INVESTIGATION INTO INTELLECTUAL CHANGES FOLLOWING PREFRONTAL LEUCOTOMY.

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INTRODUCTION.

THIS investigation is not concerned with the clinical indications or results of prefrontal leucotomy, but attempts to re-examine changes following the operation, especially in regard to the impairment of some of the manifestations of the highest integrative psychophysiological functions of the central nervous system that may bring about such alterations. Amongst these we were primarily interested in cognitive changes, but the interpretation of apparent cognitive changes led to the consideration of orectic alterations as well. Such changes have so far been impossible to localize exactly, but are considered to be partly related to the phylogenetically more recent parts of the cerebral cortex. Masserman (1946) compared the mechanism of shock treatment and leucotomy with the effects of alcohol and states that "its main actions are those of a cortical depressant," as manifested by impairment of finer perceptions and discriminations and a "constriction of the integrative field." He believes that shock therapies and leucotomy partly produce their results by temporary or permanent decorticating effects, "rendering the individual no longer capable of fine spun fantasies or elaborate delusions." These decorticating effects can be assumed to be reflected in cognitive, conative and emotional alterations following the operation. The interpretation of change following leucotomy presents many difficulties, one of them being that only dysfunction can be related to structural damage of the frontal lobe and not function. Another is that psychotics or severe neurotics operated upon usually do not have a sufficiently intact pre-operative personality to draw conclusions about the normal functions.

Several different theories have been advanced in explanation of the changes found after leucotomy. The performance on intelligence and other cognitive tests has been found by the majority of workers not to be significantly impaired (Halstead 1947, Robinson 1946, Kisker 1944, Brody 1946, and others). Orectic theories of change have, therefore, been expounded by some authors. Robinson (1946) believes that prolonged attention and deliberativeness are reduced. Malmo (1948) speaks of a diminished ability to maintain a set in face of interference. Penfield and Evans (1935) suggest loss of initiative and capacity for planned action, Brody (1946) a stripping of emotion in relation to the task set. Freeman (1942) believes that the post-operative changes follow emotional alterations. He explains them by a bleaching of affect attached to the ego.

Kisker (1944) speaks of an emotional re-channelling. Halstead (1947) has presented an important cognitive theory of impairment of biological intelligence after lobectomy, head injuries and similar lesions, but states that this impairment is not evident after bilateral subcortical lobotomy.

A minority of workers have argued, on the contrary, that intellectual deterioration does occur. There is considerable variety in the functions which have been found to be impaired and in the causal explanations invoked. Porteus (1944) using his maze-test, found that lobotomized patients often improved on their pre-operative level of performance, but showed an increased tendency to repeat mistakes and inability to improve as rapidly as a control group. Rylander (1948) found in a number of post-operative cases a lowering of I.Q., a reduced capacity for association and a tendency to think in a more concrete way. Malmo found after prefrontal lobotomy a slight drop in general intelligence and a significant reduction in vocabulary; he explains this in terms of his conative theory. Yacorzynski, Boshes and Davis (1948), studying exhaustively a single case of frontal lobotomy, found a decrease in I.Q. on two tests and attributed this to a reduced capacity for abstract reasoning. They speak of a reduced capacity to grasp complex relationships dependent on destruction of connection of the cerebral cortex with other areas of the brain. Kiskoff, Dennis, Lazovik and Wheeler (1948) found that many intellectual functions are impaired after frontal lobotomy, but that there is a gradual return of intellectual capacities. Cobb (1948), Hutton (1942) and Reitman (1947) also tried to explain the change found after leucotomy in terms of cognitive function.

Cobb (1946) speaks of short-circuiting and believes that associative functions of the frontal lobe are impaired. This contrasts with Le Gros Clark's latest conception (1948) based on anatomical evidence regarding the prefrontal lobes as mainly projection areas.

The extent of the lesion in the patients concerned in most inquiries has varied; usually but not always, it has been more extensive than in leucotomy proper. The general finding, however, has been that there is no significant relation between degree of impairment and extent of lesion or amount of tissue removed. (Halstead, Malmo and others.) This seems to indicate that the same amount of frontal lobe damage does not always lead to the same impairment, and that as far as the leucotomy technique is concerned, there is not only an uncertainty as to the exact localization of the cut, but also in regard to the sensitivity to frontal lobe loss. In general, however, it appears that the relatively posterior cuts have produced the more severe impairments.

Despite the generally negative psychometric findings, several neurologists, e.g. Goldstein (1944), Cobb (1941 and 1948), urge that intellectual deficit must occur after any injury to the frontal lobes. The finding of Jacobson, that monkeys show an impairment in immediate memory after frontal lobotomy, has been taken to suggest that a similar impairment must occur in man after similar lesions. Many clinicians are convinced that leucotomized patients do show an impairment in cognitive capacity, especially in memory and conceptual thinking, and that this is not disclosed by tests because they are not sufficiently sensitive or searching.

The general purpose of our inquiry was a psychometric investigation into possible impairment of memory and conceptual thinking with a clinical assessment of cognitive and orectic changes after leucotomy, which might throw light on the impairment disclosed by these tests. The psychometric tests were given to an operated and a non-operated group for comparison.

Clinical Assessment of Changes.

The leucotomized patients have been rated independently on clinical evidence (based on observation over a number of weeks) in regard to :

(*a*) General post-operative clinical status.
(*b*) Cognitive changes.
(*c*) Conative changes.
(*d*) Affective changes, on a scale :

1. Markedly impaired.
2. Somewhat impaired.
3. Unchanged.
4. Somewhat improved.
5. Markedly improved.

The improvement was assessed only on the basis of behaviour.

Changes concerning a patient's desire, wish or will could be studied in several different stages. Apathy has often been seen after an operation. In some patients all kinds of inducements or bribes were of no avail in getting them to take up any activity or occupation. This sort of change is generally more marked for the first few days following the operation, but often persists to a smaller degree. Some patients if confronted with a task, state that they are not trying as hard as they could. Others, however, show an improvement in volition ; they take more interest in occupational activities and show improved emotional expression and striving. Cognitive or intellectual changes are usually small and, therefore, more difficult to assess clinically. Some impairment of memory and judgement was, however, observed in a number of patients. It was assessed by studying the patient's performance in recreational activities, such as playing whist, and whether they went about their occupations more intelligently or not. Some examples may be of interest :

One patient who was usually quite particular about her belongings before the operation, afterwards proceeded to burn her dirty clothing which was otherwise in good condition. Another, while out for a walk, had no hesitation in entering the gardens she passed and proceeding to pick flowers. This latter kind of disturbance was hypothetically interpreted by Reitman as due to a loss of the abstract concept of ethics.

A journalist complained that ideas did not come as quickly as before the operation and that he was unable to muster the same interest and enthusiasm for his work, which change can be tentatively interpreted as an impairment of cognitive capacity combined with a decrease in conative functions.

Operated Patients.

The operated group consisted of 24 patients, 7 male and 17 female. The age range was 21 to 68 years; the mean age was 37·8 years, S.D. 11·7 years. Nosologically, 17 were schizophrenics, 6 depressives, and 1 psycho-neurotic (obsessive-compulsive). The nature of the operation was: bilateral low vertical leucotomy 17, bilateral upper vertical leucotomy 2, middle vertical leucotomy 3, combined upper and lower vertical leucotomy 1, bilateral lobotomy (Freeman and Watts' technique) 1. So far as intelligence was concerned, the mean score of the operated group, prior to operation, on the 1938 Progressive Matrices (administration without time limit) was 36·4, S.D. 11·9, range of scores 14 to 56.

Operative Technique.

For a detailed description of the operative technique used for most of our case material, we refer to a recent publication by Dax and Radley-Smith (1948).

The skin and bone incision is about 3 cm. lower than in the technique used by Freeman and Watts. The centre of the skin incision lies 3 cm. behind the outer border of the orbit and 3 cm. above the zygoma. After opening of the dura, the vessels in the lower end of the Sylvian fissure are sought. This incision is very near the floor of the anterior fossa. A stab incision in the pia arachnoid is made at a point where an imaginary line 1 cm. above and parallel to the Sylvian vessels crosses a horizontal line just over the centre of the opening. The leucotome with its blade closed is inserted there. The direction in which it is intended to point is varied according to the particular sections of fibres to be cut. In the vertical plane an upper, middle and lower vertical leucotomy were used. Sections were also made in the horizontal plane in some cases, or several of the mentioned types of sections were combined. The original technique described by Freeman and Watts was also employed.

Non-Operated Patients: Criteria of Matching.

The goal was to have a control group of non-operated patients matched as closely as possible for age, intellectual level and clinical status. The criteria of matching adopted were:

1. Identity of sex.
2. Identity of general clinical status.
3. Difference in age not exceeding 6 years.
4. Difference in untimed Progressive Matrices score of not more than 5.

Matching by sex and general clinical status was readily achieved. It was not, however, possible with the available population, to secure a fine symptomatological matching and at the same time to match closely for intellectual level. As cognitive changes were chiefly under investigation, preference was given to the latter criterion. The age range of the matched group was 20 to 62 years; the mean age was 35·8 years, S.D. 10·6 years. It was possible to ensure a very close matching between the two groups on the Progressive Matrices scores. The mean score of the matched group was 36·8, S.D. 11·1, range of scores 13 to 57.

The high proportion of schizophrenics in the two groups was imposed by the nature of the operated group. Several workers, notably Rylander, have convincingly urged that, because of the notorious psychotic fluctuation in test-performance, investigations into cognitive and other changes after frontal-lobe operation should be restricted to psycho-neurotics. It may be noted, however, that the schizophrenic and depressive patients included in the two samples tested here were indubitably psychotic; the clinical status of leucotomized patients said to be psychoneurotic is often greatly open to question. (Reitman, 1948.)

Rationale of Psychometric Investigation.

The rationale of the psychometric inquiry was to apply a battery of tests that involved remembering or conceptual thinking to the leucotomized group, in the week prior to their operation and to apply a battery of similar (or the same) tests to them in the period six to eight weeks after the operation. The same two batteries were administered to the control group with an intervening period of seven to eight weeks. A minimum period of six weeks after operation was allowed to elapse because of the finding of investigators into physiological changes after leucotomy that the patient can be confidently regarded as stabilized at his new level by that time. (Reitman 1945, 1947, and others.)

The test employed were (1) Memory for Objects, (2) Paired Associates, (3) Verbal Similarities, (4) Specially devised Sorting Tests, (5) Reitman's Pinman Test, (6) Items from Kohs' Blocks, (7) Bender's Visual-motor Gestalt Test. The use of these will be more specifically described below and such quantitative and qualitative alterations as were evident will be stated.

If it is true that there is a deterioration after leucotomy in ability to remember and to think conceptually, it would be expected that the performance of the operated group on the second battery would be less effective relatively to their first performance than would that of the non-operated group. The situation on a test varies according to whether or not a practice-effect is involved and whether the second test is harder than the first, easier or of equal difficulty. Assuming that there is a deterioration of ability after the operation, there are four chief possibilities:

1. The operated group show a loss in score, while the control group remain at the same level.

2. The operated group show a loss (or remain at the same level) and the control group a gain in score.

3. Both groups show a gain, but that of the operated group is less than that of the control group.

4. Both groups show a loss, but that of the operated group is greater than that of the control group.

In all eventualities, if there is deterioration after leucotomy, the difference between the mean-score of the operated group on a pre-operative test and their mean-score on its post-operative parallel should be either significantly greater negatively or significantly less positively than the difference between the mean-score of the non-operated group on the first test and their mean-score on the

second test. The statistical problem then is to determine whether or not this difference of changes could easily have arisen from the chance variability of sampling; this has been ascertained in the conventional manner by calculating students' t-ratio. The performances were also carefully scrutinized for evidence of fine qualitative changes.

Tests Employed and Results.

(The main quantitative results are shown in a table in the Appendix.)

1. *Memory for Objects.*

The aim here was to apply a straighforward test of immediate and delayed recall, using everyday material. Fifteen common articles (scissors, pencil sharpener, etc.) were exhibited to the patient in a constant order at 5-second intervals. At the end he was asked to name as many articles as he could remember. The score was the total correctly named or described. Repetitions and paramnestic statements were noted, but neglected in the scoring.

For delayed recall the patient was asked, after three other tests had intervened at an interval of approximately 30 minutes, to name as many articles as he could still remember.

In the second testing the same articles were exhibited in the same order, and the patient's immediate and delayed scores determined in the same way. The difference in change between the two groups was non-significant. There was no evidence of an increased tendency to repetition or paramnestic statement in the operated group.

2. *Paired Associates.*

The test of paired associates has often been found a valuable indicator of diminished learning capacity owing to cognitive deterioration.

Five paired associates taken from the original Babcock Scale (earth-hole, cane-beat, lawn-cap, spark-tears, twig-song) were read to the patient in the first testing. He was told that he would afterwards be given the first word in each pair and required to say the word that went with it.

The test was carried on till the patient achieved perfection. The patient was allowed 15 seconds to recollect the second word; if he could not do so by that time he was told what it was. To prevent recollection by position the first words were read out in a systematically varied order. The score was the number of repetitions of the whole group of five words necessary for the patient to attain perfection; the optimal score was zero.

In the second testing, five pairs from Babcock's parallel list were employed (barn-mouse, oil-coin, ice-mumps, man-boot, lump-way). The administration and scoring were as in the first testing.

The operated group showed a marked mean increase in the number of repetitions necessary, the control group a slight mean increase. The difference in changes is significant.

The difficulty of tests such as Paired Associates can be greatly reduced by forming mental pictures of links between the words or otherwise linking them

Table of Quantitative Results.

Test.	Prior means.		Subsequent means.		Difference in change.				
	Operated.	Control.	Operated.	Control.	Mean.	S.D.	$S.E._{m.d.}$	t-ratio.	df.
Immediate object memory	8·77	9·14	9·23	9·32	0·28	1·29	0·27	1·037	23
Delayed object memory	8·72	9·02	8·92	9·47	0·25	1·47	0·31	0·806	23
Paired associates	10·86	9·73	14·48	10·11	3·24	5·51	1·15	2·817	23**
Verbal similarities	31·24	32·81	31·45	33·26	0·24	1·31	0·27	0·889	23
Sorting, Part 1	3·90	3·58	5·02	6·71	2·01	3·46	0·72	2·792	23*
,, ,, 2	4·82	5·13	5·97	7·11	0·83	2·16	0·45	1·844	23
,, ,, 3	12·86	13·74	12·09	17·03	4·06	4·37	0·91	4·462	23**
Reitman responses	12·65	13·86	15·32	17·00	0·47	2·18	0·48	0·979	21
,, drawing	2·78	1·84	2·57	2·24	0·61	1·34	0·45	1·356	9
Kohs' Part I	28·23	25·94	19·68	16·83	0·56	2·75	0·57	0·982	23
,, ,, II	10·76	11·88	13·67	11·69	3·10	4·94	1·03	3·010	23**
,, ,, III	29·91	30·46	34·29	29·70	5·14	6·60	1·38	3·725	23**
Bender reproduction	21·32	19·52	18·32	20·81	4·29	5·16	1·08	3·972	23**
,, motor	10·98	10·24	10·89	10·64	0·49	1·81	0·38	1·289	23
,, counting	3·08	3·12	1·81	2·54	0·69	0·67	0·14	4·929	23**

* Statistically significant at 5% level.
** Statistically significant at 1% level.

by a constructed third term (e.g. twig-song, a bird sitting on a tree singing). It was not possible till the end of the second testing to find out how far this had played a part in the good scores of some patients. Such devices had been used by 2 of the operated and 3 of the control group, according to their statement. This factor, therefore, seemed not to play a great part in the results.

3. *Verbal Similarities.*

Both clinical experience and the researches of Wechsler and others indicate that the task of stating how two or more named objects are similar or alike is good evidence of capacity for conceptual thinking and of its impairment owing to various causes.

Two parallel lists of pairs or trios were constructed from alternate items of this sort in the Terman-Merrill and Wechsler Scales, starting with easy pairs, such as "wood and coal," and leading up to difficult ones like "life and death."

The patient was asked to say how the objects named were alike or similar, or what they had in common. The essence of this task is to disregard manifest differences and isolate a less obvious likeness. A fully adequate performance subsumes the objects under an appropriate class; a completely inadequate performance names only the differences. Between these possibilities there are varying degrees of inadequate abstraction owing to concreteness of thinking or awareness of differences. The following scale of marking was adopted:

3 *marks.*—Fully adequate abstraction, e.g. coal-wood, "both fuel."

2 *marks.*—(*a*) Abstraction with concrete components, e.g. coal-wood, "light fires with both."

(*b*) Good abstraction with difference also named, e.g. apple-orange, "fruit, but one red and other yellow."

1 *mark.*—(*a*) Concrete or situational conjunction with abstract component, e.g. penny-shilling, "both in your purse."

(*b*) Too wide abstraction, e.g. shoe-glove, "both objects."

(*c*) Too narrow abstraction, e.g. bee-sparrow, "both have eyes."

(*d*) Far-fetched abstraction, e.g. ocean-river, "you could drown in both."

(*e*) Mild inaccuracy, e.g. cow, snake, sparrow, "all have legs."

½ *mark.*—(*a*) Situational conjunction with no abstraction, e.g. fly-tree, "fly lives in tree."

(*b*) Marked inaccuracy, e.g. bee-sparrow, "two mammals."

0 *marks.*—(*a*) Statement of difference, e.g. bee-sparrow, "insect and bird."

(*b*) Denial of similarity, e.g. coal-wood, "not alike."

(*c*) Inability to answer at all.

The maximum mark on each test was, therefore, 60. The difference in mean change between the groups was non-significant.

A detailed qualitative scrutiny of the answers also suggested that there was no general tendency to increased difficulty after the operation in disregarding the differences and isolating what was similar.

4. *Sorting Tests.*

Several investigators into conceptual thinking have remarked that tests such as Verbal Similarities are unsatisfactory because they involve familiar material in relation to which there are well-established habitual modes of reaction. For this reason sorting tests involving unfamiliar material are regarded as preferable indicators of weakened conceptual thinking. Certain difficulties arose in choosing a suitable sorting test for this investigation. Some of the well-established sorting tests, such as the Hanfman-Kasanin are extremely difficult for all but the super-normal, others such as Weigl's Colour-Form test are too easy for all but the seriously deranged. Moreover, most of the well-known sorting tests are not capable of repetition, once the principles of classification have been grasped, and few have parallel forms. For these reasons it was decided to devise two special sorting tests which seemed likely to be of approximately equal difficulty.

The aim was to present the patient with a number of shaped pieces marked in various ways and capable of grouping into mutually exclusive classes according to the shape or various markings, with one number of classes corresponding to each kind of marking. In each test 15 pieces were used. In the first test, the pieces could be classed into three groups according to shape (square, circle or triangle), two groups according to a mark at the top (square or circle), four groups according to the number of times the letter V was marked on them, five groups according to the number of times a red X was marked on them, and six groups according to the number of blue dots on them. In the second test, the pieces could be classed into three groups according to the same shapes, two groups according to the mark at the top (X or XX), four groups according to the number of times a red S was marked on them, five groups according to the number of times a red O was marked, and six groups according to the number of blue straight lines on them. It was intended to determine, first, how quickly in order to make a given number of classes, the patient could isolate a common marking and disregard differences in marking, and, secondly, how quickly he could shift from one principle of classification to another.

In all sorting tests there is great difficulty in conveying to subjects of average or poorer intelligence and education what the nature of the task is. Subjects who have not had an advanced scientific or literary education often find the notion of classifying material exceedingly hard to grasp, quite irrespective of difficulties in carrying out the classification. It was necessary, therefore, to exercise special care that the patient understood the nature of the task.

The patients were first familiarized with the notion of classification by analogies. They were given coins to sort out and ways in which people could be classified were discussed—according to sex, occupation, rank, etc. Owing to differences in the intelligence and education of the patients it was not possible to adopt a fixed form here, but the process was carried on till the patient apparently grasped the notion of classifying with complete understanding.

The patient was then asked to sort the pieces into groups according to shape, then according to the mark at the top, and so on through all the other markings.

Nothing was said about the number of classes made each time and no patient remarked on this. Attention was, however, carefully drawn to the fact that in each classification a piece must belong to one group and only one group, and that all the pieces had something in common which the pieces in the other groups did not possess.

When this had been done, the patient was told "Now you've seen all the different ways these pieces can be grouped according to shape or markings. I want you next to arrange them into four groups so that all the pieces in a group have something in common that the pieces in the other groups haven't got, and so that no piece could be in any group but the one it is in. You can use the shape or any of the markings, but don't combine different sorts of markings." Where necessary the instructions were repeated till the patient grasped them. The patient was then given five minutes in which to achieve the classification. If he did not succeed by that time, the grouping was made and the patient was given up to five minutes to look at it and say on what it was based. Where wrong groupings were made, the reason for their incorrectness was pointed out. The sub-test was scored by deducting one mark from 10 for each complete minute the patient took during the two phases combined.

Next the patient was asked to make five groups some other way. The same procedure and method of scoring were used. Then the patient was asked, as an indication of his capacity, to shift from one aspect to another, to make the grouping of four again and then once more the grouping of five classes. For each regrouping he was allowed up to five minutes; one mark was deducted from 20 for each complete half-minute taken during the two regrouping phases.

Thus there were three sub-tests of sorting, the first two having a maximum of 10 marks each and the last of 20 marks.

In the second battery the parallel pieces were used with precisely the same administration and scoring, except that the elaborate explanation of classifying was not necessary. The similarity of the two tests would suggest the likelihood of a considerable practice-effect in the second performance. The control group showed mean gains on all three sub-tests; the operated group gained on the first two but lost slightly on the third sub-test. The difference in change between the two groups was significant on the first and third sub-tests, non-significant on the second. The difference on the first sub-test is suggestive that the leucotomized patients benefited less from their previous experience than did the non-leucotomized patients; the difference on the third sub-test is suggestive that on the basis of their previous experience the non-leucotomized subjects were able to make quicker shifts than were the leucotomized ones.

Qualitatively, subjects differ in their mode of tackling sorting tests of this kind. Some regard the material abstractly without making any efforts at physical trial-and-error sorting; others use the latter in varying degrees. Some make a systematic elimination of variables; others (not always of poorer intelligence) are unsystematic and manipulate or regard the material until the common component suddenly comes to the forefront of awareness. It was not possible to detect in the leucotomized patients any consistent change in these modes of approach. Sorting tests with schizophrenic and organic patients usually evoke a number of more or less pathological phenomena—

patterning with the pieces, distributions instead of classification with the variable, physiognomonic reference to the pieces, etc. In both samples such phenomena appeared in both testings, but no increased tendency to them was evident in the operated group after leucotomy. Qualitatively as quantitatively, the essential difference between the two groups was that on the second testing the non-operated patients seemed to show a marked improvement in isolating the common factor, disregarding differences and shifting from one principle to another, while the operated patients showed a much less marked improvement or none at all.

Reitman's Pin-man Test.

In this test the subject is shown a number of Pin-man drawings strongly suggestive of various emotional states and asked to say what feeling they express. The responses are marked according to the extent to which the subject can ascribe inner feeling to the figure, the degree of abstraction or generality by which he does so, and the presence of bizarre reactions. The subject is also required to draw one of the figures from memory and the drawing is marked by similar criteria to those for the responses. The test is essentially one of capacity to conceptualize emotional expression.

The Pin-man responses were obtained from 22 leucotomized cases before and after the operation, the drawing from 10. The results have been compared with their matches only. The Pin-man test consists of 12 figures altogether; half of these were presented in the first testing and half in the second. The maximum score on the responses was 30, on the drawing 8. Both on responses and drawing the difference in change between the two groups was non-significant.

Kohs' Block Designs.

Goldstein and Scheerer treat Kohs' Blocks as a test of abstract and analytical thinking. More usually it is regarded as a test of capacity to deal with spatial relations. In either eventuality it seemed of value in this inquiry.

It was decided not to use the entire series but in order that practice effects might be reduced to employ two parallel series of approximately equal difficulty. The first series consisted of Kohs' No. 3 as the first sub-test, Kohs' No. 7 as the second sub-test, and Kohs' No. 11 as the third sub-test. The parallel series consisted of Kohs' No. 2, Kohs' No. 8, and Kohs' No. 10 as the first, second and third sub-tests.

In order to give full opportunity for differences to appear, the patient was allowed unlimited time on each figure. On the first design, the score was the total time taken in seconds, on the second, the number of five-second intervals, and on the third the number of ten-second intervals taken. In each testing, the patient was first given Kohs' No. 1 design as a trial in order to illustrate the nature of the task. When the patient made an incorrect reproduction he was told that he was wrong, if he did not spontaneously say so, but left to find out why. The nine-block designs are often insuperably difficult for subjects of poor intelligence; to make them feasible in all cases, the blocks were here turned up to the correct sides and the task was merely to place them in the proper way.

In the second testing both groups showed a marked mean gain on the first sub-test, but the difference in change was non-significant. On the second sub-test the leucotomized group showed a mean loss, the non-leucotomized group a trivial mean gain. The difference in change was significant. The chief difficulty in doing the second sub-test (Kohs' Nos. 7 and 8), is the shift from a square to an oblique design. Qualitatively there seemed to be an increased difficulty in shift in the operated group.

In the third sub-test on the second testing, the leucotomized group showed a marked mean loss, the non-leucotomized group showed a slight gain. The difference between the groups was again significant. Qualitatively there seemed to be a definite increase of difficulty after the operation in breaking up or analysing the nine-block figure into its constituents and in relating the blocks to this analysis. No such increased difficulty was apparent in the non-leucotomized group.

Bender Visual-Motor Gestalt Test.

This test, developed by L. Bender from the Wertheimer Gestalt figures, is widely recognized as a delicate indicator of cognitive disturbance dependent on brain lesions.

The 9 Bender figures were used in both testings. Each figure was exhibited to the patient for 10 seconds; he was then required to draw it from memory.

Bender's system of marking did not prove conveniently applicable to these groups. The following alternative system was employed.

3 *marks: Close resemblance to figure shown.*
2 *marks: Moderate resemblance to figure shown.*

(*a*) Size considerably increased.
(*b*) Size considerably decreased.
(*c*) Components separated spatially.
(*d*) Other slight spatial displacements.
(*e*) Slight simplification of the figure.

1 *mark: Slight resemblance to figure shown.*

(*a*) Omission of components.
(*b*) Marked spatial displacements.
(*c*) Fairly considerable simplification of the figure.

0 *marks: No resemblance to original.*

(*a*) Complete inability to remember the figure shown.
(*b*) Extreme simplification of the figure.
(*c*) Pictorialization of figure (faces, animals, etc.).

This gave a maximum of 27 marks for the test. So far as possible, purely motor execution (straightness of lines, regularity of curves and circles, etc.) was disregarded in allocating the above marks; the emphasis was on the fidelity with which the subject apprehended and retained the figure.

Motor execution was marked separately on the following scale for each figure:

2 *marks:* Good motor execution.
1 *mark:* Fair motor execution.
0 *marks:* Poor motor execution.

The maximum motor-score was 18.

In the second testing, the non-leucotomized group showed a mean gain in marks for reproduction of the figure, the leucotomized group a mean loss. The difference between the two groups was significant.

The difference in change between the samples so far as motor-scores were concerned was not significant.

The evidence suggests that leucotomy impairs the patient's capacity to reproduce the Bender figures accurately. Qualitative consideration of the reproductions made indicates that the change is chiefly in the direction of an increased tendency to spatial displacement, simplification of the figures and omission of parts.

One respect in which subjects differ on this test is that where there is a repetition of dots or other components in the figure some subjects carefully and systematically count them, while others rely on the general impression. It might be expected that after leucotomy this counting behaviour would be less evident. The phenomenon was investigated by giving one counting mark for each figure where counting was shown. As counting is possible on five figures the maximum was 5. Both groups showed a diminution in counting on the second testing, but the leucotomized group more markedly so. The difference in change was significant.

Changes on Psychometric Tests.

The changes suggested as probable by the foregoing tests would support the minority of investigators who have found evidence of impairment after leucotomy. In detail they were:

1. Diminished punctiliousness. (Bender counting.)
2. Diminished apparent capacity to analyse and reproduce unfamiliar spatial relations. (Kohs' and Bender tests.)
3. Diminished apparent capacity to form linkages in unfamiliar verbal material. (Paired Associates.)
4. Lesser apparent capacity than matched group to benefit from experience on first testing. (Sorting tests.)
5. Diminished apparent capacity to shift from one aspect of situation to another, taking into account previous experience. (Sorting tests and second Kohs' design.)

The first of these changes is clearly conative. The others might be interpreted either cognitively as a true reduction in capacity or conatively as a reduction in the effort made to master an unfamiliar task. Undoubtedly there were changes in attitude; at least three operated patients made remarks to the effect, "I'm not trying as hard as last time," and none of the non-operated

group spoke or behaved in this way. On the other hand, the leucotomized performance on Paired Associates and the Kohs' sub-tests was suggestive to the examiner of genuinely increased intellectual difficulty.

In order to relate the changes on psychometric tests to the clinical assessment of changes, the leucotomized patients have been given an approximate impairment—improvement rating in the following manner. On each of the six tests where significant differences in change were shown between the two groups, the leucotomized patients have been rated by the position of their change in score relative to the mean change and S.D. of changes of the non-leucotomized group, thus :

1. *Markedly impaired :* Adverse change 1½ S.D. or more from mean change of control group.
2. *Somewhat impaired :* Adverse change ½ S.D. up to 1½ S.D.
3. *Unchanged.*—Change less than ½ S.D. in either direction.
4. *Somewhat improved :* Favourable change ½ S.D. up to 1½ S.D.
5. *Markedly improved :* Favourable change 1½ S.D. or more from mean change of control group.

The ratings on the six tests have been averaged to give a general indication of impairment. The final ratings thus obtained corresponded fairly closely to the general qualitative impression of changes in the patient's performance.

The product-moment correlations between the impairment-improvement rating on the tests and the clinical ratings were :

(*a*) With general clinical status .	minus ·44
(*b*) With cognitive changes . .	·06
(*c*) With conative changes . .	·41
(*d*) With affective changes . .	·05

These figures are very approximate and tentative, but they would suggest two conclusions :

1. That general clinical improvement or deterioration is inversely related to improvement or deterioration on cognitive tasks, i.e. that the patients who are most improved clinically are those who are most impaired on the tests and vice versa.
2. That the changes on the tests are dependent on conative changes in the patient, not reduction in capacity.

Discussion and Comments.

Though the tests results were suggestive of true intellectual impairment the clinical assessment seemed to indicate that this impairment would also be explained on the basis of conative changes, that patients were not trying so hard after the operation and could not focus their attention as well and as persistently on the different tasks, thus confirming Malmo's theory of the incapacity to maintain a set. It is, however, impossible to explain the " impairment " by changes based on one factor alone. The mechanism appears more complex or global. Consciousness can be looked upon as the sum total of

cognition, conation and affection. Modern neuropsychiatric conceptions of consciousness may provide other interpretations of the changes, as for instance outlined by Purdon Martin (1949). The acuteness of awareness embracing cognitive and conative and emotional aspects to the external and internal situation may be impaired, leading to a more detached attitude towards obsessions and delusions.

Cobb (1948) put forward the hypothesis that the impulses from the hypothalamus keep the thalamus "awake," and "ready to receive impulses from the cord and brain stem." "The neuron circuits from thalamus to cortex and back supply the mechanism for sustaining a stimulus by reverberation once the thalamus has been stimulated." "Consciousness is especially related to the cerebral cortex and the reverberating connections that exist between the cortex and thalamus." (Cobb, 1948). It is considered to be integrated at many different levels like other important functions of the central nervous system. An impairment at the highest level must be assumed following leucotomy.

Consciousness is also related to hypothalamic function (Russell Brain, 1949). This region is mainly concerned with the activity of the autonomic nervous system.

Autonomic disturbances after leucotomy were studied by Reitman (1945, 1947) and Rinkel (1947). Both found that the autonomic equilibrium is established on a new and higher level, thus homeostatic functions seem to be altered. Changed hypothalamic functions might, therefore, also have some bearing on the results seen after the operation, which would follow Cobb's hypothesis of the hypothalamus keeping the remaining parts of the thalamus more "awake."

The degree of cognitive and conative impairment might sometimes not be sufficient to reduce the awareness of very intense or torturing delusions. Other factors related to the mechanism of improvement like the "shock factor," can be largely excluded because all our patients had received some or other form of shock treatment, though definite brain injury might have an additional "shock" effect. It seems, however, that the super-imposed organic change, i.e. frontal lobe damage, often paves the way to further improvement. The continued clinical improvement cannot be explained only in terms of an impairment of cognitive or conative functions, as these also often improve in time. Perhaps it might eventually be found to be related to the influence of altered hypothalamic activities.

Summary.

1. A group of 24 leucotomized patients were tested with a battery of tests involving memory and conceptual thinking in the week before their operation and with a parallel battery 6 to 8 weeks afterwards.

2. A group of 24 non-leucotomized patients, matched for sex, age, intelligence and clinical status, were tested with the same batteries over the same intervening period.

3. The statistical significance of the difference in the mean gain or loss on each test between the two groups was examined.

4. The leucotomized group showed a significant loss on Kohs' Blocks, the

Bender Gestalt test and Paired Associates. They gained significantly less than the matched group on Sorting tests.

5. The possible mechanisms of leucotomy were discussed. It proved impossible to reduce the impairment either to only cognitive or only conative changes. The neurophysiological aspects and the neuro-psychiatric formulations of consciousness were considered in relation to the mechanism of improvement.

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