THE EFFECTS OF PREFRONTAL LEUCOTOMY UPON VISUAL IMAGERY AND THE ABILITY TO PERFORM COMPLEX OPERATIONS

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INTRODUCTION

Two observations made on the post-leucotomy patient inspired the investigation to be reported in this paper. They are, first, that the post-leucotomy patient seems unable to deal with two things at once. Both Ackerly (1935) and Brickner (1939) have referred to this deficit. The second observation was that there was apparently lesser vitality of imagery after operation. A photographer in Pippard's study (1955) who had had, as he said, a "photographic memory", could no longer connect people's faces with photographs of them he had taken in the past. A 35 year old schoolteacher in the same study completely lost her visual imagery after operation, and Brain (1954) has reported a similar deficit in two cases. Zangwill and Humphrey's report (1951) of cessation of dreaming in some patients after brain injury is possibly related to this deficit. Petrie (1952) found an increase in reversals, especially willed reversals on the Necker Cube after operation, and Gordon (1950) has presented findings showing that the control of fluctuation was significantly related to less vivid and controlled imagery.

The investigation reported here was designed to examine further these two post-leucotomy deficits, and to see if they were related in any way.

SUBJECTS

Patients

Results on all or some of the tests were obtained from twelve patients. There were seven male and five female patients, and the age range was from 20 years to 61 years. They fall into the following diagnostic groupings:

Schizophrenia	4
Paranoid Schizophrenia	4
Manic Depressive	1
Hysterical Psychopath	1
Depression (Obsessive-Ruminative State)	1
Obsessional Neurosis	1

All the patients were given a Standard Bilateral Prefrontal Leucotomy.

All twelve patients studied were co-operative and did not seem to have any difficulty in orientating themselves to the test situation. Two other patients proved unco-operative before leucotomy and were not included in the group.

Normal Group

Fifteen subjects were tested. There were nine male and six female subjects, and the age range was from 20 years to 31 years. The group was made up of nurses at the Crichton Royal and psychology students.

METHOD

The main test of the battery used is based on Von Kuenburg's Figure-Matching Test used by Rylander (1939) in his study of patients with frontal lobectomies. The test was given to examine the post-leucotomy patient's ability to deal with two things at once. In this test the subject is given a data card (for five seconds) bearing a number of meaningless figures (see Fig. 1). Although the figures are similar, one occurs twice, i.e. it appears in identical form in two different positions on the data card. The subject is then asked to find this identical figure on a multiple choice card (identification) (see Fig. 1), and to indicate on another location card (see Fig. 1), the positions which the identical

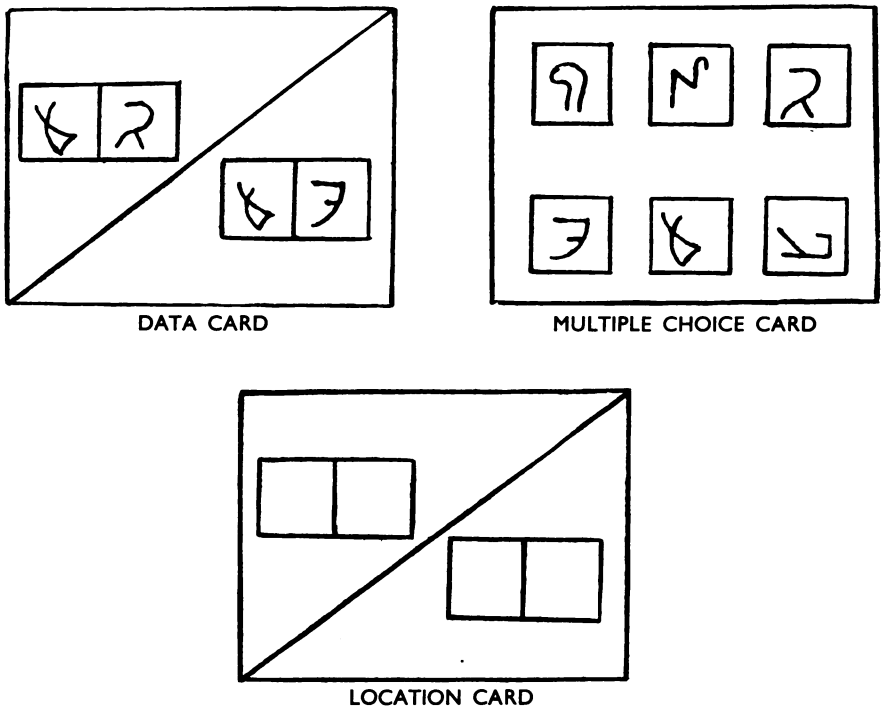

FIG. 1.—An example of the 2×2 type of problem in the Figure-Matching Test.

figures had occupied on the original card (localization). There are thirteen cards of the two by two type. The first card is a trial card and the performance on this is not scored; in the first three cards of the test proper the subject has to identify the figure first and localize it second; for the second set of three cards the localization comes first and then the identification; for the third set of three cards the subject has only to identify the figure; for the fourth set of three cards the subject has only to localize the figure.

There are thirteen cards of the three by three type (see Fig. 2), and they are arranged as the two by two type.

A Letter-Matching Test was designed. This test is exactly the same as the Figure-Matching Test apart from the fact that instead of figures there are letters (see Fig. 3), and one arrangement of letters occurs twice.

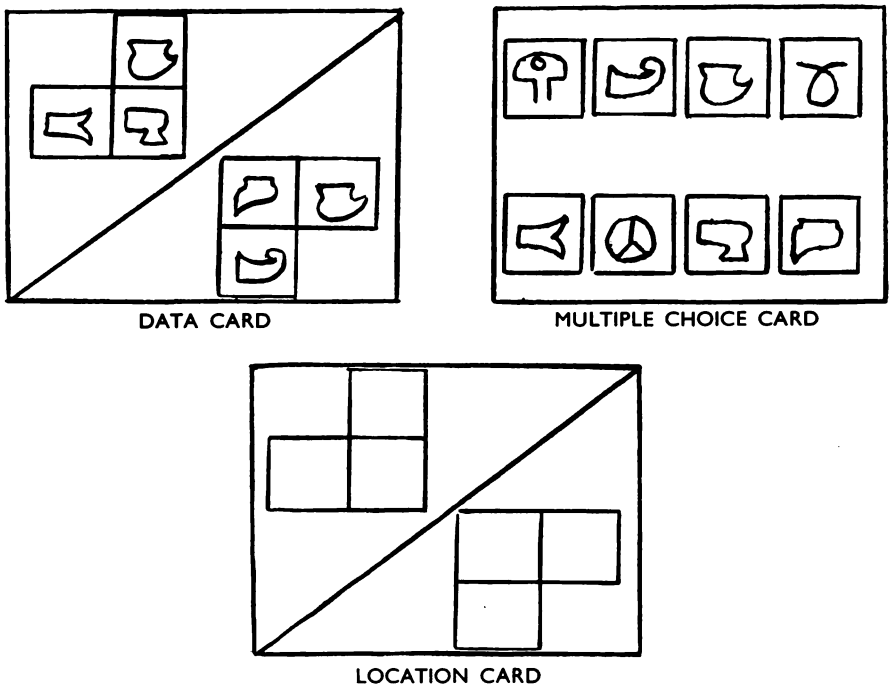

FIG. 2.—An example of the 3×3 type of problem in the Figure-Matching Test.

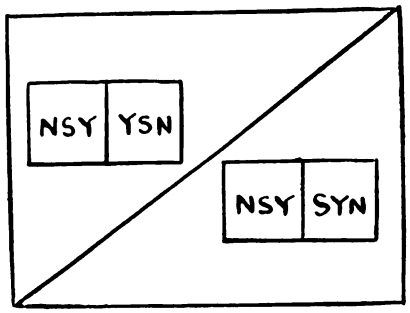

FIG. 3.—An example of the data card of the 2×2 type of problem in the Letter-Matching Test.

The following tests were also given to the patients:

Raven's Progressive Matrices (1938)—to assess changes in intellectual capacity.

The Mill Hill Vocabulary Scale—to assess changes in verbal ability.

The Moray House Space Test Adv. 1.

Group Test 80A of the National Institute of Industrial Psychology, which is also a Space Test.

Both of these tests were given to assess changes in the ability to manipulate visual images.

The patients were tested one week before (Session I) the operation, and at intervals of two weeks (Session II), and ten weeks (Session III) after the operation.

The normal subjects were given, in addition to the tests described above,

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the following tests in order to examine further the relationships between performance on the Space Tests and the nature of the subjects' visual images:

The Necker Cube.

The Rosemary Gordon Test of Visual Imagery in which the subject has to visualize eleven scenes involving a car, e.g.:

1. A car standing in front of a garden gate.
2. The same car, but in a different colour than that seen at first.
3. The same car lying upside down.

The subjects were also asked a number of questions about their visual imagery and dreams.

Hypotheses and Results

Patient Group

Figure-Matching Test

If the post-leucotomy patient is unable to hold in mind and deal with two things at once, we would not expect him to perform so well after the operation on the Figure-Matching Test where he has to remember the figure in order to identify it, and also the positions of the identical figure. The patient's performance on the first three cards of the two by two and three by three problems we will refer to as his FP score (FP indicates that the subject has to identify the figure on the multiple choice card first, and then pick the positions on the location card). To obtain a score of 1 on each item the patient has to both identify the correct figure and pick the positions correctly. Failure on either one or both of these aspects is given a zero score. The patient's performance on the second set of three cards of the two by two and three by three problems we will refer to as his PF score.

The first hypothesis can be stated thus:

Hypothesis I. There will be a drop after leucotomy in the patient's FP and PF score.

Adding together the FP scores and PF scores for the two by two and three by three problems (maximum score=12) the means for the group of nine patients at each Session is as follows:

Session I	*Session II*	*Session III*
M=9·66	M=5·55	M=7·66

The difference between the means of the scores at Session I and II is significant at the ·01 level (t=3·18; d.f.=16). The difference between the means of the scores at Session I and III is not statistically significant (t=1·57; d.f.=16).

The results provide evidence for a temporary drop in FP and PF scores after leucotomy on the Figure-Matching Test. The slight rise again from Session II to Session III may be due to practice effects and familiarity with the material. It is not in itself evidence against an hypothesis of the deficiency being a permanent one.

The results for the FP and PF scores can also be presented in the following form:

Session I–Session II (9 patients).

		No. of patients whose scores at Session II are:		
		Lower	*Unchanged*	*Higher*
FP score:	2×2 problem	4	5	0
	3×3 problem	5	4	0
PF score:	2×2 problem	7	2	0
	3×3 problem	8	1	0

Session I–Session III (9 patients).

		No. of patients whose scores at Session III are:		
		Lower	*Unchanged*	*Higher*
FP score:	2×2 problem	3	6	0
	3×3 problem	6	3	0
PF score:	2×2 problem	3	6	0
	3×3 problem	6	3	0

The number of patients whose scores are lower, unchanged, and higher is given rather than the actual difference in scores, because the maximum score for each set of problems (e.g. FP score 2×2 problem) is only 3. It should be pointed out that the column headed "Higher" has been included for completeness. Actually a number of the patients obtained a full score of 3 at both sessions, and there was no room for a rise in score.

It will be seen on examining the above tables that at Session II the tendency for the scores to be lower is more marked in the PF scores than in the FP scores. No explanation can be given for this, but it may be worth further investigation. The above table also suggests that though the drop in score at Session III is not statistically significant, there is a marked tendency for the scores to drop on the three by three problems.

If the difficulty encountered by the post-leucotomy patient is that of holding two things in mind at the same time, we would not expect his scores to drop when he has only to identify the figure or pick the positions of the identical figure. F scores refer to the third set of three cards (2×2 and 3×3 problems). P scores refer to the fourth set of three cards (2×2 and 3×3 problems). The next hypothesis can be stated thus:

Hypothesis II. There will be no drop in the F and P scores.

Adding together the F and P scores for the two by two and three by three problems (maximum score=12) the means for the group of nine patients at each Session is as follows:

Session I	*Session II*	*Session III*
M=11·77	M=11·22	M=11·77

The difference in scores is not significant and the results support Hypothesis II. The results for the F and P scores can also be presented in the following form:

Session I–Session II (9 patients).

		No. of patients whose scores at Session II are:		
		Lower	*Unchanged*	*Higher*
F scores:	2×2 problems	0	9	0
	3×3 problems	1	8	0
P scores:	2×2 problems	2	7	0
	3×3 problems	2	7	0

Session I–Session III (9 patients).

		No. of patients whose scores at Session III are:		
		Lower	*Unchanged*	*Higher*
F scores:	2×2 problems	0	9	0
	3×3 problems	0	9	0
P scores:	2×2 problems	0	9	0
	3×3 problems	1	8	0

Letter-Matching Test

In view of the observation made by Petrie and others as to the lesser vitality of visual images after operation, the question that presented itself was: Could it be that in the Figure-Matching Test two visual images of shape and localization are involved, and that one must be lost if the other is to survive? If this is taken as our hypothesis then the following deduction can be made: Due to the lesser vitality of imagery in post-operative patients, there will be a bigger drop in score when only one form of imagery is used (visual) compared with his score when two forms of imagery (visual and visuo-verbal) are employed. The Letter-Matching Test was designed to test this deduction.

LP scores refer to the first set of three cards (2×2 and 3×3 problems), PL scores to the second set of three cards (2×2 and 3×3 problems). The deduction from Hypothesis III can be stated thus:

Deduction from Hypothesis III. The drop in LP and PL scores will be less than in the FP and PF scores.

The mean difference in the FP and PF scores for Session I and Session II is 4·11. The mean difference in the LP and PL scores for Session I and Session II is 2·44. The difference in mean differences is not statistically significant ($t=1\cdot01$; d.f.$=16$). The mean difference in the FP and PF scores for Session I and Session III is 2 and the mean difference in the LP and PL scores for Session I and Session III is 2·22. The difference in mean differences is not significant.

The results do not provide evidence in support of the deduction from Hypothesis III.

Space Tests

If there is lesser vitality of visual imagery after leucotomy, we would expect some change on the space tests. El Koussy (1950) has shown that the more the tests are saturated with the K factor, the more they depend on the process of visualization and manipulation in the mind.

Moray House Space Test, Adv. 1 and N.I.I.P. Space Test (7 patients).

An examination of Figures 4 and 5 suggests a centralizing tendency, i.e. those whose score is high before leucotomy obtain lower scores after the operation, and those whose score is low before the operation obtain higher scores afterwards. This centralizing tendency, evident at Session II, is more marked at Session III. Though this change is not statistically significant, in the few cases available it seems sufficiently marked to justify some speculation.

Evidence will be provided later, when the results of the normal group are presented, showing that subjects with vivid autonomous imagery tend to score low on the space tests and subjects with weak controlled imagery tend to score high. This suggests that the patients who before leucotomy, scored low on the space tests had vivid autonomous imagery, which was made weaker and more controlled by the operation, thus resulting in a higher post-operative score. Secondly, patients who had high scores before leucotomy had weak controlled imagery which was made weaker by the operation. The drop in score for these patients is apparently due to the fact that, though their imagery is controllable, it is now too weak for the images to be formed easily.

Miscellaneous Tests

Raven's Progressive Matrices (1938) (11 subjects).

	Session I	*Session II*	*Session III*
Mean scores:	34·90	30·45	33·36

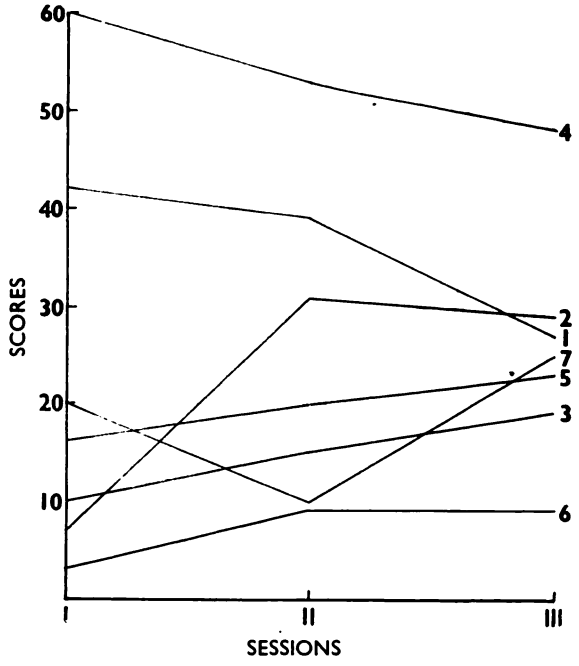

FIG. 4.—The Scores of seven patients on the Moray House Space Test Adv. 1, at Sessions I (before leucotomy), II and III (after leucotomy).

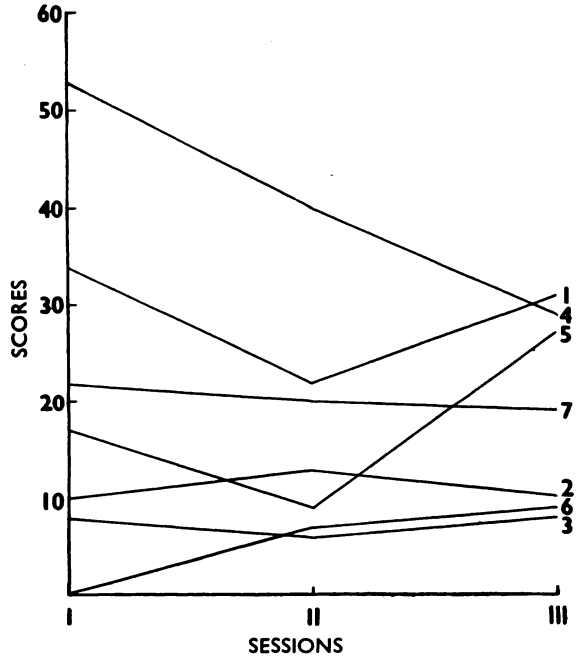

FIG. 5.—The Scores of seven patients on the N.I.I.P. Space Test at Sessions I (before leucotomy), II and III (after leucotomy).

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The tendency is for the scores to drop at Session II and to rise again at Session III. The difference in score is not statistically significant.

Mill Hill Vocabulary Scale (11 subjects).

	Session I	*Session II*	*Session III*
Mean scores:	50·90	49·45	50·54

There is little or no drop on the Vocabulary Scale after leucotomy.

Normal Group

Rosemary Gordon Test of Visual Imagery

The fifteen subjects were given this test and then split into two groups. Group 1 consisted of those subjects who were able to visualize all the eleven scenes in the test. Group 2 consisted of those subjects who were unable to visualize one or more of the eleven scenes. It is noteworthy that even where subjects in both groups were able to visualize a scene, the subjects of Group 2 had more difficulty in doing so than those in Group 1.

All the subjects of Group 1 said that they rarely had dreams, or that they were vague and not remembered. None of them reported what is known as a "photographic memory", and were not conscious of visual images playing any part in their thought processes.

All the subjects in Group 2 reported frequent vivid dreams; two of the subjects reported experiences of autonomous vivid images, and one claimed a photographic memory.

There were nine subjects in Group 1, and six subjects in Group 2, and all the subjects were given the following tests:

Necker Cube

The subject was first of all asked to look at the cube for one minute, and to tap with a pencil each time the cube reversed its perspective. He was then asked to look at it for a minute and try to increase the number of reversals per minute as much as he could tapping each time it reversed. Lastly, the subject was asked to reduce the number of reversals per minute as much as he could.

The mean difference in number of reversals for normal and fast speeds for Group 1 is 24·78, and for Group 2 it is 8. Groups 1 and 2 differ significantly in their ability to vary the rate of reversal. Comparing their ability to change from a normal to a fast rate of reversal, t—calculated on the basis of the difference in number of reversals for normal and fast speeds—was found to be 3·6, P being, therefore, less than 0·01.

The mean difference in number of reversals for fast and slow speeds for Group 1 is 34·67, and for Group 2 is 14·5. In the case of a change from fast to slow speeds t was found to be 3·89, P being, therefore, less than 0·01. The autonomous group in each case was significantly less capable of adjusting the rate of reversals to the new instructions.

Space Tests

	Group 1	*Group 2*
N.I.I.P. mean score	52·89	29·83
Moray House mean score ..	69·17	50·66

The subjects of Group 1 obtained higher scores on the space tests than the subjects of Group 2. The difference is not significant statistically on the Moray House Space Test Adv. 1, but is statistically significant at the ·001 level on the N.I.I.P. Test (t=4·36).

Raven's Progressive Matrices (1938)

	Group 1	*Group 2*
Mean scores	55·44	54·5

The difference in score between the two groups on this test is not significant.

Mill Hill Vocabulary Scale

	Group 1	*Group 2*
Mean scores	67·67	65·5

The difference between the two groups is not significant.

Figure and Letter Matching Tests

All but three subjects gave a completely correct performance on both these tests. The three subjects (two from Group 1, and one from Group 2) failed on one or two items in the Letter-Matching Test.

Discussion and Conclusions

One explanation proposed for the difficulty patients have with the Figure-Matching Test is that it requires the patient to attend simultaneously to two different aspects of one task. This means that the difficulty of the post-leucotomy patient is encountered on the data card where he has to find the identical figure and note the positions. The present investigation has shown that the necessity not only to attend simultaneously to different aspects of a task, but even more to maintain two simultaneous modes of response, appears to be an important feature of the test, and that it is on this part of the test that the post-leucotomy patient has difficulty. If the first explanation were the correct one, then we would expect a drop in score after leucotomy on those items of the test where the patient has only to remember one thing, remember the figure or remember the positions, because the problem on the data card is the same as on the data card of the other items, particularly where he has to search for the identical figure and then note the positions to be remembered.

The study of the normal group has shown that people with weak controlled visual images do better on space tests than those with vivid autonomous visual images. The difference in performance of the patients on the space tests before and after leucotomy suggests that the operation lessens the vitality of their images and makes them easier to control. Although a comparison of performances on the Figure-Matching and Letter-Matching Test does not indicate that the finding of a change in visual imagery has anything to do with the drop in performance on the Figure-Matching Test, the finding is itself interesting.

The lesser vitality of visual images may partly explain what Freeman and Watts (1942), have described as the deficit in foresight and planning after leucotomy. Brain (1951), has pointed out that emotion provides the motive power which sustains our course of action, and if the action is to take time, the object to which it is directed must be constantly represented to us by means of mental imagery. Without images the person lives in a perpetual present unable to adapt future behaviour to his past.

The role played by vivid images in the illness of a patient is not clear. That mental illness is not a necessary concomitant of vivid and even autonomous imagery is fairly certain. Two intelligent normal subjects in the present group reported experiences of autonomous images. One, a female subject, described an experience in which she saw herself throwing a kitten into a fire. "I tried to change the picture," she said, "so that I would be stroking the kitten. I was not

able to do so and I felt a tenseness in my body." A male subject said he often saw a ball of wool before him which he would unwind continuously without ever coming to the end. The role played by vivid images in the pre-occupations of obsessionals, the memories of the depressed, and the painful anticipation of the anxiety states and their relation to hallucinations, needs to be investigated further.

Summary

(1) A battery of tests was given to a group of twelve patients one week before, and two weeks and ten weeks after a standard bilateral prefrontal leucotomy.

(*a*) Performances on a Figure-Matching Test suggest that the post-leucotomy patient is less able to maintain two simultaneous modes of responses after the operation.

(*b*) Performances on a Letter-Matching Test suggest that the task is not made any easier for the post-leucotomy patient when he can employ two forms of imagery (visual and visuo-verbal).

(*c*) Data from the Moray House Space Test Adv. 1 and the N.I.I.P. Space Test suggest that leucotomy produces a centralizing tendency in performance on these tests, i.e. those whose score is high before leucotomy obtain lower scores after the operation, and those whose score is low before the operation obtain higher scores afterwards.

(*d*) There are no significant changes on Raven's Progressive Matrices (1938), and the Mill Hill Vocabulary Scale.

(2) A group of normal subjects was given the Gordon Test of Visual Imagery, and a dichotomy was obtained between those with weak, controlled, visual images (Group 1), and those with vivid, autonomous, visual images (Group 2).

The difference in scores for these two groups was statistically significant on the Necker Cube and the N.I.I.P. Space Test, and was not significant on the Progressive Matrices (1938), the Mill Hill Vocabulary Scale, and the Moray House Space Test Adv. 1.

(3) The general significance of the results is discussed.

Acknowledgments

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References

Ackerly, S., *Amer. J. Psychiat.*, 1935, **12**, 6.

Brain, W. R., *Proc. Roy. Soc. Med.*, 1951, **44**, 37.

Idem, ibid., 1954, **47**, 288.

Brickner, R., *Arch. Neurol. and Psychiat.*, 1939, **41**, 580.

El Koussy, A. H., *Proc. XII Inter. Congress of Psychol.*, 1950. Edinburgh: Oliver and Boyd, Ltd.

Freeman, W., and Watts, J. W., *Psychosurgery*, 1942. Springfield, Ill.

Gordon, R. A., *Brit. J. Psychol.*, 1950, **41**, 63.

Petrie, A., *Personality and the Frontal Lobes*, 1952. London: Routledge and Kegan Paul.

Pippard, J., *J. Ment. Sci.*, 1955, **101**, 774.

Rylander, G., *Personality Changes after Operations on the Frontal Lobes*, 1939. Oxford Univ. Press.

Zangwill, O. L., and Humphrey, M. E., *J. Neurol. Neuros. and Psychiat.*, 1951, **14**, 322.