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PERFORMANCE ON THE RAVEN'S COLORED PROGRESSIVE MATRICES TEST BY SUBJECTS WITH CEREBRAL COMMISSUROTOMY[1]

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The Raven's Colored Progressive Matrices Test has been viewed as a nonverbal intelligence test requiring perceptual abilities and spatial reasoning (Raven, 1965). In view of the evidence that space perception deficits are correlated with lesions of the right hemisphere, one might expect such lesions to produce inferior performance on the Raven's as well. However, conflicting results have been reported. Arrigoni and De Renzi (1964) found lower scores in patients with unilateral left hemisphere lesions, on the one hand, and Piercy and Smyth (1962) and Costa and Vaughan (1962) reported inferior performance in patients with right hemisphere lesions.

Commissurotomy patients with surgical disconnection of the cerebral hemispheres offer special advantages for studies involving quantitative and qualitative comparisons between the mental capacities of the two hemispheres in that the two can be compared directly on the same task in a single individual. In the present study the Raven's Colored Progressive Matrices (RCPM), 1965, was modified for lateralized testing in a group of commissurotomy patients. The matrices were viewed in free vision, as in normal testing, but the answer presented among a choice array of raised metal-etched patterns to the right or left hands separately, i.e., to the left or right hemispheres respectively.

Material and Method

Subjects

The tests were administered to a total of seven commissurotomy patients of P. J. Vogel[2] and J. E. Bogen.[3] All had undergone surgical disconnection of the cerebral hemispheres for control of intractable epileptic convulsions. The operation

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[3] Ross-Loos Medical Group, Los Angeles.

was basically the same in all cases and included midline section of the corpus callosum, anterior and hippocampal commissures plus the variable massa intermedia where it was found to be present (Bogen, Fisher and Vogel, 1965). The number of years following surgery at the time this study was undertaken (August to December 1969) ranged from 2½ to 7 years. (NW, 3 years; RY, 4½ years; LB, 5½ years; NG, 7 years; AA, 6 years; CC, 5½ years; RM, 4½ years.) Additional pre-existent brain damage associated with the epilepsy and relevant to this study was known to be present in some of these patients. The left temporal region in RM showed marked abnormality in the EEG records and previous motor tests have shown poor performance with the right hand. AA suffered left hemisphere damage at birth and his right hand has shown poor tactile sensibility when compared with his left hand (Nebes, 1971). NW is presumed to have postoperative changes in the right occipito-parietal area resulting from repeated revisions of a ventriculo-jugular shunt.

Procedure

The original printed form of the Raven's Colored Progressive Matrices (RCPM) was used in presentation of the large design with the missing section. This pattern was examined in normal free vision while the subject, sitting at a table, reached behind a screen with one hand searching by touch among three choices for the correct missing part. The arrays of choice items duplicated in dimension and design those used in the original test but were formed of raised metal lines etched by standard photochemical process and mounted on wooden blocks. Thus both hemispheres saw the problem but only the one having access to the tactual information could be used to find the answer. Preliminary trials revealed that six patterns in the choice array would be too many to try to work with under these conditions of blind tactual exploration and the number was accordingly reduced to three.

Subjects were instructed to tap on the one tactual choice which would most logically complete the visual design. Table I shows the multiple choice items used. Each hand explored the raised configurations in a separate series of trials on the

TABLE I

Multiple-Choice Items Used with Each Matrix and Order of Tactual Investigation

A	A_B	B
1. 3,4,2	1. 4,2,6	1. 1,6,2
2. 5,4,6	2. 5,4,1	2. 4,6,1
3. 2,1,3	3. 4,2,1	3. 6,4,1
4. 3,5,2	4. 4,2,6	4. 6,2,5
5. 4,6,5	5. 2,1,5	5. 1,3,6
6. 3,6,1	6. 2,1,6	6. 2,6,3
7. 1,6,4	7. 5,6,3	7. 6,5,1
8. 2,5,1	8. 4,1,3	8. 4,6,3
9. 1,4,6	9. 2,4,6	9. 4,5,1
10. 6,3,4	10. 6,5,3	10. 1,6,3
11. 6,3,4	11. 6,5,1	11. 1,6,4
12. 2,6,5	12. 4,6,2	12. 5,1,3

same day. In all cases the left hand started the test first and when it went through the entire test a 15 minute break was given and the patient then repeated the test with the right hand. This order gave a bias in favor of right hand performance but had to be used because the left hemisphere otherwise was found to interfere and disrupt right hemisphere performance when the order was reversed. The interference was manifested in excessive verbal comments during left hand performance and a subsequent low score. As a silent and presumably interested and attentive observer of the visual problems during right hemisphere performance in the present design, one would expect the left hemisphere to benefit and score higher. This, however, was not the case.

The simpler stage of the test was administered first (stage I) and it included 12 items chosen arbitrarily as follows: AB_1, AB_2, AB_5, AB_4, AB_7, AB_8, AB_{11}, AB_{10}, B_1, B_2, B_5, and B_{11}. When the first stage of the test was completed and found to be workable in the transmodal form, the entire RCPM (stage II) was administered in the same manner.

For the more involved and complex test in stage II only LB, CC, RY, and NG were selected. They are relatively free of extracommissural damage and sensory defects present in the other three patients. As a control, all four subjects were later administered the RCPM in normal, free vision presentation. In addition two patients who underwent only a partial commissurotomy 3 years previously and who failed to show any functional deficits in behavioral tests (Gordon, Bogen and Sperry, 1971) were also tested in stage II. They served as control for the biased order of presentation which favored the left hemisphere in the complete commissurotomy subjects.

Results

The scores for the left and right hands, summarized in Figures 1 and 2, show a consistent pattern of better performance by the left hand-right hemisphere. A higher percentage rate of correct answers was obtained by all subjects with their left hands and the difference between the two hands was found to be significant in stage I only at $p < .001$ on a 2-tailed distribution ($t = 4.07$). At the same time right hand-left hemisphere performance remain-

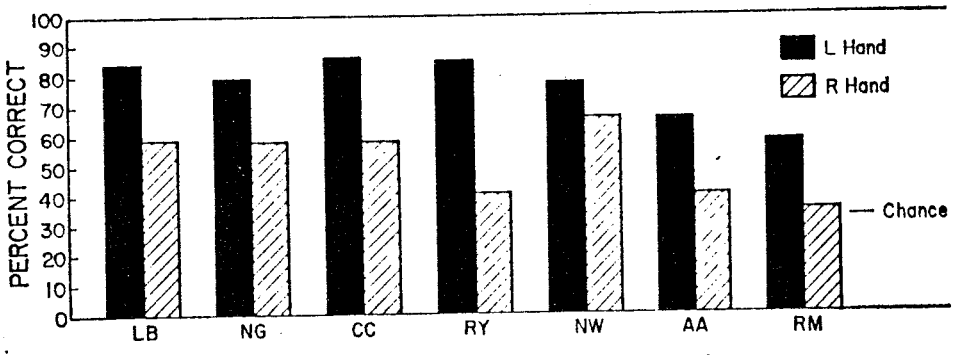

Fig. 1 — *Results for each commissurotomy patient in stage I of the test.*

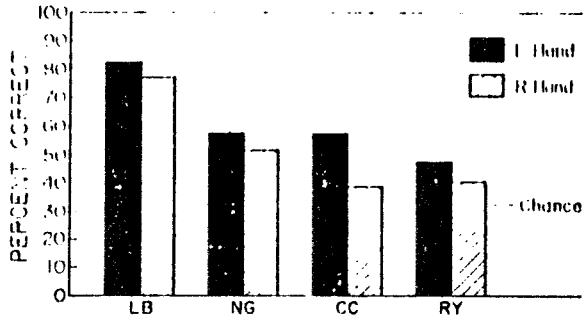

Fig. 2 — *Results for each commissurotomy patient in stage II of the test.*

ed above chance level. The Weighted Average Difference (WAD) was computed to be 29.2% between the two hands for stage I of the test and 9% for stage II.

In addition to these quantitative scores for correct choice other pertinent differences were evident in the overt behavior exhibited by the two hemispheres during tactile exploration. When identifying patterns with their right hand, subjects tended to work slowly and to verbalize their reasoning, giving verbal labels to aspects of the pattern such as number, distance or angle. By contrast, when working with the left hand, subjects' performance was much more rapid, confident and silent. Performance with the right hand was in all cases slower than with the left hand by 25%.

Scores obtained on the full RCPM administered in free vision were as follows: LB = 35; NG = 20; CC = 17; RY = 14. Except for LB the other three patients obtained somewhat higher scores with their right hemispheres than when both hemispheres had simultaneous access to all information. In the case of LB there is evidence that he has attained a level of re-education that would enable the two hemispheres to cooperate to obtain the high score on the standard test. In the two control patients with partial section of the forebrain commissures, scores were higher (NF = 33; DM = 33) than in the commissurotomy patients, excepting LB, and higher still than their performance with each hand separately. In the lateralized test (stage II) their correct scores in percentages were as follows: NF: left hand = 52%, right hand = 61%; DM: left hand = 77%; right hand = 80%. The fact that their right hand scored an average of 6% above their left hand indicates a transfer of knowledge to the opposite hemisphere.

Discussion

The Raven's Colored Progressive Matrices was modified for lateralized presentation to the left and right hemispheres of patients with cerebral

commissurotomy. The results show that scores with the left hand were consistently superior to those with the right hand and the difference between the two was significant on a preselected sample of the RCPM (stage I). However, when the complete version of the RCPM was administered the results, although showing the same trend, lost statistical significance. The right hemisphere superiority is inferred to be greater than appears from the scores because the order of presentation involved a bias in favor of the left hemisphere. A greater difference between the two hands in the same direction on both stages was noted in speed of performance, where the left hand consistently completed the test in less time than the right hand, again in spite of the bias factor.

In addition to the quantitative differences there were indications that the left and right hemispheres solved the same problems by employing different strategies. Performance with the left hemisphere was accompanied by verbal comments and seemed to involve sequential verbal reasoning, while that with the right hemisphere, by contrast, was usually silent and more rapid and direct. Similar qualitative distinctions between the modes of central processing in the two hemispheres in 2 of the same patients had been observed earlier by Levy (1969) on a crossmodal spatial transformation test.

The fact that the left hemisphere could perform the test and that the difference in scores between left and right hemispheres on the complete version of the RCPM was small, if the time factor is ignored, would help explain the discrepancy in results obtained previously by several investigators mentioned above where only the scores were compared. The present findings indicate that the test is not highly specialized for either right or left hemisphere function, especially in stage II, but can be performed by either, though in different ways. Many aspects of the Progressive Matrices can easily be processed verbally without involving gestalt-like spatial apprehension. Design features like cardinality of lines or dots, and size and degree of angularity can be categorized, labeled or conceptualized linguistically. The sequential interrelation of successive items in the RCPM is another aspect of the design that might well favor left hemisphere processes. It would appear accordingly that the RCPM is not eminently suited for measuring functional differences between the hemispheres.

The generally low scores obtained throughout as compared with standard RCPM norms suggest that this is a task in which performance with the intact brain typically involves considerable interhemispheric integration and accordingly is substantially handicapped by sectioning of the commissures. This is supported also in the higher scores of the two control subjects with partial commissurotomy. Presenting the test to the right hand before the left resulted in interference with right hemispheric expression apparently through the establishment of a persevering left hemisphere "set" evidenced in insistent verbalization and subsequent low scores. This would appear to be

another instance of the rather common suppression of minor hemisphere function in these patients by the prevailing dominance of the language hemisphere.

Summary

A modified form of the Raven's Colored Progressive Matrices Test was administered to a group of patients with surgical section of the cerebral hemispheres in order to compare the independent capacity of left and right hemispheres for spatial apprehension and reasoning as indicated by this standardized test. The patterns with missing parts were presented in free vision but the answer had to be sought among a choice of three metal-etched patterns in blind tactual exploration using the left and right hands separately. Scores for the two hands as well as speed of performance showed a consistent left hand-right hemisphere superiority, even though the order of presentation was biased in favor of the left hemisphere. Scores for the left hemisphere, however, were well above chance and the results indicate that the test can be performed by either the right or left hemisphere but that the two use different strategies of approach and different modes of central processing.

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