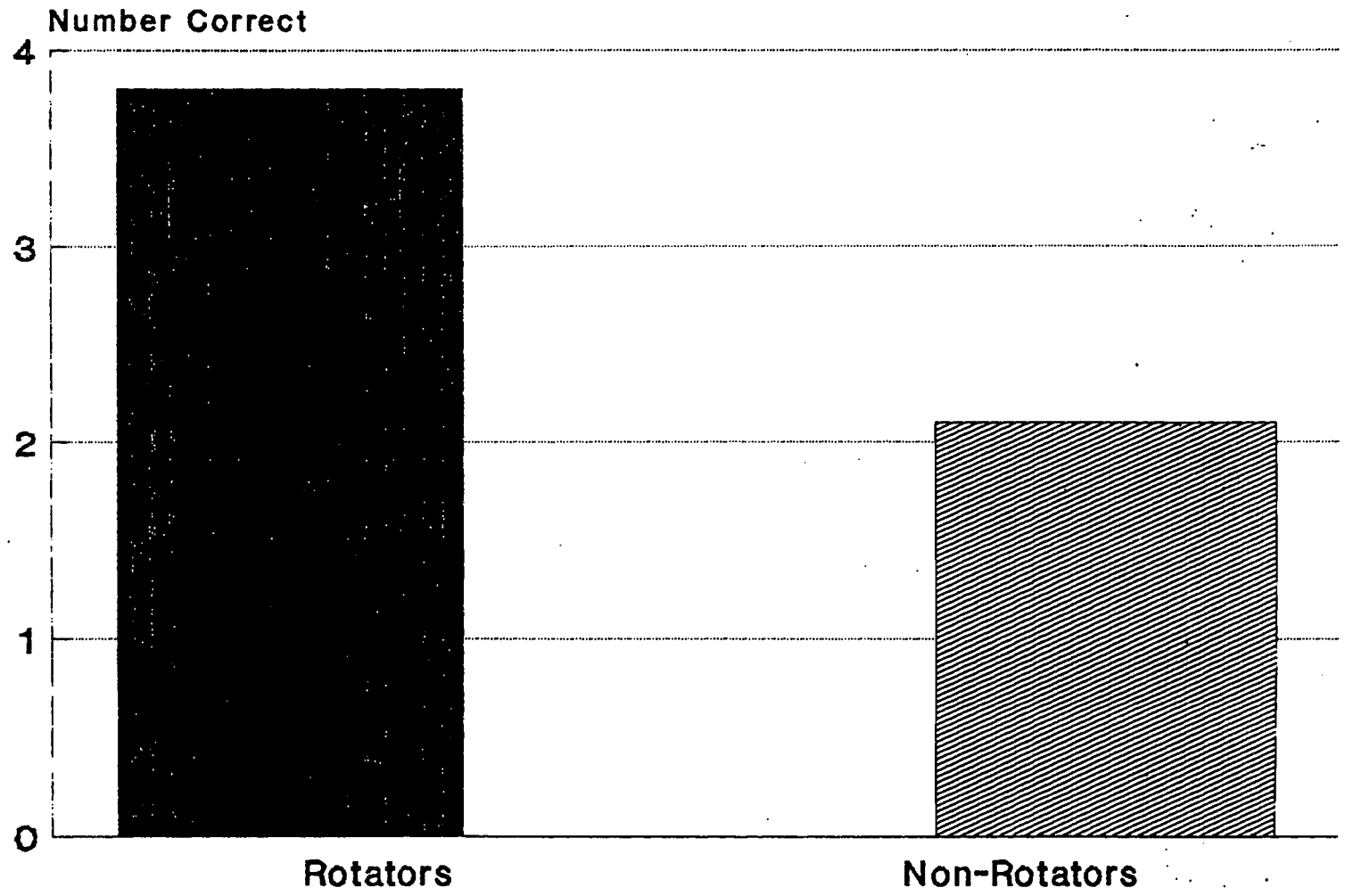

Regression Line of a Non-Rotator
Response Time in Seconds
10
9
8
7
6
5
4
3
2
1
0
0
45
90
135
180
Angle of Rotation in Degrees

Figure 5

Number of Correct 5-Card Sequences for Rotators and Non-Rotators



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