PSYCHOLOGICAL CHANGES FOLLOWING PREFRONTAL LEUCOTOMY; A REVIEW.

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		PAGE
I.	CLINICAL STUDIES:	
	(*a*) General clinical studies	50
	(*b*) Specialized clinical studies	56
	(*c*) Pathological studies	57
	(*d*) Studies using modified operative techniques	59
	(*e*) Summary	62
II.	STUDIES USING PSYCHOLOGICAL TEST TECHNIQUES:	
	(*a*) Cognitive tests	64
	(*b*) Special investigations	67
	(*c*) Summary	77
III.	GENERAL CONCLUSION	79

THE literature on prefrontal leucotomy has been reviewed previously by Freeman and Watts (23), Fleming (15, 15*a*), Kisker (50), Walker (93), Partridge (69), Klebanoff (52) and Robinson (81). Of these, Klebanoff's review of psychological changes in organic brain lesions and ablations, including leucotomy, is probably of the most interest to psychologists because of his emphasis on statistical and methodological considerations. Fleming's (15*a*) review, being both up-to-date and comprehensive, is probably the review which is of most interest to clinicians.*

The present review is specifically concerned with investigations on psychological changes following prefrontal leucotomy. Thus, studies such as the Columbia Greystone Project (60) on cerebral topectomy are excluded from consideration. The field is more circumscribed than that covered by previous reviewers, and an attempt is made to describe individual investigations in greater detail. Large scale statistical summaries, such as that of the Board of Control (102) and of Ziegler (100, 101), are not discussed. The differences, from one hospital to another, in psychiatric diagnoses and in the criteria of postoperative adjustments are such as severely to limit the value of these summaries.

* I am indebted to Dr. Fleming for his kindness in allowing me to consult and to quote his paper in advance of publication.

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I. Clinical Studies.

(a) *General Clinical Studies.*

In an early report Moniz (65) describes his procedure and the results from his first group of patients. This procedure as first developed consisted in the injection of alcohol into the sub-cortical white matter of the prefrontal area. Subsequently sections were made in the sub-cortical white matter by a leucotome with a steel loop which tended to crush the white matter in the area; and, later still, a leucotome was used which had a steel band that cut rather than compressed. He concludes from the first 38 patients "from mental hospital and clinic" that deteriorated patients obtain slight or no benefit from the treatment, but that with patients ill for less than 5½ years, including schizophrenics, "clinical recoveries have been observed." Some of the patients left hospital and assumed their usual occupations. In the light of future research perhaps the most important suggestion in the report is that leucotomy is contraindicated for deteriorated patients.

In America, Freeman and Watts have been the main exponents of prefrontal leucotomy. Freeman and Watts' operative technique, a "blind" approach utilizing skull bearings to locate the position of the incision, is described in their major monograph (23). Their results have been reported in a series of papers (94, 21, 22, 25, 26, 28). Exact percentages of recoveries considered good, fair or poor in the various diagnostic groupings fluctuate as the number of cases has been increased. This is unavoidable, and is probably due to developments in operative technique, to variations in the psychiatric material and to unreliabilities of post-operative assessment. It does mean, however, that to quote any given set of figures may be misleading. The general trends indicate that chronic anxiety states, involutional depressions and obsessional disorders respond best to leucotomy, having a "good" recovery in half to two-thirds of the cases; schizophrenia is most difficult to relieve, having a "good" recovery in under half the cases operated upon.

In the selection of patients three broad criteria are suggested (94, 23, 24, 25, 26). These are (1) poor prognosis, (2) failure of other treatments, (3) selection should be based upon symptomatology rather than upon type of disease. Emotional response is said to be the most important criterion. When emotion dies out the patient is not suitable. Hence docility, vagueness, true apathy are contraindications; apprehension, tension, anxiety, depression, agitation, hypochondriacal ideas—these may be relieved by the operation. The importance of adequate convalescent care is stressed (24, 25), especially after an extensive operation.

Mixter, Tillotson and Wies (64) reported two cases of agitated depression who, after leucotomy, showed a relief of symptoms. An affective desensitization of the psychosis seemed to take place, lessening the hypermotility and abnormal concern. Strecker, Palmer and Grant (87) reported favourable results from a group of 16 agitated depressions, of whom 12 (75 per cent.) recovered sufficiently to live in their own homes "in a relatively satisfactory degree of emotional adjustment." Five chronic, violent schizophrenics "improved" after leucotomy: in three cases the "gain was considerable," two of these patients being

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discharged. The authors feel this to be a definite "salvaging of psychotic material which would have been adjudged irretrievably lost."

McGregor and Crumbie (54, 55) reported results on small groups of psychotic patients, predominantly cases of schizophrenia and melancholia. Of these, over half the melancholics made social recoveries as compared with about 20 per cent. of the schizophrenics. The authors felt that the best results were among those cases who show by their response to other treatments that they are potentially capable of recovering, though not of maintaining normality by these means. Petersen and Buchstein (70) reported the results of leucotomizing 46 chronic psychotic patients selected on the criterion of presence of "psychic tension," the majority of whom were schizophrenic, mainly of the hebephrenic sub-group. Though their results were "not spectacular," they concluded that prefrontal leucotomy is a valuable method of treatment in certain chronic psychoses.

Rees (76) discussed the indications for prefrontal leucotomy, basing his remarks presumably upon a group of 30 patients, the diagnosis and chronicity of whom are not discussed. In this group 9 patients (30 per cent.) made social recoveries, and 13 (43 per cent.) are improved for the hospital routine. Among schizophrenics the operation was most successful where the symptoms suggest active mental conflict, worst in the hebephrenic group. The best results were obtained in depressive and obsessional patients. Leucotomy should be reserved until all other methods have failed and the prospect of spontaneous recovery is remote. This conclusion was concisely stated in a report by Bennett, Keegan and Wilbur (5), in which detailed case-histories are given for 5 chronic schizophrenics. These authors concluded that the leucotomy operation should be reserved for "chronic and apparently permanent institutional patients in whom any improvement is pure gain and the procedure, even with its hazards, seems justifiable."

Heilbrunn and Hletko (36) report poor results from a group of 10 restless, irritable, noisy, excitable schizophrenics and 1 mental defective with periods of excitement, who had shown psychotic symptoms for 6–32 years. After 9 months only two patients showed some insignificant amelioration of their conditions, and the operation is not recommended in chronic schizophrenia. Tarumianz (91) reports results on 10 cases, 8 involutional melancholics and 2 schizophrenics, all of whom were much deteriorated. Of these, 7 became "fully adjusted socially and mentally . . ." Two studies, by Hutton, Fleming and Fox (42), and Hutton (39) report the results of leucotomizing a group of 50 patients who had made no permanent response to other methods of treatment and for whom the prognosis was bad or hopeless. They describe their results as "encouraging . . . considering the chronicity of many of the cases." Leucotomy was tried in schizophrenic, depressive, obsessional disorders, and for anxiety states. The results are said to be best in the presence of a very strong negatively toned emotional factor, e.g. apprehension, anxiety, inadequacy or guilt; worst in cases of dementia simplex characterized by emotional apathy and general mental reduction. In the later of these papers (39) personality changes after leucotomy are discussed. Though there is considerable variation in the subsequent characters of treated patients, there

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are certain characteristic tendencies to be traced in all of them, of which complacency is the most outstanding. Patients are self-satisfied and easily pleased with their environment. They are "not incapable of taking thought for to-morrow should anything stimulate them to do so, but are content for to-morrow to take care of itself." A more detailed description of personality changes following leucotomy is given by Hutton (40) in a careful paper which gives the histories of 10 patients successfully treated by leucotomy, all of whom had a bad prognosis, but who varied considerably in psychiatric diagnosis, age, education, occupation, intellectual ability and temperament. Particular attention was paid to the study of character and personality traits. Records were compiled from the information of relatives interviewed at home, information as to pre-morbid personality being obtained only after illness, operation and recovery. There are disadvantages in obtaining information in this way, especially, perhaps, because of variations in the reliability of different informants. It is, however, important that information should be sought from the patient's home; and depending on the skill of the interviewer, it should be possible to obtain a considerable amount of valuable data. Certain apparently common features were found in the pre-morbid personalities—lack of social adaptation and restriction of personal relationships; the majority were conscientious and meticulous. It seems likely, however, that at least the first two traits would be found in many pre-psychotic personalities, and that they may have no special significance in the pre-morbid personalities of patients who recover after leucotomy. The question cannot be answered with certainty without examining the pre-morbid personalities of a control group whose clinical response to leucotomy is poor. The most obvious feature of the post-leucotomy personality was a diminution of self-consciousness which showed itself variously—in less shyness and reserve; more indifference to adverse criticism; less preoccupation with bodily functions; sometimes in smugness and self-satisfaction. Accompanying this there is also a decreased awareness of the feelings of other people, expressing itself, for example, in tactlessness. There is a shallowness in the emotional life, no tendency to make new friends and sometimes an absence of old affection. In some patients there is a change in the moral aspect of character, mostly for the worse. The patient is less truthful, less reliable, less scrupulous than in pre-morbid days. The sense of personal responsibility is somewhat reduced, though reaction is normal to immediate situations.

Berliner, Mayer-Gross, Beveridge and Moore (6) and Moore (67) describe the results of leucotomizing 150 chronic psychotic patients, of whom 130 were schizophrenics, mainly aggressive, restless, negativistic paranoids and catatonics. The criterion for the selection of cases was the presence in the clinical picture of signs of mental tension symptoms, e.g. irritability, rage, fear, and motor manifestations such as aggressiveness. Approximately 30 per cent. of the group made a "social recovery," that is, they could leave hospital, live at home under normal conditions, and resume some sort of useful employment, not necessarily up to former standards. About 20 per cent. were classed as "much improved," i.e. these patients have parole, enjoy the amenities of the hospital, and do useful work under supervision. About 6 per cent. are "unchanged," i.e. remain in approximately their pre-operative state; and the

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remainder, about 40 per cent., show some degree of improvement within the hospital, or the loss of certain troublesome features of their illness, e.g. violent or impulsive behaviour, faulty habits or destructiveness. It is stated that, within the schizophrenic group, those with the least signs of tension benefit least (6) ; and it is concluded that there is a " remarkable change in outlook for distressful cases of schizophrenia " (67). The best results were on a small group of obsessionals ; and the results in chronic melancholia were also considered encouraging. These latter observations are, however, limited in value because the groups were small. It is pointed out that most of the groups were from the educated classes, and that their better than average pre-morbid personalities may have helped the results.

Ström-Olsen, Last and Brody (89) and Ström-Olsen (88) present the results of leucotomy performed upon over 100 selected chronic patients with a hopeless or very poor prognosis. Approximately two-thirds of the cases were benefited to a greater or lesser extent by the operation. The most favourable outcome is with severe obsessional neurosis, chronic melancholia, and paraphrenia and chronic paranoid states. Parker (68) reports on 100 female patients treated by prefrontal leucotomy. Of these almost one-half were manic depressive (the majority melancholic), and though no exact criterion of clinical recovery is given, it is stated that with all except three cases of manic-depression, prefrontal leucotomy " apparently removed or relieved symptoms of depression, agitation and restlessness almost without exception." Thirty-three of the patients were schizophrenic, and the majority showed no change. Of 19 paranoid illnesses 2 "recovered" and, in general, the patients became less suspicious and more pleasant, though delusional ideas persisted. Parker doubts whether, in schizophrenia, paranoid states and paraphrenia prefrontal leucotomy is more effective than other methods of treatment. Twenty-nine discharged patients were followed up by letters written to relatives, to determine whether these patients could take their place in society. Ten of these patients show a " poor " social adjustment ; the remaining 19 appear to have adjusted on a medium low level. There are no skilled workers among this group, although the relatives and/or the patient are apparently satisfied as regards employment and present personality. In this study, out of 100 patients, 29 per cent. were discharged and, of these, 19 per cent. are apparently a " success."

Frank (17, 18) reviews the results of 200 cases of leucotomy performed on chronic mental hospital patients : average length of hospitalization over 4 years, and over two-thirds working class. The prognostic criteria are taken to be sudden onset ; plasticity of symptom production ; degree of cyclic tendency underlying partial preservation of personality. " Paramount is a conflict situation with emotional colouring." The criteria of clinical recovery are carefully defined. Of the three main diagnostic groups the best results were achieved in the affective group : in this group of 52 patients, about two-thirds involutional depression, there was a social recovery rate of 69 per cent. The paraphrenic group, consisting of 41 cases diagnosed paraphrenia or paranoia, were " helped magnificently," 61 per cent. of this group achieving a social recovery. Results are quoted as " disappointing " for the schizophrenic group, though "startling individual recoveries" were made, especially in cases

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of paranoid schizophrenia. The schizophrenic group consisted of 92 patients diagnosed catatonic, hebephrenic, schizophrenia simplex or paranoid. Twenty-one per cent. of this group achieved a social recovery. Frank considers that the direct effects of the operation on the psychic life are those on the personality. Although the fundamental personality patterns are unchanged there is an emotional desensitization. A poverty or lack of dreams is recorded, and a thinning or disappearance of dereistic experiences: the leucotomized patient cannot day-dream about wishes or be abstractly angry in a sustained fashion. He becomes more plain and matter of fact. Passions and conflicts expressed in the psychosis shift gradually out of focus. He wants to remain in a more or less stereotyped routine of activities.

Frankl and Mayer-Gross (19) followed up 68 patients who had been discharged to their homes. The patients were followed up by a letter of general inquiry. In assessing the replies each statement was tabulated, so that the frequency of each item and a brief picture of each patient was given. Nearly all the subjects (63) replied. The results are considered under various headings: (1) Work and occupation: The professions and housewives showed the best results. More than half the patients could earn their living; more than three-quarters were usefully employed. Over half had the same occupation as before operation; the other half had gone down the occupational scale. There was a greater tendency for occupational deterioration in the schizophrenic group. The frequent change of jobs noted is an interesting feature, possibly due to a general restlessness apparent in other fields of behaviour. (2) Interests and hobbies: Here there are signs of the same restlessness. Most of the group preferred sports or light entertainment, although many had had former serious interests in art, literature, religion or politics. (3) Social life: In contrast to the pre-operative reserve and withdrawal, the patient post-operatively took a definite part in the social life of the community, though there is little individual personal friendship. (4) Family life: The shortcomings of the post-leucotomy personality are more obvious to the family—the shallowness of feeling, self will, temper, etc. Wives and children often feel the emotional estrangement. (5) Sex and married life: There was little indication of irresponsible behaviour; no serious conflict with law and order. (6) Physical characteristics: Changes are often reported—increased weight; greater care of dress; good appetite, sound sleep, etc. (7) Mood: Most striking to the eye, and reported in all 63 letters, is increased self-esteem and lack of self-criticism. From these data the authors sketch the character of a patient after leucotomy. He is physically healthy and cheerful in mood; has a high opinion of self, and may take responsibilities too easily or shirk them. He leads an active life, is restless; has a hobby preference for light entertainment, etc. He is easy going and is a good mixer, though his relations with people round him are often without depth of feeling; he has little sympathy. He is self-willed, and has outbursts of temper. He may attend to work as before or do less well, but thinks he does well: he is not a perfectionist. The picture is modifiable in any particular case by special features traceable to the personality before operation. A weakness in this valuable investigation is that the basic data were gathered by letter, and that no check could be kept upon the reliability of the informants. It is possible

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however, that information is spontaneously recorded in a letter which would be suppressed or overlooked in a more structured interview situation. Standardized questionnaires administered by the experimenter in person may be of use when the field has been studied more thoroughly and when more is known of the questions it is important to ask.

Partridge (69) reports on a personal follow-up of 43 cases of patients suffering from affective disorders who were discharged following leucotomy and who were at home. The great majority had resumed former functions, and had proved to be as effective in work as before their illness. Every subject is reported to have shown features of frontal lobe deficit at some time, the commonest symptoms being a lowering of affect and activity facilitated by a lack of restraint.

Garmany (31) reports on 59 cases in whom the operation had been performed not less than three years previously. Each case was examined by the author and, where discharged, a social worker interviewed the family at home. In these latter cases the inquiry was directed to what leucotomy had done to the patient as a social unit, what other people thought of him. Every source of information was tapped. Occasionally an employer was interviewed. A written directive was issued to the social workers indicating the scope of the investigation. The possibility of personality changes was considered in 11 cases of depression which had made successful recoveries. In 9 cases there was no sign of personality change: no inertia, "reasonable and appropriate self consciousness," no lack of social judgment. It was concluded that "reorganization, given adequate time and good surroundings, can progress to the ultimate degree with a restitution that appears to be total." Of 27 schizophrenics (15 hebephrenic, 12 catatonic), only 2 cases were successful. These cases had outstanding home environments. The social efficiency was reasonable in both, the patients being placid, content, and holding down secretarial posts. Of 10 paranoid schizophrenics 5 made a successful recovery. In this series bad prognosis was associated with a high incidence of passivity, early confusional pictures and psychoneurotic onset. It is pointed out that these features correspond with the types of schizophrenia having a bad prognosis apart from leucotomy. Garmany concludes tentatively that in cases of hebephrenia and catatonia it is doubtful whether the operation is worth doing except in special circumstances. The design of this research has much to recommend it, especially in the employment of clearly briefed personnel to help collect the data. The clinical descriptive work, however, is not presented in enough detail for the reader to be able to check the author's conclusions, especially those regarding the outstanding post-operative normality of the affective group.

Ström-Olsen and Tow (90) report upon the late social results of prefrontal leucotomy. The first group (Group C) consisted of 100 chronic, severely disordered psychotics, of whom one half were schizophrenic, the other half diagnosed as paraphrenia, epilepsy, chronic mania, depression. The second group (Group A) consisted of 25 patients admitted specifically for the operation and suffering from neurotic depression, obsessive-compulsive neurosis and chronic, tense hypochondria. Of the C group over 50 per cent were considered purely psychiatric improvements. Using the same standards of grading, all

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members of the A group suffered some personality defect. Weighing up the results the authors note that there is considerable nett loss due to the operation. Considering work, pleasure and social status together with the presence of severe anti-social features, psychiatric recovery is often gained at the expense of great reduction in the efficiency, enjoyment and acceptability of the person. Further, the more endowed with higher qualities, the worse is the relative outcome in the end for that particular patient. The only unequivocal indications, it is suggested, are chronic psychosis with severe disorders of behaviour; and chronic intractable obsessional and depressive states with prolonged and total incapacity. It is not certain in other cases with so-called "specific indications" that there is a nett gain.

(b) *Specialized Clinical Studies.*

A number of researches have been reported in which leucotomy has been performed with a special experimental aim in mind or upon groups or individuals who are in some way unusual. In many cases these studies have not been repeated, and so their importance tends to be limited. Banay and Davidoff (3) report the leucotomizing of a sexual psychopathic personality with a history of masochistic practices. He was operated upon chiefly because of his agitated state and the obsessional-compulsive nature of his ideas. After leucotomy the agitation and sexual phantasies disappeared; there were no temperamental changes, and the patient seemed to possess insight not apparent pre-operatively. Cohen, Novick and Ettleson (7) considered the effectiveness of leucotomy in the treatment of chronic psychotic overactivity. The experimental group consisted of six schizophrenics who had been ill from 8–28 years, and whose psychosis was characterized by persistent aggressiveness, destructiveness and excitement. One year post-operatively there was some degree of improvement in five of the patients, that is, a reduction in overactivity so that a more satisfactory ward adjustment was possible. Govindaswamy and Rao (32) report on prefrontal leucotomy performed on 25 Indian patients, mostly chronic schizophrenics. In just under half the group there was no clinical improvement after the operation; 6 patients improved within the hospital environment, and 7 (28 per cent.) recovered, that is, they could adjust in home surroundings and carry out work "as efficiently as could be expected." Reitman (77) made the first experimental study of the autonomic responses of leucotomized subjects. His experimental group consisted of 15 chronic schizophrenics of the excited and catatonic type; his controls of 5 chronic schizophrenics and 5 other psychotics. He reports that leucotomized subjects show an increased resistance to drugs which upset autonomic equilibrium. Thorpe (92) reports the results of performing leucotomy on two cases of adult post-encephalitic Parkinsonism, in which severe behaviour disturbances present from childhood were removed by leucotomy, "leaving immature but socially acceptable personalities." Two years had elapsed since operation, and both patients appeared to have made satisfactory institutional adjustments. Mackay (56) presents the results of leucotomizing criminal mental defectives who manifested impulsive, violent, self-destructive behaviour. The best

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results were in cases uncomplicated by physical disorders, e.g. epilepsy or a post-encephalitic state. Six out of 9 of this group were considered recovered or much improved. Eleven of the 200 cases reported by Frank (17) were categorized aggressive oligophrenic psychopathy—defectives with violent episodes. Seven of the cases were considered improved after leucotomy. Shorvon (86) reports the results of leucotomy on 5 patients in whom depersonalization was fundamental, the predominant and presenting symptom, existing almost alone as a clinical entity. Of the 5 patients, 4 lost their symptoms of depersonalization and the fifth has improved. Jones and McCowan (43) report the results of leucotomizing twelve subjects whose psychosis showed well-defined periodicity. The patients were part of the group of 250 subjects leucotomized at the Crichton Royal, Dumfries, since 1943 (6, 19), and consisted of 9 periodic catatonics and 3 manic-depressives, with an average psychotic history of 14 years. The patients were followed up for 3½ years. Five were considered recovered, and in five there was a marked improvement. The results are considered "strikingly better" than the remainder of the 250 subjects. It is suggested that periodic psychoses are "eminently suitable for treatment by lobotomy." Whether or not these statements are later confirmed by others, this paper must be criticized for its emphatic generalization from the results of so small a group.

Prefrontal leucotomy has been used to relieve the pain of organic disease (27). It is suggested that the operation alters the individual reaction to pain, without materially changing the patient's ability to feel pain. Freeman and Watts (29) described the use of prefrontal leucotomy in the modification of childhood schizophrenia. Of eleven individuals whose schizophrenia developed before the age of ten years but who were not all operated upon in childhood, only one is "able to assume responsibilities commensurate with his age, or intellectual attainments." Despite these results, and in view of the poor prognosis without operation, Freeman and Watts feel encouraged to continue with certain patients of this type.

(c) *Pathological Studies.*

A major contribution to the literature of prefrontal leucotomy consists in the pathological studies of Meyer and Beck (61), Meyer, McLardy and Beck (63), Meyer and McLardy (62) and McLardy and Meyer (58). In an early paper (61) the available material consisted of 7 histologically investigated cases of prefrontal leucotomy and 1 case of frontal lobectomy in a mentally normal patient. Certain interesting points emerged. Two cases showing a "notable degree of recovery" were patients with little or only moderate deterioration. During the decisive period following the operation there were no clinical complications to interfere with recovery. The operation itself produced circumscribed lesions uncomplicated by severe haemorrhage and softening of any appreciable extent. Of three unrecovered cases, one was "severely deteriorated"; in one the cut was too posterior, and extensive haemorrhage had destroyed a considerable part of the white matter. In the recovered cases it was "surprising how little damage was sufficient to produce

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remarkable clinical improvement." The cut may be incomplete in severing the thalamo-frontal tract. "It follows that in suitable (non-deteriorated) cases a good recovery may follow rather surprisingly incomplete and circumscribed cuts in the white matter of the prefrontal lobe. In a similar type of case recovery may be prevented by an excessive lesion either by cutting in too posterior a plane or by causing extensive haemorrhage."

Meyer, McLardy and Beck (63) reported on 28 patients, average duration of illness eight years, who had lived over seven weeks post-operatively. The first sub-group consisted of nine patients who "showed substantial improvement" and survived over six months. They consist in the main of cases of manic-depressive or other affective disorder. The second sub-group consisted of nine patients who were unimproved but who lived over six months post-operatively; the third sub-group of ten patients who were unimproved and lived under six months. Most of this last sub-group died from the delayed effect of the operation. A number were "improved," i.e. lost certain psychotic manifestations, but this was offset by highly undesirable symptoms such as an extremely severe frontal lobe syndrome (manifesting itself in fatuous euphoria, inertia or restlessness); hyperkinetic movements; trophic disturbances, resulting in skin eruptions; persisting incontinence; disturbance of speech. The involvement of the white matter is far more complete than in the other two groups, and it is not confined to the prefrontal region. There is a striking incidence of striatal involvement. Damage to area 6 is not conspicuous, but there is always the possibility that cuts extending into the striatum may sever fibres connecting with this area. It is possible that the involvement of these regions accounts for at least some of the motor and autonomic post-operative sequelae.

These findings were followed up (62) in a clinico-pathological study of posterior cuts in prefrontal leucotomy based on 40 cases. The usual leucotomy cut remains entirely within the prefrontal region, but the cuts are sometimes more posterior. Personality change, graded according to severity, tends to be most severe when posterior lesions are most widespread. It is, however, not dependent upon (though amplified by) damage to the posterior regions of the frontal lobes. Personality change also occurs after lesions confined to prefrontal regions proper. "That personality change becomes more severe in posterior cuts may simply signify that the prefrontal connections have been more completely cut off."

In a later paper (58) an attempt was made to answer specific questions, i.e. (1) Is any attribute common to the lesions a pre-requisite to clinical improvement? (2) Does the degree of improvement vary with any qualitative or quantitative feature of the lesions? (3) Does any relationship revealed between the lesions and improvement hold good in equal degree for each of the main types of functional psychosis? Three rough clinical groups were defined: The first group consisted of predominantly affective conditions: 15 patients of whom 11 were improved, 4 unimproved. The second group consisted of mixed, mainly paranoid psychoses: 12 patients, 6 improved, 6 unimproved. The third group consisted of 13 schizophrenics: 5 improved, 8 unimproved. In a gross comparison between the improved versus the unimproved cases no evidence

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was found of any segment of white matter the bilateral involvement of which is indispensable to improvement. The central segment comes nearest to being such a region. There was, however, a greater average total number of segments involved in the improved cases than in the unimproved. Further, the severity of the post-operative personality change varies directly with the total number of segments involved. In this series of cases, therefore, post-operative personality change would appear to have the same anatomical correlates as has the clinical improvement. Comparing the diagnostic groups, in the affective and paranoid groups the more improved cases have on the average more posteriorly placed cuts. The improved cases of the schizophrenic group in general have a more extensive isolation of the prefrontal cortex when the plane of the cuts and their extent are considered together. These findings point to one general principle, namely, clinical improvement varies, among cases of equally moderate prognostic potential, directly with the total amount of prefrontal cortex isolated from its white matter. At the same time fibres which run in the central segment seem to be those whose cutting matters most. This would still be in conformity with a quantitative principle, since thalamic fibres to and from all other segments tend to collect in this central region. Its full involvement in a posterior plane will sever most of the fibres coursing between the thalamus and prefrontal cortex. In progressively more anterior cuts the fibres travelling in it will become progressively more only those connecting with regions near to the frontal pole (areas 10 and 46 and the anterior parts of areas 9, 11, 12, 47 and 32). In cuts in the middle plane (the commonest plane of cut in the best improved cases) such rostrally connected fibres will already constitute a high proportion of the fibres in the central segment. It may be that with cases of better prognostic potentiality more circumscribed and more rostral lesions may well constitute the optimum amount of damage.

(d) *Studies Using Modified Operative Techniques.*

In an attempt to effect the desired psychiatric and social changes while avoiding the undesirable sequelae of prefrontal leucotomy as practised by Freeman and Watts (23) or minor variations of this technique (57, 96 and others), modified operative techniques have been devised. Attempts have been made to limit the transection of the prefrontal lobe to the orbital areas alone. Dax and Radley-Smith (10, 11) and Reitman (78, 80) have reported over 200 cases, in some of whom the low vertical or "orbital" cut was attempted; on others a full leucotomy was performed. In an early paper (10) 50 cases were reported a "short time" after operation. These were the most disturbed patients in the hospital. Sixty per cent. were paranoid reaction types, mostly paranoid schizophrenics. Of the remainder, half were deteriorated schizophrenics, half were manic-depressive, either chronic mania or agitated depression. The "active" symptoms improved: the patients became less violent, hostile, noisy, etc; the "passive" characteristics, worry, depression, preoccupation, delusions, etc., failed to benefit. In approximately one-third of the cases there was "considerable improvement," one-third were "moderately better," and in the remainder there was little change. Dax and Radley-Smith

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(11) report the effect of varying the position of the brain sections, methodically working down to the orbital cortex. A group of 125 cases classified as gross conduct disorders, the majority long-standing psychotics, showed 9 per cent. "good" results, 42 per cent. "fair," 46 per cent. "poor." A group of 54 non-chronic patients showed a 37 per cent. good, 37 per cent. fair, and 22 per cent. poor post-operative clinical status. An analysis of the cases is presented according to the type of incision, and suggestions are given as to the type of syndrome affected by different incisions. In view of the pathological evidence of the unintentional variability of the cuts in consequence of a "blind" leucotomy operation (62), it would seem necessary to interpret the suggestions from this analysis with caution until the claim to be able to place incisions with accuracy, a claim fundamental to, and implicit in, the suggestions, has been substantiated from the post-mortem examination of a sufficient number of brains.

A follow-up study of 60 patients is reported by Reitman (80). The patients had been out of hospital between six months and 4½ years and represent a discharge rate of 24 per cent. Assessment of the results was by (1) questionnaire; (2) letters from the patient and from relatives; (3) visit of a social worker; (4) psychiatric interview. Patients were grouped into "better than fair recovery" and "fair recovery," and statistical analyses were undertaken to determine the relationship between this dichotomy and other dichotomized variables. Sex, civil status and duration of illness were insignificantly related to post-operative status; the relationship between age and post-operative status was significant at the 5 per cent. level, patients under 45 years tending to be in the "better than fair" group. Single persons tended to fall in the "better than fair" group more often than those who were married, but it is suggested that the relationship is probably accounted for in terms of the age factor. When the group was divided into two sub-groups, the first sub-group characterized by the low vertical or "orbital" cut, the second group by cuts "other than orbital," the discharge rate for the whole group of 250 was significantly higher (at the 1 per cent. level) for the low vertical cut. Within the discharged group 64 per cent. had the orbital cut. Reitman notes that the significance of the superiority of the orbital cut is independent of duration of illness or of age.

Hofstatter, Smolik and Busch (37) report results obtained using an "orbital" cut. The patients were psychotics, average length of illness 10 years, many of whom showed social maladjustment and anti-social behaviour on a noisy, combative and destructive level. The post-operative recovery rate of 40 per cent. the authors state is at least equal to the results obtained with the full leucotomy. Of the best results they state: "the patients . . . show resourcefulness, common sense, interest and planning for the future. . . . Their pathological personality trends are now only faintly recognizable . . ." Egan (12) reports the use of an orbital technique on a group of 52 chronic patients, mostly schizophrenics, average duration of illness 10 years. Of those patients living outside hospital, 26 of whom have lived outside for over two years post-operatively, 11 are gainfully employed; 6 are fully occupied in their own homes; 4 take full housekeeping responsibilities; 8 are

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idle. The discharged subjects were followed up by letter. They are reported as cheerful, optimistic, pleased with their condition. Relatives comment upon their happy, carefree disposition. Restlessness and hyperactivity are shown in frequent changes of employment and diversity of interests. The patients are sometimes described as difficult to live with. The group of 100 patients described by Berliner *et al.* (6) was used for comparison of the results by the present technique and that using the standard procedure. The crude rate of recovery is lower than that of Berliner (45 per cent.), but the difference is not statistically significant. The recovery rate is, however, significantly lower in the paranoid group—respectively 22 per cent. and 50 per cent. Egan concludes that in certain cases the isolation of a larger area of frontal cortex than the orbital regions is needed for the satisfactory relief of psychosis. The clinical results are less favourable than with the coronal section, especially in the paranoid and obsessional groups.

A further modification of the leucotomy technique consists in the trans-orbital leucotomy (20), in which an attempt is made to sever the thalamo-frontal radiation fairly far anteriorly without disturbing the cortex except to a minimal degree. Freeman performed the operation on 10 patients with "encouraging results": after two years six were fully restored. The series was extended to 100 cases. Describing the results, it is said that general and undesirable changes in personality are usually minimal. Occasionally there is some indolence and tactlessness. The only thing lacking is said to be a certain subtlety and insight into the subject's own mental mechanisms. Personality tests have revealed "richness and depth" in post-operative personalities. Details of the tests are not given. Response to the operation depends on the previous personality, and upon the type and the severity of the illness. The worst patients show little change. Anxiety and emotional tension are often overcome; depressive ideas, phobias and obsessive thoughts usually improve; fixed delusions and hallucinations are rather resistant; motor compulsions and tics may continue unchanged. Emotional dilapidation is the chief contraindication. Fleming and Phillips (16) report the use of transorbital leucotomy upon 8 cases, 5 of depression, 2 paranoid, 1 catatonic, whose average duration of illness, was three years. Two of the patients recovered completely, 5 were improved. These results appear promising, but little comment can be made until further studies are reported in which the clinical description and post-operative follow-up is on a level comparable with that reported in the most careful of the studies previously reported.

A modification of major importance in leucotomy technique is the "open" method described by Worchel and Lyerly (97) and modified by Poppen (73). Worchel and Lyerly state that the open procedure is "more complete and probably more effective" than that of Freeman and Watts. It would seem, however, that on a basis of 13 cases of agitated depression or involutional melancholia described in their paper, this statement may be premature. The open method is, however, anatomically preferable to blind methods (4); as there is direct visual control, there can be more certainty of the fibres cut. Moore, Friedman, Simon and Farmer (66) report on the use of the Lyerly or open technique for nearly all the 200 subjects in the co-operative clinical study

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by the Connecticut Lobotomy Committee. The sections were done conservatively rather than radically. Definitions of diagnoses, personality description, symptoms, and criteria for evaluating results were agreed upon by all members of the team. A common protocol was used for recording the data in a standard manner consistent with the definitions. Clinical descriptions of each subject and follow-up notes were made 1, 3, 6 months and 1 year post-operatively. The great majority of the subjects (163) were schizophrenic. Ninety per cent. had been hospitalized for one year or more, the mean length of hospitalization being five years. The pre-operative intelligence distribution of the group showed a slight concentration at the extremes of the curve. After three months 36 per cent. of the whole group were slightly improved, unimproved or worse ; 36 per cent. were moderately improved ; 24 per cent. were markedly improved or symptom-free. At the end of the year the picture changed in the direction of continued improvement. The authors state that the paranoid group of illnesses has the best prognosis, catatonia next, hebephrenia the poorest. The non-schizophrenic group tend to do better than the schizophrenic group but, after three months, the difference in the recovery rates is insignificant. Sex and intelligence may be ignored as prognostic criteria. The more troublesome symptoms, e.g. anxiety, depression, hypochondriasis, impulsiveness, destructiveness, were eliminated in 75 per cent. of the cases. The authors consider frontal leucotomy to be " a highly effective procedure for the treatment of intransigent mental disorders."

The research provides no evidence, however, that the Lyerly technique gives clinical results superior to those of the blind leucotomy. It remains for future research to determine whether the results in individual cases, especially, perhaps, those cases which make a " social recovery " after the operation, are better than those of other techniques. Poppen (73) reports on 470 cases operated upon by the modified Lyerly technique. Good results were achieved with 20 per cent. of the schizophrenic group, who were able to return to work and to make a living. A fair degree of improvement was achieved in 37 per cent. of this group, there being symptomatic improvement, making the patients easier to manage. In 40 per cent. of the group the condition was unchanged. A group of involutional melancholics showed good results in 55 per cent., fair results in 33 per cent. " Gratifying " results are said to have been obtained on a group of agitated depressives. No details are given. The author comments that neither duration of illness nor age are important factors compared with existing degree of tension, anxiety, fear and self-concern.

(e) *Summary.*

The main points which emerge from a review of the *clinical studies* of prefrontal leucotomy are: (1) Approximately 25 per cent. of *schizophrenics* can be expected to make a " social recovery " after leucotomy. This figure is based mainly upon researches which include large groups of schizophrenics (17, 18, 66, 73). It is supported by the studies of McGregor and Crumbie (54, 55), Govindaswamy and Rao (32), Egan (12). The validity of this figure is subject to the limitations of all such statistics derived by combining the results of several leucotomy researches : the proportions in each schizophrenic

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clinical sub-type are not the same in each research ; several different operative techniques are included ; the judgment of post-operative clinical status varies from one research to another. The effect of varying one of these factors can be seen from an example : Freeman and Watts (28) include paranoid illnesses in their schizophrenic group. They report that 46 per cent. make a " good " recovery, which is considerably higher than most other authorities.

(2) Probably the best results are obtained in the *affective disorders*—involutional melancholia, agitated depression. From studies in which large numbers of subjects were examined, " social recovery " or " good recovery " is reported in from one-half to two-thirds of the cases (28, 17, 18, 73). These figures have been confirmed in several smaller studies (87, 54, 55, 91).

(3) *Paranoid illnesses* are usually considered to respond better to leucotomy than other schizophrenic illnesses, but not as well as the affective disorders (17, 18, 89, 6, 67, 10, 66).

(4) *Obsessional disorder* is said to respond well to leucotomy. Freeman and Watts (28) report that 61 per cent. of their 51 cases made a " good " recovery. Other authorities agree that results from obsessionals are very favourable, but in most cases the numbers in the groups upon which these opinions are based are small (76, 6, 67, 89). The evidence must be regarded as inconclusive, and the response of this disorder to leucotomy decided when larger numbers have been operated upon.

(5) Other contexts in which the psychiatric results of leucotomy have been reported as favourable are : in controlling the violence and impulsiveness of selected *mental defectives* (17, 56) ; in reducing chronic psychotic *overactivity* (7) ; in abolishing the *periodicity* in certain psychoses, especially catatonia (43) ; in removing the symptoms of *depersonalization* (86).

(6) Many workers have stressed that psychiatric diagnosis, as such, is of less importance in selecting cases which will respond well to leucotomy than certain specific indicators in the symptomatology of which *emotional response* (presence of apprehension, tension, anxiety, depression, agitation, hypochondriacal ideas, etc.) is considered by many to be the most important criterion of selection (76, 25, 20, 70, 42, 39, 6, 46, 67, 17, 18, 8, 66, 45, 73, 33, 83).

(7) Follow-up studies of patients treated by leucotomy almost invariably report that certain *personality changes* have followed the operation. Robinson, Freeman and Watts (82), from a study of minimal, standard and radical lobotomies and transorbital leucotomy, state that all patients show some lack of personality depth after leucotomy. In varying degrees they are cheerful and complacent, and sometimes indifferent to the opinions and feelings of others. Hutton (40) considers the chief features of the group followed up by her to be a diminution in self-consciousness showing itself in less shyness and reserve, more indifference to adverse criticism, etc., and, accompanying this, decreased awareness of the feelings of others, which shows itself in tactlessness and shallowness in emotional life. There is no tendency to make new friends, and sometimes an absence of old affection. Frankl and Mayer-Gross (19) report an increase in self-esteem and lack of self-criticism to be the most consistent finding from all their cases. Egan (12) reports patients post-operatively to be cheerful and optimistic, restless, and sometimes difficult to live with.

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II. Studies using Psychological Test Techniques.

(a) *Cognitive Tests.*

It has been claimed by some investigators that there are no changes in formal tests of intelligence following prefrontal leucotomy. In several such investigations it is impossible to check the validity of the claim, either because the intelligence tests used are not specified or numerical results are not given (64, 87, 55, 14, 39, 17, 86, 30).

Thorpe (92) reports a rise of a few points of score on Raven's Progressive Matrices Test administered to a single patient before and after leucotomy. Other tests were administered, sometimes to several patients but only post-operatively ; therefore no conclusions can be drawn as to the effect of prefrontal leucotomy upon intelligence. Worchel and Lyerly (97) administered the Stanford-Binet to five psychotics, cases of affective disorder, before and after leucotomy. Numerical results are not given in the paper, but it is said that there were almost identical pre- and post-operative responses to each individual test item. The slight changes were not significant or consistent. Hunt (38) included Kohs Blocks in her battery of intelligence and personality tests given to 40 subjects, varied in age, sex and psychiatric diagnosis, before and two weeks after leucotomy. This test showed no change post-operatively. Ström-Olsen *et al.* (89) administered a variety of formal intelligence tests to 11 chronic patients before and six weeks and four months after leucotomy. As the authors present no statistical evaluation, the results at the first retest from the more important of these tests were analysed for significance by the writer (Table I). Changes on all tests were quite insignificant. The study included

Table I.—*Changes in Scores on Eight Cognitive Tests after Leucotomy.*

(Data from Ström-Olsen *et al.*, 89). N = 11.

	Pre-leucotomy mean.	Post-leucotomy mean.	*t* ratio.	Level of probability.
Terman Vocabulary (mental age)	15·182	15·091	0·363	0·700
Stanford-Binet Form L (I.Q.)	94·273	92·091	0·529	0·628
Raven's Progressive Matrices (I.Q.)	87·273	90·000	−0·846	0·442
Porteus Mazes (mental Age)	12·000	12·136	−0·160	0·845
Kohs Blocks (mental age—months)	151·818	159·636	−1·275	0·223
Alexander's Passalong Test (mental age—months)	143·091	159·364	−1·476	0·165
Shipley Vocabulary (mental age—months)	182·182	170·273	1·584	0·141
Shipley Abstractions (mental age—months)	146·909	152·182	−1·283	0·223

verbal tests (Stanford-Binet, Terman Vocabulary, Shipley Vocabulary, Shipley Abstraction), performance tests (Kohs Blocks, Alexander's Passalong Test, Porteus Mazes), and a non-verbal intelligence test of the perceptual type (Matrices). This study provides perhaps the main experimental support to

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the view that there are no significant changes in formal tests of intelligence following leucotomy. Jones (44) included the Porteus Mazes, the Goodenough Drawing-a-Man Test and digit span in his test battery administered to 24 chronic schizophrenic patients before and after leucotomy. Scores on the Porteus Mazes increased insignificantly; scores on the Goodenough Test and the digit span increased significantly post-operatively. In addition the Wechsler scale was administered to two subjects. There were losses of seven and four I.Q. points three weeks after operation, both losses occurring because of verbal rather than performance sub-test decrements. However, after three months both subjects had regained their small losses and scored a few points above their pre-operative I.Q.

Contrary to these results several investigators support the view that scores on certain formal tests of intelligence decrease after leucotomy. Porteus and Kepner (74) gave to 17 psychotic patients, heterogeneous as regards I.Q. and degree and type of psychosis, the Porteus Maze Test, and to 18 subjects a modified Stanford-Binet Test. This test was a composite of forms L and M in which lesser emphasis is placed on verbal sub-tests. Scores on the Binet test decreased after leucotomy, but the decrease was insignificant. The actual statistics computed from Porteus' data are given in Table II. Changes in

TABLE II.—*Changes in Binet I.Q. after Leucotomy.*

(Data from Porteus and Kepner, 74.) N = 18.

Pre-operative mean I.Q.	= 83·889
Post-operative mean I.Q.	= 80·667
t ratio	= 1·386
Level of probability	= 0·179

scores of the experimental group on the Porteus Mazes after leucotomy were compared with those of a control group of 17 cases all over fourteen years of age, drawn at random from the clinic files, who had had repeated applications of the maze. Of the clinic cases 71 per cent. improved on the second testing, the average gain being 1·94 years. Of the leucotomy cases 6 per cent. improved on the second application, the average loss of the group being 1·97 years. The assessment of the significance of these changes by orthodox statistical techniques is not reported by Porteus. In a later research, however, Porteus and Peters (75) report the results of testing 55 patients on the maze test before and after leucotomy. From the case-histories of these patients it appears that they are a sample drawn from a psychotic population very similar to that of the earlier research. Combining the two groups to form one group of 72 subjects, the significance of the difference in scores before and after leucotomy was computed, for this group, by the present writer. The results are given in Table III (A). The drop in scores after leucotomy is statistically highly sig-

TABLE III (A).—*Changes in Mental Age on the Porteus Maze Test after Leucotomy.*

(Data from Porteus and Kepner, 74; Porteus and Peters, 75.) N = 72.

Pre-operative mean M.A.	= 11·312 years.
Post-operative mean M.A.	= 9·583 years.
t ratio	= 6·500
Level of probability	= <0·01

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nificant. A group of 55 criminals (resembling in age, social status, intelligence and racial composition the experimental group in the investigation by Porteus and Peters) was tested and re-tested on the maze test, though at a much longer interval. Sixty-nine per cent of this group showed gains on retest compared with 27 per cent. of the experimental group. The authors note that practice effects which are not apparent with the patients a short time after leucotomy appear with criminals even after years. It seemed possible, however, that the results reported by Porteus and his collaborators had been exaggerated by the fact that in both investigations many of the subjects had been tested very soon after leucotomy. To check this, the present writer abstracted from the 72 patients tested on the mazes by these authors 23 patients on whom the first retest after leucotomy was three months or more after the operation. These figures were tested for statistical significance. The results are given in Table III (B). It will be seen that the differences in test scores following leucotomy are still highly significant.

TABLE III (B).—*Changes in Mental Age on the Porteus Maze Test after Leucotomy. First Re-test Three Months or more Post-operatively.*

(Data from Porteus and Kepner, 74; Porteus and Peters, 75.) N = 23.

Pre-operative mean M.A.	= 10·413 years.
Post-operative mean M.A.	= 9·000 ,,
t ratio	= 3·233
Level of probability	= <0·01

Robinson (81) administered the Porteus Mazes to 7 leucotomized subjects and to 7 controls matched on diagnosis and vocabulary. She found that the leucotomized subjects scored reliably lower than the controls. Koskoff *et al.* (53) studied 7 subjects psychometrically before and after prefrontal leucotomy. The study is especially interesting, as the group was operated upon for the alleviation of pain. Pre-operatively members of the group suffered from no functional or organic brain disorders. They were retested three months post-operatively. On the Wechsler Test, full scale, 5 cases showed an average decline of 20·4 I.Q. points—from 87·2 to 66·8. This difference is statistically highly significant. Further, whereas the average verbal I.Q. declined 16·1 points, performance I.Q. dropped only 7·9 points.* Interestingly in view of this result, scores of four subjects on the Terman-Merrill Vocabulary showed no consistent change. The scores of 3 patients tested with the Porteus Mazes all declined, the average decline being 4·1 years. Malmo (59) included certain formal intelligence tests in the battery which he administered to small groups of patients before and after frontal gyrectomy and frontal lobotomy. A group of 6 patients, including one gyrectomy, were given the Wechsler. All the I.Q.'s were lower after operation, the average drop being 8·33 I.Q. points, from 107·8–99·5, which is significant at the 5 per cent. level. Stanford-Binet Vocabulary scores showed consistent losses on the lobotomized group. The mean pre- and post-operative difference for a group of 6 lobotomy

* Koskoff notes that the post-operative average verbal intelligence was based on five cases, the average performance intelligence quotient was based on six cases, and that these average quotients were not derived from identical cases. He feels, however, that the direction of the change in intelligence, if not the extent, represents a reliable change.

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cases and 3 gyrectomy cases was reliable at the 2 per cent. level. Similarly on the Capps Homograph test (a form of vocabulary test in which the subject has to give various different meanings for the same word) definite reductions in score are reported following frontal lobe operations. Of 7 lobotomized subjects the scores of 5 decreased on the Porteus Maze Test ; 2 gained slightly in score. These results are considered as not in disagreement with Porteus.

Rylander (84) applied psychological tests before and after leucotomy to small groups consisting of 1, 2 or 4 patients. No exact statement of results is given. Four subjects were tested with the Binet. The differences were not large, but there was reduction of I.Q. in every case. Despite repeated testings, I.Q.'s do not reach the pre-operative level. Various other tests were given, but it is difficult to interpret the results. There are too few cases, and no exact statement, or statistical evaluation, of the results. Yacorzynski *et al.* (98) made a careful psychometric investigation on a single individual, tested before and after leucotomy. Of the intelligence tests given, the I.Q. on the total Wechsler scale decreased from 104 to 87, and the decrease on the verbal scale (111–89) was greater than that on the performance scale (94–86). The Binet test decreased from 118–97. Petrie (71) used the Wechsler Scale and the Porteus Mazes as the main cognitive tests in her investigation of 20 severe neurotics tested before and 2–3 months after leucotomy. The patients are described as depressed, anxious obsessional or paranoid. A mean loss of over 7 I.Q. points on the Wechsler verbal scale was found, this decrease being significant at the 5 per cent level. There was no significant drop on the performance scale. On the Porteus Mazes there is a mean loss of 1·82 years of mental age at the three months' re-test which is significant at the 5 per cent level.

(b) *Special Investigations.*

Several of the tests given by Hunt (38) could be scored for speed and accuracy. These were : the Cube Construction Test ; arithmetic test ; a substitution test (key with 6 symbols, to which have been assigned the first 6 digits. Beneath the key is a list of symbols with blank spaces for inserting numbers) ; spatial test ; colour naming (100 patches of colour. Five sample patches at the top for practice. Subject to name colours represented in the 100 patches). On these tests the speed scores showed reliable changes, but the direction of the speed change is not consistent. The author comments that the changes showing a decrease in speed are more reliable. Seven patients were tested several months post-operatively, however, when the loss in speed was largely regained. The Kent-Rosanoff Word Association Test was given two weeks post-operatively. Subjects took a longer total time to do the test, but there were fewer extremely delayed responses ; fewer failures to respond ; fewer peculiar responses ; fewer responses of a self-reference type ; less perseveration ; and less objection to taking the test. The Bernreuter Personality Inventory was given to 7 patients. The largest changes were decreases in neurotic tendency and introversion. Other statistically reliable changes were on the Match Stick Test (ability to reproduce designs from memory) and the Coin under Cups Test (ability to identify cups under which coins have been placed after a

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short interval). On both these tests there was a better performance post-operatively. On a cancellation test there was a reliable increase in accuracy. On the Rorschach Ink Blots the subjects showed more restricted and constricted records post-operatively. The quantitative changes in the records are generally small. In summary they consist in a further constriction of personality shown in decreased R, Z and M responses ; greater extratensive tendency shown by a change in the M : Sum C ratio ; a slight loss in organizational, synthesizing and related higher intellectual tendencies, shown, for example, by a change in the manner of approach : there is a shift of emphasis on the W post-operatively, which, in subjects of relatively low intelligence, is considered probably indicative of loss of synthesizing ability post-operatively ; there is a larger percentage of "normal" or "popular" type responses post-operatively. Of the qualitative signs, post-operatively there is less response perseveration ; less self-reference ; less concern over performance and less self-criticism ; a shift in attitude toward the experiment from one of predominantly high affect and pained constraint and reluctance to one of apathy ; there are fewer indications of neurotic trends. Six subjects were tested again 3–12 months after operation. These records are considered "better" on the whole than the two-week records. They show a general expansion, greater indication of intellectual adequacy, fewer indications of abnormality. There is an increase in the total number of responses, better distribution of W–D–d–S responses, more movement, a better proportion of good form responses, a more normal number and distribution of colour responses. Qualitative aspects include an absence of perseveration, and an improvement in attitude towards the test and the absence of excessive self-reference.

Kisker (51) made pre- and post-operative Rorschach analyses on a few cases. He notes the lack of quantitative change of scoring signs, and that qualitative changes are not large in most cases. In general he concludes that the neurosurgical transection of the frontal association areas plays a less important role in the reorganization of Rorschach patterns than does the pre-psychotic and pre-operative personality structure. Other psychological test procedures were carried out on 20 subjects (48, 47, 49), though numerical results are not given in these articles. It is concluded, first, that there are no important intellectual defects. Second, defects in abstract and categorical thinking do not make themselves felt in any important way in the total personality picture. This conclusion is based upon experiments of a qualitative type (49). Tests used included Kohs Blocks interpreted qualitatively, the Weigl-Scheerer-Goldstein Colour-form Sorting Test, Halstead's Grouping Behaviour Test and the Rorschach Test. Third, an analysis of linguistic form and meaning relationships was made using the word association technique, a sentence construction test and the analysis of syntactical relationships. No linguistic form of semantic trend was found to be characteristic of the post-leucotomy patients. Fourth, investigations were undertaken in the perceptual-motor field (47) in an attempt to determine both experimentally and on a basis of general observation the degree of disturbance present in the series of 20 leucotomized patients. The Luria tremographic technique was used to study psychomotor pattern. Post-operatively the clinically improved patients showed definite alterations in motor organization in the direction of more stable and symmetrical responses.

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The unimproved patients either showed no changes or changes in the direction of better motor organization resembling those seen in clinically improved patients. Kisker suggests that this latter group had in some manner profited by leucotomy, but conditions were such that overt improvement was not possible. This explanation is unconvincing, but in the absence of data from which the statistical significance of the various changes in test results can be assessed, no criticism is possible. Visual motor patterns were studied using modified Wertheimer patterns of varying complexity. The effect of the operation on the memory trace system of the patients was studied. The reproduction of the designs and the subsequent analysis of the reproduced material, with particular emphasis on gestalt principles, failed to reveal widespread impairment of so-called gestalt function. The motor components of speech and gait remained unchanged as a result of leucotomy. In a few patients apraxic and agnosic phenomena were observed, but these were atypical. These disturbances showed themselves in tests of "constructive praxis," drawings, reproduction of designs, etc. The gnosis study was negative. Leucotomy, it is concluded, has no appreciable effect on elementary motor integrative functions. This is true for all the tests. While the operative group showed pre-operative and post-operative motor irregularities, and the improved patients less pronounced irregularities post-operatively, the pattern of motor integration approximates to that of psychotic patients in general.

Schrader and Robinson (85) attempted to evaluate the post-operative improvement of 16 chronic schizophrenics using the Gardner Behaviour Chart. This chart rates the patient on 15 categories easily observable by nurses and attendants, e.g. appetite, sociability, work capacity, care of property, etc. Degrees of behaviour in each category are defined for the rater and are scored 0–1–2–3–4. One advantage of this procedure is that it permits the rating of untestable subjects. The mean score for the entire Gardner chart and for the whole group increases significantly after leucotomy, i.e. as judged by the Gardner indices leucotomy has produced a reliable improvement in the patient's behaviour. Various types of behaviour did not improve equally. Care of property, work capacity, work initiative improved least; sociability, appearance, various types of self control of behaviour with relevance to the situation improved most. Jones (44) also used a ward behaviour chart to provide evidence of patient improvement. Behaviour chart variables were rated in terms of a four-point continuum, each point representing a behavioural description. Specific variables on which significant improvement is shown vary slightly from one post-operative retest to the next, but the important finding is that total adjustment scores suggest that overall behaviour does not improve after the eighth week. Orientation questions regarding marital status, home town data, pre-hospital occupation, and telling the time from a watch reflected significant improvement post-operatively.

Robinson (81) tested the hypothesis that there is a loss of the capacity for prolonged attention after leucotomy. The cognitive aspect of this capacity she tested by deliberation tests, consisting of making rhymes and doing simple mental arithmetic. The combined test showed that compared with matched control groups the leucotomized subjects suffered a definite intellectual deficit

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in a function which she calls prolonged attention. This finding was confirmed in a later study (82). The motor aspect of prolonged attention she tested using three of the Downey Will-Temperament Tests—speed of decision, volitional perseveration (disguised handwriting), and motor inhibition (slow writing). On the three tests combined the leucotomized subjects did significantly less well than the controls. The author feels that the factor common to deliberation tests and the Downey Tests is one of deliberativeness or capacity for prolonged attention, and that this is diminished by prefrontal leucotomy. It is difficult to judge this experiment in isolation, as the significance of the results depends largely upon the results of research into the psychological nature of deliberativeness, if such a quality exists, and whether, it if exists, it can be validly measured by the tests described.

Halstead *et al.* (35) and Halstead (34) attempted to measure the psychological deficits following circumscribed brain lesions. He develops the concept of "biological intelligence," which he considers a kind of intelligence of fundamental importance, but different from that reflected by standardized psychometric tests. A four-factor description of biological intelligence is given, which is based on a factor analysis of the intercorrelations between 13 neuropsychological indicators administered to 50 healthy adult males regarded as medically recovered from a recent concussive type head injury. These factors are, first, a central integrative field factor which is described as representing the organized experience of the individual. Some of its parameters, it is suggested, may be reflected in measures of psychometric intelligence. Second, abstraction, the basic capacity to group to a criterion, which involves the comprehension of essential similarities and differences. Third, a power factor, a dynamic factor reflecting the over-all status of the brain. Fourth, a directional factor, which is the medium acting as direction or outlet for the exteriorization of biological intelligence. Halstead attempts to localize these basic factors in the cortex. Tests are examined to determine which of these differentiate between groups of neurotic patients without head injury, and head-injured patients without neurosis. The ten best tests are used to form an impairment index. Score on this index differentiates significantly between controls, frontal lobectomy and non-frontal lobectomy groups. The mean impairment index for frontal lobectomies is six times that of normals and three times that of the non-frontal lobectomies. Halstead concludes that the impairment index reflects brain functions, and specifically functions which have their maximum representation in the frontal lobes. Leucotomized patients show no significant change in the impairment index before and after operation. Biological intelligence as reflected by the impairment index is not significantly altered by prefrontal leucotomy. It is suggested, in explanation of this finding, that the biological intelligence of the leucotomy patients was impaired prior to operation, and that leucotomy produced no consistent change.

The main points of criticism of this research are, first, that the central concept, "biological intelligence," is discussed but not defined nor clearly differentiated from other more generally accepted concepts of intelligence. Second, the number in the group (50) is small, and the number of factors extracted (4) is such as to throw doubt on the statistical significance of at

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least two of the factors. Third, the identification of the factors is based in each instance on very few significance loadings. These criticisms are made because the factor analysis is fundamental to the description of biological intelligence. An elaborate theory is built on a basis which appears statistically unsound. It must be agreed with Zangwill (99) that "all that has been established is that cases of unilateral frontal lobectomy show significant impairment on an arbitarily selected battery of psycho-physical and mental tests."

A special investigation of a qualitative type was carried out by Reitman (79), in which he studied the "creative spell" of schizophrenics after leucotomy. He notes that the schizophrenic personality is changed after leucotomy, and suggests that personality changes are reflected in the artistic activity of the patients. He makes an attempt to evaluate the personality changes in connection with the artistic products of two patients. In one patient the operation activated a creative spell of typical schizophrenic art; in the second case, that of a music teacher of high intelligence, her musical compositions appeared to reflect her post-operative mentality. The factor common to the two forms of activity is that the creative spell is activated or modified by the operative brain injury. Typical features are the disorganized form sense, the chaotic appearance, and the rapid development towards organized form tendencies and towards normal symbols and patterns.

Hutton and Bassett (41) have investigated the effect of leucotomy on the creative personality. They define "creative activity" as "that form of activity which results in the actualization or realization of some object or event, which only comes into being because the creator having first conceived it in his imagination deliberately transforms his idea or vision into fact." On the Rorschach Test the results are not presented in detail, but it is stated that the leucotomized group show less originality and creativity than normal people of the same age, social status and educational background. Answers tend to be conventional responses evoked by large, obvious details. Where there was a pre-operative record, many post-operative records are mere repetitions rather more accurately described and with the more bizarre details omitted. Human and human movement responses are introduced post-operatively, but they are relatively infrequent, and the majority of new answers are provoked by colour, or in some cases by texture, and are mainly conventional animals or objects. The introduction of new shading responses is relatively uncommon. These authors also used the multiple choice Rorschach of Harrower-Erickson, upon which they compared a group of leucotomized patients with a group of adolescents. There is no statistical evaluation of the results, but certain conclusions are suggested. The leucotomized group shows a small number of human responses, but the outstanding feature is the high proportion of completely formless answers in uncoloured cards, including those indicative of unpleasant feeling—tone in looking at the card (nightmare, etc.); and in card Nine an evasion of the responses or mere statement of the colours of the blots. Also outstanding was the high proportion of failure indicating inability or refusal to formulate anything. The investigators feel that these findings, coupled with the clinical observations of the lack of initiative in some of the patients and a tendency to live in the

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immediate present and to depend on the immediate environment for stimulation, suggest that there might be a definite diminution of creative activity after leucotomy. As a test of imagination the subjects were asked to write a story introducing certain sentences. Though there is little data as to how normals do the task, it is suggested tentatively that leucotomized patients find this test more difficult than normals. The patient's stories tend to be brief, and are either auto-biographical or an account of something read or heard. A further qualitative test consisted in getting the patients to draw or paint either to order or as they liked. Paintings of the leucotomized group were ranked low for creative ability, though this deduction is very tentative because of an insufficient number of paintings. This investigation was handicapped, because few patients show evidence of a creative urge prior to leucotomy, and therefore it was impossible to tell whether the absence of creative imagination after the operation was the result of the operation. This acknowledgment by the authors seems to underline the main weakness of the investigation, which is their failure, in most cases, to examine patients before and after operation.

In actual fact, in a later study Ashby and Bassett (1) developed a more specialized test to measure creative ability. The test depends, essentially, on the patient's ability to add to a painting imaginative details which were neither present in the example, nor suggested by the examiner. The performance of a group of leucotomized subjects on the test was compared with that of groups of psychotic and normal subjects. The results showed no evidence that creative ability is impaired by prefrontal leucotomy. It is still necessary, however, to support this conclusion by testing the same subjects before and after leucotomy.

Babcock (2) tested one case of anxiety neurosis with the Babcock tests, before and three months after leucotomy. These include verbal tests (vocabulary, opposites, sentence completion, analogies, etc.) and tests of "basic efficiency" (perception, speed, learning, motor control, etc.). The results indicate greater mental impairment in both the understanding and efficiency variables of functioning. The subjects total rating of mental efficiency was over one year lower than pre-operatively, and more than five years below the norms for his verbal level. Koskoff *et al.* (53) administered the Babcock-Levy examination to five cases and report an overall loss in the functions measured by the efficiency battery. This suggests a general post-operative deterioration.

The most striking of Rylander's (84) results was on a word enumeration test (the subject gives as many nouns as possible in three minutes with his eyes closed) given to three subjects. There was a definite and considerable reduction at the first retest 2–4 months post-operatively. Later there were gains, but performance did not reach the pre-operative level. Yacorzynski *et al.* (98) administered a considerable number of special tests to a single subject pre- and post-operatively, tests with ambiguous figures, illusions and reversal of perspective ; level of aspiration ; level of motivation on the Thematic Apperception Test : results on these tests were unchanged post-operatively. The number of responses on the Rorschach decreased post-operatively from 71–14 ; popular responses decreased from 4–2 ; tendencies to confabulation and contamination were exaggerated. The effect of leucotomy appeared, therefore,

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to be a release of the psychosis. Scores on the Minnesota Multiphasic Personality Inventory, however, show a return to normality following leucotomy. There were many high scores pre-operatively, but no wide divergencies in profile post-operatively, and these are well within the limits of the average population. Certain grouping tests were given involving, for example, the separation of blocks into groups on the basis of common categories. Such tests are considered to involve reasoning and concept formation. The Vigotsky Test and Kohs Blocks were also used. There were marked changes on tests of this type. The results indicate that after leucotomy reasoning and concept formation are markedly affected when the subject has to deal with factors removed from his immediate environment, i.e. abstract concepts. He is capable of handling his immediate environment as well as pre-operatively.

Malmo (59) attempted to measure changes in certain special psychological functions after leucotomy and gyrectomy. There were 8 leucotomy cases, though not all were tested with each test, and sometimes one or more gyrectomy cases is included in the group. The ability to learn nonsense syllables in series by the rote method appeared to suffer after operation. The patients took longer to learn following the operation in spite of pre-operative practice. There was no loss on the Wechsler Memory Scale, but there were reductions in score on the Hunt Minnesota Test. Other tests of immediate memory (e.g. digit and sentence span, picture recognition, Halstead memory for objects) yielded negative results. Tests of abstract thinking were administered. There were changes in the direction of greater concreteness of definition post-operatively on Vocabulary Tests. Small groups showed a loss in categorical attitude on the Halstead Sorting Test, and a loss of abstract thinking in Kohs Blocks. Deliberation was tested by the time taken to do the Matrices. This test was done more quickly post-operatively. This result is in line with Robinson's (81) suggestion that deliberation is reduced after leucotomy. Malmo's results on the " slow writing " and " disguised writing " tests, which Robinson used to demonstrate decreases in deliberation, did not confirm her findings. Malmo reports results from only three patients on these tests, however, and so the disagreement cannot be considered crucial. On a pain stress test there was a greater incidence of withdrawals in the frontal lobe group than in a group of unoperated subjects, and, in the frontal lobe group, a greater incidence of withdrawals post-operatively than pre-operatively. Every case tested pre- and post-operatively showed some increase in galvanic skin response upon stimulation. This shows increased responsiveness to external stimulation. On the mirror drawing test, it has been suggested by Wechsler and Hartogs (95) that impairment of manual control is shown by an increase in the distance of the line drawn from one point to another. A poor performance is characteristic of the anxious neurotic. Malmo's experimental group showed a statistically significant reduction in manual disturbance after operation. It is pointed out that this is not the effect of practice, because neurotics who have had no treatment actually perform worse on retest, and, with normals, the practice effect is slight. These results are considered objective evidence of a reduction in anxiety following leucotomy. The experimental results as a whole, including those from the intelligence tests, discussed earlier, is considered

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" strong evidence for the conclusion that frontal lobe operations lead to a definite loss of general intelligence." Furtado *et al.* (30) gave the Rorschach Test pre- and post-operatively to a group of six subjects whose pre-morbid personality was well known. A decrease in the number of W responses is considered as reflecting an alteration in abstract thought. There was a corresponding gain in D and Dds responses. An increased number of weak original responses following a growing number of F-forms it is considered emphasizes the intellectual weakening.

The major part of an investigation by Petrie (71) on a neurotic group consists in an attempt to verify the hypotheses that personality changes following prefrontal leucotomy are in the direction of a decrease in intelligence, a decrease in neuroticism, and a movement away from extreme introversion. These hypotheses are based on the work of Eysenck (13), who, in a factorial analysis of the inter-correlations between 39 trait ratings carried out by psychiatrists on 700 neurotic patients, extracted two main factors. The first factor was a general factor of " neuroticism." The item which was most characteristic of this factor was " badly organized personality." The second factor was bipolar, and opposed the affective or dysthymic group of symptoms (anxiety, depression, obsessional tendencies, etc.) to the hysterical group of symptoms (conversion symptoms, sex anomalies, etc.). Later, on the basis of experimental studies, Eysenck decided that the hysteria-dysthymia factor was identical with Jung's conception of extraversion-introversion. Petrie used tests previously validated by Eysenck in order to investigate the hypothesized decreases in neuroticism and introversion following leucotomy.

The hypotheses are supported by the experimental results. The decrease in intelligence has been described. A decrease in neuroticism is suggested by a significant decrease in body-sway suggestibility. This finding is supported by a significant increase in the smoothness of the curves of activity of two tasks. First, rate of tapping in 4 quarter-minute periods : before operation the mean deviation from the average is significantly greater than after operation. Second, on the track tracer, relapses, i.e. losses in speed in consecutive trials, were greater prior to operation than post-operatively. These results are relevant, because of the finding that the work curve of neurotics is more jagged and uneven than that of normals. Further, on the arithmetic, picture completion and picture arrangement sub-tests of the Wechsler there is a decrease in the number of mistaken answers in relation to the number of correct answers ; on the perseveration test involving alternating work, there are reduced P-scores following leucotomy. These changes all support the hypothesis of decreased neuroticism after leucotomy.

The increase in extraversion is suggested by significant changes on the scores of several tests. There is a loss in persistence. On the Track Tracer the time taken is decreased and the number of mistakes increased : post-operatively the group tends to go for speed rather than accuracy. On the level of aspiration test the discrepancy between goal and performance is less, and the gap between performance and judgment is decreased : after leucotomy aspiration and judgment are more in line with reality.

Certain other changes, not directly relevant to the main hypotheses, are

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reported by Petrie. The patients show a decrease in the number of traits for which they blame themselves, and, further, a decrease in the intensity of self-blame. Their attitude to the present and the future was judged by answers to eight standardized questions: the subjects tended to leave the past behind, to live largely in the present and to look hopefully to the future. Pre-operatively they tended to be orientated towards the past. Petrie points out that, as a result of these changes in the cognitive, conative and affective facets of personality, leucotomy causes some considerable alteration in personal effectiveness.

There are features to this investigation which make it of importance. First, the group consists of patients diagnosed as neurotic rather than psychotic. Thus the quality of the psychiatric material is unusually high for this type of investigation. Second, this is one of the few investigations in which a definite quantitative hypothesis is investigated which can be verified or disproved. Third, the group is moderately large for work of this type. Fourth, one surgeon operated throughout and used a standard operative technique (57).

The picture of the post-leucotomy personality supports the hypotheses more clearly at the nine-month retest (72). Although nearly all the changes in neuroticism, introversion and intelligence had appeared after three months, there are exceptions. Some changes are clearly shown only after nine months; some tendencies are accentuated and some are damped down. Persistence continues to decrease during the year, speed and number of mistakes to increase. Planning as measured by the Porteus Mazes appears to improve after the early loss. There is no significant loss in score on this test after nine months. Increased distractibility manifests itself clearly only after a longer period, and reverses the earlier impression.

An investigation also largely based on the work of Eysenck was conducted by the present author (9). Thirty-six psychotic patients were tested before, and three months after, prefrontal leucotomy on a test battery which included cognitive tests, objective personality tests and the Rorschach Test. The post-operative changes on tests of speed-accuracy, persistence, level of aspiration and on the Rorschach "Experience Type" gave no consistent support to the hypothesis that a psychotic group becomes more extraverted following leucotomy. There was little change after leucotomy in the scores on tests of "neuroticism," although the general direction of the changes on the tests of suggestibility, static ataxia and reversal of perspective suggest a decrease in the "neuroticism" of the group. Post-operative changes in scores on the cognitive tests are also small. Of the tests used, the Mill Hill Vocabulary Test and the Porteus Maze Test were the most sensitive to changes in intelligence following prefrontal leucotomy. The results gave no real support to the hypothesis of a decrease, after leucotomy, in the intelligence, neuroticism and introversion of the group. The differences between these results and those of Petrie (71, 72) are probably due to differences in the type of group tested: Petrie's group was entirely neurotic; the present group was almost entirely psychotic.

The research was extended to investigate certain problems suggested in the psychiatric literature which had not been studied using objective methods. An attempt was made to assess the relation of changes in test scores after

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leucotomy to the following factors : psychiatric diagnosis, pre-operative length of illness, the different techniques and intentions of the surgeons, and the post-operative clinical status achieved by the patients. Psychiatric diagnosis was significantly related to the changes on the " affective discrepancy score " derived from the level of aspiration test. The paranoid and affective groups tended to become more realistic in their aspirations and judgments after leucotomy, the schizophrenic group to become less realistic. This may confirm the general finding that a smaller percentage of schizophrenics tend to be clinically improved by leucotomy.

Length of illness may be related to the changes in the scores on one test, the test of static ataxia, but the evidence from the present group (mean length of illness just over four years) does not demonstrate this convincingly.

More posterior surgical lesions tend to cause a deterioration in scores on the Porteus Maze Test. This may be due to the effect of the operation on certain non-intellectual personality factors such as planning and foresight, measured by this test.

Post-operative clinical status was related significantly to changes in scores on the R-V Manual Dexterity Test. Patients who were clinically improved to any extent performed better on this test after leucotomy ; patients who are unimproved performed worse. These results may reflect the increased normality of the improved patients ; they may also be related to the pre-operative presence of, and post-operative relief from, mental tension in the clinically improved patients. Changes in scores on the Rorschach Test were found not to be related to post-operative clinical improvement at a statistically significant level.

An attempt was made to predict, from the pre-operative test scores, the most probable degree of recovery for each patient. This was done by calculating the multiple regression of the recovery rating on the pre-operative test scores. The R-V Manual Dexterity Test and the total number of responses on the Rorschach Test, used together, gave a multiple correlation of 0·646 with the criterion. By the use of an " improvement score," derived by suitably weighting the pre-operative scores on these two tests, it was found possible to predict, with about a 30 per cent. error of misclassification, whether patients in the present group would be clinically " improved " or " unimproved " after leucotomy.

Jones (44) analysed Rorschach records for 27 variables which revealed no great post-operative changes. This fact suggests that the personality structure is not basically disturbed. There are, however, several statistically significant changes : mean total responses increased, mean card rejections decreased and reaction time decreased. The first ten cards of the T.A.T. were presented as a basis for the patients to build stories. Very few of the patients really made up a story. Post-operatively, there were certain statistically significant changes ; a smaller percentage of pictures were rejected, and there were increases in the number of descriptive responses and in interpretations. The Bender Visual Motor Gestalt Test records were analysed for 19 variables. There was a significant decline in rejections and a decrease in schizophrenic elaborations. The arrangement of figures was categorized as confused, horizontal or vertical.

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There were significant changes in the direction of fewer confused arrangements. Size reproductions were classified as the same, diminished or expanded. The early post-operative testing revealed a statistically significant tendency to reduction of figure size. Further post-operative changes were in the direction of fewer reductions and slightly more expansions, with the percentage of " same " size reproductions remaining somewhat below the pre-leucotomy level. There was a statistically significant improvement six months post-operatively on several short tests : naming pictured objects, reading names of objects, interpreting a pictured social situation, detecting picture absurdities and solving simple arithmetic problems. Sixteen patients were given the Goldstein-Scheerer Colour Form Test. Three successfully sorted according to both colour and form pre-operatively. Three months after operation six accomplished successful shifts. Emphasis on colour sortings tended to increase during successive re-testings. Prior to leucotomy there were six colour and four form sortings for the group ; at the third retest six months post-operatively there were seventeen colour as compared with six form sortings. This suggests a greater tendency to outer rather than inner control.

(c) *Summary.*

The main conclusions to be drawn from the results of *cognitive testing* before and after prefrontal leucotomy are as follows :

1. Results from the Stanford-Binet and the Wechsler-Bellevue tests show that scores on the *Binet* consistently tend to decrease slightly after leucotomy. These changes are, however, statistically insignificant (89, 74, 84, 98). A decline in score on the full Wechsler scale is reported, this decline being statistically significant in the investigations of Koskoff *et al.* (53) and Malmo (59). Further, it is emphasized that the losses are greater on the verbal than on the performance scale (53, 98, 44, 71).

2. These indications tend, on the whole, to be confirmed by the results from other verbal tests. In the investigation by Ström-Olsen *et al.* (89) scores on the Terman and Shipley Vocabulary Tests both decrease, although the changes are statistically insignificant ; in the investigation of Malmo (59) scores on the Stanford-Binet Vocabulary Test show statistically reliable losses for a group consisting of six lobotomy and two gyrectomy patients. Robinson *et al.* (82) report that on the Stanford-Binet Vocabulary Test, the scores of 68 leucotomized subjects were slightly, but not significantly, worse than the scores of 12 non-leucotomized subjects matched for age and diagnosis. Of the cognitive tests used by Crown (9), the Mill Hill Vocabulary Test was the most sensitive to changes in intelligence following prefrontal leucotomy.

3. The main performance test for which results are available is the *Porteus Mazes.* Results from the more important investigations are not entirely consistent. Ström-Olsen *et al* (89) and Jones (44) report slight, but statistically insignificant rises in score after leucotomy. Porteus and Kepner (74) and Porteus and Peters (75) report statistically significant decreases after leucotomy. Crown (9) found a slight but statistically insignificant post-operative loss in score on this test. Petrie (71, 72) found a significant loss in score on the

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Mazes three months after leucotomy, which was partly regained by the nine months' retest. However, as Porteus and Peters (75) have shown that non-leucotomized subjects show a marked practice effect on retesting with the maze, their conclusion that the maze test is sensitive to post-leucotomy changes in intelligence would appear justified.

4. Of other performance tests, scores on *Kohs Blocks* and *Alexander's Passalong Test* tend to show a slight, but insignificant, rise after leucotomy (38, 89). In one report (44) the *Goodenough Drawing-a-Man Test* shows a statistically significant increase.

5. Scores on a non-verbal, perceptual type test, *Raven's Progressive Matrices* in one study (89) show a slight, statistically insignificant rise.

6. These results support the view that there are certain intellectual changes following prefrontal leucotomy. Of those tests so far investigated scores on certain verbal intelligence tests and the Porteus Mazes Test show the greatest post-operative deficits.

Findings from the *special investigations* have not been confirmed to the same extent as those from the clinical studies and the studies using formal tests of intelligence. Certain findings appear, however, to have been reliably established. These are as follows:

1. Quantitative changes on the *Rorschach Test* are small (38, 51, 44). Further, there is little agreement between investigators as to the changes that take place.

2. A decrease in *neurotic tendency* is reported by Hunt (38) using the Bernreuter Personality Inventory and the Rorschach Test; and by Petrie (71), who reports a post-operative decrease in body-sway suggestibility, and an increase in the smoothness of certain work curves. On certain sub-tests of the Wechsler Test there was a decrease in the number of mistaken answers in relation to the number of correct answers. On a perseveration test there were reduced P-scores following leucotomy.

3. An increase in *extraversion* is reported by Hunt (38) and by Greenblatt *et al.* (33), shown on the Rorschach test by changes in the M : Sum C ratio. A similar change is suggested by Petrie (71) because of changes in the scores on certain objective personality tests: the group is less persistent post-operatively, goes for speed rather than accuracy and, on the level of aspiration test, brings aspiration and judgment more in line with reality.

4. Schrader and Robinson (85) and Jones (44) rated groups of chronic schizophrenics on *ward behaviour* charts. Improvement in total adjustment scores following leucotomy is reported in both investigations.

5. Impairment, after leucotomy, on the Babcock tests of "*basic efficiency*" (perception, speed, learning, motor control etc.) is reported by Babcock (2) and Koskoff *et al* (53).

6. There is little consistency between investigators as to whether or not *abstraction* is affected by prefrontal leucotomy. Kisker (49) and Jones (44) suggest there are no important changes, whereas Greenblatt *et al.* (33), Yacorzynski *et al* (98) and Malmo (59) consider that there is a loss on tests of abstract thinking. This lack of agreement is not surprising considering the variety of tests used by these and other investigators to test abstraction. Tests used

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include: Kohs Blocks, the Goldstein-Scheerer Colour-form Sorting, Halstead's Grouping Behaviour Test, the Rorschach Test, the Vigotsky Test, Vocabulary Tests (49, 33, 98, 59, 44); the Shipley Hartford Test (14, 81); proverbs, fables and abstract words (84). These tests seem to be of two main types: First, tests which must be considered primarily as intelligence tests; these include Kohs Blocks, Vocabulary Tests, the Shipley-Hartford Test, proverbs, fables and abstract words. Second, tests which appear to conform to Halstead's (34) definition of abstraction as the basic capacity to group to a criterion which involves the comprehension of essential similarities and differences. This group includes tests such as the Goldstein-Scheerer Colour-form Sorting Test, Halstead's Grouping Behaviour Test, the Vigotsky Test and others. It is suggested from this analysis that, in factorial terms, sorting tests, if included in a test battery with other cognitive tests, would cluster together, these tests having, in addition, moderately high correlations with intelligence. Whether the abstraction group factor would be different from group factors already widely recognized remains a problem for further research.

III. General Conclusion.

It is clear from this review that certain psychological changes can be observed in patients following prefrontal leucotomy. From the psychiatric point of view the syndrome caused by prefrontal leucotomy has been described as being characterized by apathy, lack of spontaneity, fatuous equanimity, absence of finer emotional response, thoughtlessness and, at times, euphoria. In the selection of cases which will respond well to the operation, the presence in the symptomatology of signs of emotional response is considered generally to be the most important criterion. Further, the suggestions have been made that there are no changes in intellectual functions following leucotomy, and that the non-intellectual changes are too slight to be recorded using psychometric methods.

Recent objective studies do not support these latter observations. On the intellectual side, the scores on verbal intelligence tests and on the Porteus Mazes have been shown to decrease following leucotomy. Other studies have shown that there are measurable post-operative changes in certain non-intellectual functions. Robinson (81) and Robinson, Freeman and Watts (82) tested the hypothesis that there is a loss of capacity for prolonged attention after leucotomy. This hypothesis was confirmed using objective tests of "deliberation" and three of the Downey Will-Temperament Tests. Petrie (71, 72), using carefully defined, quantitative hypotheses susceptible of clear confirmation or rejection, showed that, in a neurotic population, changes take place along at least two dimensions of personality: after leucotomy neurotic patients show a decrease in general "neuroticism" and an increase in extraversion.

It is with clearly formulated hypotheses that future psychometric studies of the changes following leucotomy should be concerned. Further, these investigations should be extended in several directions: the cognitive testing by the inclusion of tests of all the widely recognised group factors;

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the non-intellectual personality testing by continued attempts to devise tests to measure the more subtle, yet clinically observable, post-operative changes. Attempts should also be made to test large enough samples to allow of sub-grouping according to important variables such as diagnosis, type of operation, etc., so as to have equal or proportionate numbers in each sub-group. In this way a factorial design may be possible in which an estimate can be made not only of the relationship of all the variables to the changes in test scores after leucotomy, but also of the effect of the interaction between these variables.

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