CHANGES IN PORTEUS MAZE SCORES OF BRAIN-OPERATED SCHIZOPHRENICS AFTER AN EIGHT-YEAR INTERVAL*

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THE voluminous literature reporting the effects of cortical lesions has shown contradictory and diverse findings from the earliest studies to the present (Franz, 1907; Klebanoff, 1945; Klebanoff, Singer and Wilensky, 1954; Meyer, 1957). Some investigators found no losses in intellectual function regardless of the locus of the lesion; others, a temporary loss followed by recovery of original capacity. Still others have reported significant losses following brain damage in the forebrain or other portions of the central nervous system. But for investigators in all three categories, what did "brain damage" consist of? The neurologists Brain and Strauss have observed "The study of psychological problems without an adequate knowledge of the physiology and pathology of the central nervous system can be likened to the exploration of the uncharted seas without the aid of a compass; and yet there are many psychologists who undertake the rash venture" (1955, p. vi). And what of the criteria on which the conclusions were based? An additional source of ambiguity is indicated by the fact that the overwhelming majority of conclusions on "mental" changes by psychiatrists and neurologists have generally been based on clinical or subjective estimates. *Measurement*, a crucial factor in any study, is of special importance in studies of brain damage and brain function, although despite a multiplicity of tests, there are few measures designed with attention to their unique problems. Tests employed in many psychological studies of brain damage were originally oriented toward quite different problems and had been carefully developed and standardized on non-brain damaged populations.

BACKGROUND OF THE PRESENT STUDY

In an effort to control anatomical and psychometric variables, three related multi-disciplinary projects introduced research design, planned sampling, experimental controls and standard measurement to the study of effects of brain surgery. The conclusions of the Columbia-Greystone (CG) I (Mettler (ed.), 1949), the CG II (Mettler (ed.), 1952) and the New York State Brain Research (NYSBR) projects were unanimous; no "permánent" decrements in intellectual function resulted from psychosurgery. The present study is based on the results of re-examinations with the same four psychological tests of the Psychometric Study section of the NYSBR project after an eight-year interval. In an earlier

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summary of the salient changes in all four tests (Smith and Kinder, 1959), four factors were identified as determiners of the effects of brain insult on psychological test performance: length of the interval, site of surgical intervention, age at the time of operation, and the nature of the measure. Although all four instruments showed differences between initial and long-term post-operative effects, the changes in the Porteus Maze scores were unexpectedly definitive and illustrate the importance of the last factor, the nature of the measure. In addition, the systematic differences in maze performance between operated groups from the initial to the eight-year post-operative period best represent the effects of the other three factors.

Procedure

Administration and scoring procedures of the Porteus Maze duplicated those reported by the original investigation in order to provide comparable data. The original Porteus standardized scoring was slightly revised and permitted a maximum of 19 instead of the 17 provided by the standard procedures. (For a detailed description of the slight revisions see p. 155 in Mettler (ed.), 1952.) Differences between pre-operative and eight-year post-operative scores were tested for significance by analysis of covariance. This statistical technique (Walker and Lev, 1953) not only provides for initial pre-operative differences between groups but by comparing the changes between operated and non-operated patients over the eight-year interval, takes into account long-term effects that might be due to factors other than the operations (e.g. chronic schizophrenia, ageing, prolonged hospitalization, etc.).

Subjects

The population (hospitalized chronic schizophrenics) consisted of 50 patients (27 operated and 23 control) still available at Rockland State Hospital who had been part of the original 68 (44 operated and 24 control) examined in the original project. Deaths, a small number (7) of discharges, transfers, and occasional inaccessibility of the patients account for the remaining difference in the number of the present study compared to the original investigation. All subjects were schizophrenics with a poor prognosis and had been carefully screened on the basis of criteria established by several co-operating disciplines. Controls had been drawn from the same pool of patients satisfying the selection criteria.

Subjects were separated into a Younger group—mean age as of 1 March, 1957, 42 years, range 36–48; and an Older group—mean age as of 1 March, 1957, 59 years, range 54–66. (For a more detailed description of the population, see Lewis *et al.* (eds.), 1956).

The Experimental Factor (Topectomy): Areas Excised

Based on the results of two earlier related psychosurgical projects. Columbia-Greystone I (CG I) (Mettler (ed.), 1949) and Columbia-Greystone II (CG II) (Mettler (ed.), 1952), only a single operative procedure, topectomy, was employed in the New York State Brain Research (NYSBR) Project. Two types of cortical ablation were carried out. In an orbital topectomy, Brodmann areas 11 (sometimes including portions of 47), 10, and Walker's area 13 were bilaterally excised. In a superior topectomy, Brodmann areas 9 (sometimes including portions of 10), 8, and 32 were bilaterally excised. More simply stated, a block of cortical tissue about the size of a half crown (or half dollar) and the thickness of 2 cm. was removed from either the lower (orbital) or upper (superior) portions

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of the forebrain. Based on the practices of Pool (Ch. 2, Lewis *et al.*, 1956) the amount of cortical tissue to be removed was standardized at 30 to 35 grams from each hemisphere. For the reader not familiar with the uncontrolled aspects of brain operations, Mettler (1949) has detailed numerous complicating factors which should be taken into account in assessing the neuro-anatomical variables. However, in contrast to the "blind" lobotomy procedures, topectomy employed an "open" surgical technique which exposed the cortex and permitted more careful definition and identification of the areas and amounts excised.

Original and Related Findings

Many investigators had found that generally accepted tests such as the Wechsler-Bellevue, Stanford-Binet and Rorschach revealed no marked post-operative changes. In contrast to the negative findings with these instruments, shortly following operations, scores on the Porteus Maze test revealed markedly poorer performance in numerous investigations (Klebanoff, Singer and Wilensky, 1954). In a review of recent maze studies, Porteus (1959) called attention to early deficits in the Porteus Maze scores after operation in the CG I, CG II and NYSBR projects. However, because of apparent increments in tests administered after longer post-operative intervals, the reports unanimously concluded that early post-operative losses in maze performance were temporary. In the CG I project, scores had steadily increased in four post-operative administrations until the score of the operated group on the last test (administered one year after surgery) exceeded the pre-operative level by approximately the same amount shown by the controls. In the CG II project, scores increased in two tests administered 10 and 90 days post-operatively. In the NYSBR project, decrements in single post-operative tests of different groups became smaller as the interval was increased from 10 to 30 to 90 days following surgery. Thus, while initial post-operative losses were found in each of the three studies, the reports unanimously concluded that early decrements were temporary and followed by subsequent recovery. Studies of lobotomy cases by Porteus (1944), Porteus and Kepner (1944), Porteus and Peters (1947) and others had also found a similar "drop and rise" pattern. Hence, it was not unreasonable for Landis to conclude at the third Psychosurgery Conference (1951) that all losses in the three related projects were temporary. However, Petrie (1949), Greenblatt, Arnot, Poppen and Chapman (1947), Porteus and Peters (1947) and Crown (1951) reported decrements with other populations after intervals of up to one year following operations. These contradictory results of investigations of *apparently* similar populations with the same psychological test reflect the paradoxical findings reported in the current literature in psychology, neurology, psychiatry and other disciplines studying the effects of "brain damage". Re-examinations of the patients of the NYSBR project after an 8-year interval afforded unique opportunities to compare short and long-term effects of surgery on a population of "brain-damaged" subjects that had been carefully differentiated on the basis of site and age.

Results

Table I presents the means of the two pre-operative and single initial post-operative tests (administered either 10, 30 or 90 days following surgery) under Columns I, II and III, and the results 8 years later under Column IV. The careful definition of neuro-anatomical variables in the original study, i.e. the differentiation of operated patients into subjects with orbital (lower) excisions and superior (upper) excisions in the forebrain permitted comparisons of a

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TABLE I

Porteus Maze: Means and Standard Deviations

Preoperative, Initial and 8-year Postoperative Scores

Groups	N	I Pre-operative 1	II Pre-operative 2	III Post-operative 1	IV 8-year Post-operative	*I and IV Difference*	(*a*)
Superiors ..	17	13·88	14·74	11·69	10·00	*−3·88**	(16)
S.D.		3·19	3·58	3·19	3·89		
Younger ..	12	14·67	15·54	12·59	10·58	*−4·09**	(11)
S.D.		2·79	3·23	3·21	4·30		
Older	5	12·00	12·80	9·70	8·60	*−3·40*	(5)
S.D.		3·62	3·98	2·31	2·49		
Orbitals	10	8·65	11·55	8·28	8·45	*−0·20*	(3)
S.D.		3·76	4·65	3·73	3·12		
Younger ..	7	6·93	9·71	6·57	7·57	*0·64*	(1)
S.D.		2·19	4·15	1·51	3·09		
Older	3	12·67	15·83	14·25	10·50	*−2·17*	(2)
S.D.		3·82	2·52	2·47	2·50		
Controls ..	23	10·87	11·89	12·59	10·22	*−0·65*	(12)
S.D.		4·61	4·92	4·35	4·29		
Younger ..	12	9·79	10·21	11·13	9·33	*−0·46*	(7)
S.D.		4·44	4·92	5·15	4·94		
Older	11	12·05	13·73	14·06	11·18	*−0·87*	(5)
S.D.		3·93	4·41	3·00	3·42		

(*a*) Number of subjects showing losses in first pre-operative and 8-year post-operative score comparisons.

* Significant at the ·05 level.

population that must otherwise have been lumped together as "brain operated", or "frontal lobe cases". Further differentiation of the population on the basis of chronological age at the time of operation provided an opportunity to study interactions of the effects of the site of operation with the age factor. The availability of pre-operative and initial post-operative maze scores afforded data for comparisons with the results eight years later. Thus, the differences in the effects of interaction of three factors: length of the post-operative interval, site of operation and age at time of surgery, are reflected in comparisons of changes for each operated subgroup for short and long-term post-operative tests. Although Porteus (1959) has pointed out that it is impossible to equate non-operated (control) subjects with the experimental (operated) group "in such factors as rate of ageing processes", the controls had been carefully matched on a large array of variables including age, education, length of illness and others described elsewhere (Lewis *et al.*, 1956).

The most striking difference in the effect of the interval may be observed in comparisons of its interaction with the site factor. Shortly following surgery, both major operated groups, Superiors and Orbitals, showed marked decrements below the pre-operative levels (see columns I, II and III). In view of the expected increment as a function of practice effect (shown by the controls), the magnitude of the operated losses presumably exceeded the absolute differences between pre-operative and initial post-operative scores. The initial losses for both operated groups were approximately equal.

Eight years later, however, the mean score of the Superiors (17) decreased still further, whereas the means of the Orbitals (10) and controls (23) were approximately the same as the pre-operative level. The eight-year post-operative loss by the Superiors, 3·88 below the pre-operative level (see Difference I and IV column) when compared to a loss of 0·65 for the controls, was statistically significant at the ·05 level by analysis of covariance. In a direct comparison of the two operated groups, the difference between the Superiors and Orbitals was non-significant. Further definition of the significance of the difference in mean

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scores may be observed by comparisons of the number of subjects in each group whose eight-year post-operative scores declined below their pre-operative level (see Table I, Column IV under (*a*)). The eight-year post-operative scores of 16 of the 17 subjects (94 per cent.) with superior topectomy declined below their first pre-operative score, the score of the 17th remaining unchanged. Of the 10 subjects with orbital topectomy, only 3 showed losses (30 per cent.), 5 gained and 2 remained unchanged. Of the 23 controls, 12 declined (52 per cent.) and 11 gained.

It is clear from these data that the two operative procedures differ markedly in long-term effects, although these differences were not readily apparent shortly following operation when both operated groups showed losses. The Superiors showed a loss shortly following surgery and, eight years later, a second loss further below the pre-operative level. Scores of the Orbitals, on the other hand, though declining shortly following operation, showed complete recovery eight years later and, like those of the controls, differed only slightly from their pre-operative level. Thus, for "brain-damaged" subjects with lesions in the superior or upper regions of the forebrain, the gradient of successive losses between short and long-term scores sharply contradicts the frequently reported findings of a "temporary" loss and a "drop and rise" pattern.

Analysis of interactions of the age factor with site of operation and interval revealed that superior topectomy affected both younger and older subjects in the same way; both age categories showed the same pattern: losses in the initial and eight-year post-operative tests. The long-term effects of orbital topectomy, however, differed for younger and older subjects. Immediately following psychosurgery, both older and younger orbitals showed losses (Column III). However, eight years later (Column IV), the mean score of the younger orbitals was slightly above the first pre-operative level. In contrast, after an eight-year interval, the older orbitals, unlike the younger orbitals, and like the subjects with superior topectomy, showed a second loss. Compared to a decrement of 0·87 by the older controls (Diff. I and IV), the older orbitals showed a mean loss of 2·17 below the pre-operative level. In view of the small number of older orbitals (3), this finding can hardly be considered definitive. However, the pattern of successive decrements is supported by similar decrements in four additional measures (Vocabulary, Object Assembly, Weigl Sorting and revised Capps Homograph). For all five measures, the pre-operative eight-year post-operative losses were considerably greater than those of the older controls. Since, in addition to the marked similarity in pattern to those of the younger and older superiors, this finding is logically consistent with clinical neurological and other psychological studies cited below, it is probable that the losses of the older orbitals have not been due simply to age or chronic schizophrenia.

Thus, in a population of brain-operated subjects which could be differentiated into four subgroups, three (the younger superiors, older superiors and older orbitals) did not show a "transient" loss in Porteus Maze followed by recovery. Instead of the "drop and rise" pattern, comparison of pre-operative, initial post-operative and eight-year post-operative scores showed a gradient of increasing losses, or a "drop and drop" pattern. Only a single operated group, the younger orbitals, showed recovery of initial post-operative losses or the "drop and rise" pattern so frequently reported in studies with shorter post-operative intervals.

This finding was not confined to the Porteus Maze results. Statistically significant losses by operated groups when compared to appropriate controls were reported in a total of 8 of 14 measures (Smith and Kinder, 1959). However,

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the greater sensitivity and discriminating capacity of the Porteus Maze when compared to the seven other individual measures showing statistically significant decrements is clearly shown by the losses of 16 of the 17 subjects with superior topectomy. (Landis has suggested that the 17th, whose pre-operative and eight-year post-operative scores were unchanged, might have shown a loss if the test ceiling were higher, since his scores approached the maximum on both occasions.)

Discussion

The four psychological tests provided 18 different measures: 14 individual test scores consisting of the 11 Wechsler-Bellevue subtests, the Weigl Sorting, revised Capps Homograph, and Porteus Maze tests; and four aggregate measures consisting of three I.Q.s (Verbal, Performance and Full Scale) and a composite score derived from the sum of the standard scores of the 11 subtests, the Porteus Maze and revised Capps Homograph. Except for the Weigl, which revealed marked long-term loss in shifting capacity by both operated and control groups, the results consistently showed statistically significant losses which had not been present shortly after operations. Although the Porteus Maze was most subject to practice effects, the maze scores provided the best illustration of the importance of differentiating the effects of four factors in efforts to assess the effects of brain insult: length of the post-trauma interval, specific site of tissue initially destroyed, age at the time of brain injury, and the nature of the measure employed.

Interval

It is obvious that the results of any examination are time limited. The maze scores in the present study consisted of the means of two pre-operative tests, one initial post-operative test and one re-examination after an eight-year post-operative interval. The first three tests were administered within the space of one year. Since, as the first three scores of the controls show, this version of the Maze is particularly susceptible to practice effects, the initial post-operative loss of all four operated groups was presumably greater than the drop below their pre-operative levels. Although noting a reduced capacity to benefit from practice for the Superiors, Sheer, the original investigator, observed that the losses of the operated groups tended to decrease as the post-operative interval increased from 10 to 30 to 90 days. Since other measures failed to show marked initial losses, interpretation of a "drop and rise" pattern with the limited available data was logical and in accord with the results of the two earlier CG studies.

However, clinical and neurological studies have increasingly demonstrated that the structural and functional sequelae of brain injury vary considerably with the passage of time. Based on extensive studies of World War I cases, von Monakow and Mourgue (1928) differentiated between "symptomes temporaires" and "symptomes residuels". Von Monakow attributed initial temporary symptoms to "diaschisis", a dynamic distance effect in which the suspension of function radiated beyond the boundaries of the lesion to distant functionally related parts of the brain even though these had not been primarily injured. Residual symptoms were those ascribed to secondary neuro-anatomical degeneration. Independent studies of large numbers of World War I cases by Head (1926) and Goldstein (1939), confirmed these findings. Head called attention to the constant changes in disorders of function and pointed out that to consider clinical manifestations at any given moment as permanent and directly associated with anatomical changes in a restricted part of the brain was a

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fundamental error. Head attributed restoration of function to three factors: recovery from pathological processes of a grossly organic nature, the diminution of diaschisis, and the gradual assumption at a latter stage of compensatory powers by uninjured portions of the brain. The numerous and extensive studies of Russell (1934, 1939, 1945, 1951, 1954) in addition to providing further evidence of the effects of diaschisis, emphasized the importance of the time factor. In numerous follow-up studies of thousands of World War II casualties and other neurological patients over periods of several years, Russell noted both the gradual disappearance of initial post-trauma symptoms, and in many cases, sometimes 5 or more years later, the emergence of new symptoms.

The unique opportunities for neuro-anatomical studies of leucotomized cerebra showed that time was also a determiner of structural changes following surgical lesions restricted to the forebrain. Yakovlev (1953, 1954a, 1954b) found that the amount of neuro-anatomical degeneration in patients who survived from 2 weeks to 4½ years increased with time; the longer the survival, the greater the degeneration.

Analysis of short and long-term effects of operation on maze scores is complicated by practice effects. Porteus (1959) reported a gain of about 2 years in test age after an interval of 4½ years "as a result of practice" in a non-hospital population (criminals). Although the controls in the present study are younger and older chronic schizophrenics hospitalized for not less than 10 years, their scores after an eight-year interval are practically unchanged from the pre-operative levels. It is therefore not unreasonable to assume that practice effects in the present study have affected scores after an eight-year interval only slightly, if at all. However, practice effect within the 9-month interval of the original study is evident in the two successive gains of the controls (Columns I, II and III). If we assume that the initial post-operative scores of the operated groups are inflated by practice gains equivalent to those shown by the controls, there appears to be no difference between initial and long-term losses of the Superiors. How can we be sure, then, that the long-term losses were not actually present to the same degree shortly following surgery and during the eight-year interval? We cannot. However, analyses of the available data for evidence of differences in interaction of both site and age point to systematic changes in the gradual evolution of long-term effects for all four operated groups.

Since practice effects are obviously related to the length of the interval between tests, we may reasonably assume that the practice gains after a 10-day interval should be higher than those for a 30-day interval and least for the 90-day interval. Thus scores of operated groups retested 10 days after operation may be expected to include higher practice gains (and should therefore show less of a drop below the pre-operative levels) than scores after a 30-day interval; and the scores after a 90-day interval should show the smallest practice gains (or the greatest drop below the pre-operative levels). However, the initial post-operative losses showed exactly the opposite pattern; the losses *decreased* as the post-operative interval increased from 10 to 30 to 90 days. This suggests that for all operated groups, the initial effects of operation, whether due to diaschisis or operative shock, gradually diminish within a limited period following surgery. The recovery of the pre-operative level by the younger orbitals after an eight-year interval indicates that as the initial effects of operation wear off, there is a slow but gradual restoration of function. For younger and older superiors and older orbitals, however, the data suggest that with the gradual diminution of the effects of diaschisis or operative shock, there is a slight recovery of part of the decrement, followed by later increasing losses as secondary degeneration

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spreads. In the absence of pathological anatomy for the subjects in the present study, this suggested rationale for the pattern of post-operative changes may be gratuitous. However, in several other measures less susceptible to practice effects, the patterns of post-operative changes for all four groups showed a high consistency. Statistically significant losses, which had not been present shortly after operations, were observed in several measures for the younger and older superiors and older orbitals in comparisons of pre-operative and eight-year post-operative scores (Smith and Kinder, 1959). The younger orbitals, however, did not show a single statistically significant long-term loss. Further evidence in support of the suggested rationale for the systematic changes in post-operative scores is afforded by the striking consonance with neurological findings in comparisons of the factors of specific site and age.

Specific Site

One of the factors differentiating the unquestionably "brain-damaged" population of the present study was the surgical definition of the brain insult. By removal of approximately the same amount of tissue from each hemisphere in open standardized topectomy procedure, comparisons of the effects of two different ablations provided evidence of possible differences in effects on psychological tests as a function of the specific areas removed. Despite the gradual accumulation of consistent and definitive findings of marked differences in effects of brain injury as a function of the specific site of injury in human subjects, many investigations adhere to Lashley's concept of equipotentiality, which was based on studies with rats.

The results of the present study show clearly that destruction in the superior portion of the forebrain results in greater losses than destruction of the same amount of tissue in the orbital region. These results are in accord with findings of other psychological studies cited by Porteus (1955), Petrie (1952), Crown (1951), Penfield (1948) and Malmo (1947). Although the studies cited were based on changes within a limited post-operative interval, and data for long-term effects are lacking, they are consistent with the results of clinical and neurological studies.

Brain and Strauss (1954) found the exact plane of cortical incision in leucotomy as being of "the greatest importance, If it is too anterior, the effects of operation will be small; if it is made too far posteriorly, the effects will be profound, amounting in extreme cases to the organic-reaction type of psychosis and dementia" (p. 24). Pool, who introduced topectomy, later (1951) reported similar findings; "deleterious effects" followed more posterior ablations "probably due to the additional quantity of brain function thereby disconnected". Le Beau (1952, 1954) reported that destruction of the posterior portion of Brodmann area 9 and areas 8 and 6 resulted in loss in intelligence while ablations of more rostral areas did not.

In a review of temporal lobe studies, Milner (1954) called attention to similar differences in effects on menta lperformances as a function of the specific areas destroyed in the temporal lobes. (It is interesting to note that in one of the studies cited, Weisenberg and McBride (1935), the Porteus Maze, compared to other measures, "notably" differentiated the experimental group from the controls.) Two of the many excellent features of Milner's review were the careful consideration of differences in the anatomical character of brain tissue destroyed and variations in neuro-anatomical degeneration as possibly significant factors related to psychological sequelae of temporal lobe lesions.

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The previously cited neuro-anatomical studies by Yakovlev (1953, 1954a, 1954b) in addition to demonstrating a positive correlation between survival time and the amount of secondary degeneration, also provide a logical rationale for the differences in long-term effects between orbital and superior topectomy in the present study. More marked and sometimes "massive" degeneration was found in the cerebra of leucotomized patients with posterior cuts compared to little degeneration for more anterior lesions.

These consonant findings not only contradict the theory of equipotentiality in the human brain; they clearly differentiate areas within the larger structures, the frontal lobes and the temporal lobes. Thus, the equation of patients with a variety of lesions under such classifications as "brain-damaged" or "frontal lobe cases", "temporal lobe wounds", etc., introduces ambiguities owing to the lack of differentiation and implied equipotentiality of areas within more or less arbitrarily defined larger structures in the brain. The neuro-anatomical studies of lobotomized subjects (Meyer, Beck and McLardy, 1947; Eie, 1954; Le Beau, 1951) have consistently shown a considerable difference between what the surgeon thought he cut and what he actually did cut. The possible variations in specific site of leucotomy lesions may therefore constitute a basis for reconciling the apparently contradictory findings of psychological studies of the effects of leucotomy.

Age

The careful selection of two different age groups (with a 17-year difference in mean ages and no overlapping of ranges) equated for symptoms, length of hospitalization, minimal education, and site of surgical intervention afforded a unique opportunity to study the effects of interaction of the first two factors, length of post-operative interval and specific site, on a third factor, age. The evidence of previous psychological studies of this last factor is understandably meagre. Swartzlander (1952) reported that losses in 19 lobotomized subjects occurred more frequently in subjects over 30. Frank (1946) found similar losses after one year only in leucotomized patients over 55. Lashley (1938) cited numerous animal studies showing the importance of age as a factor limiting recovery of function following brain injury.

In view of the small number of older subjects in the present study, the findings can hardly be considered definitive. However, the greater losses of older operated subjects after an eight-year interval show an internal as well as external logical consistency. The "drop and drop" pattern of the older orbitals, clearly shown in the maze scores for the two post-operative tests, was also shown in other measures which were not markedly affected shortly following surgery. Externally, the results in psychological test performances are in accord with the findings of neurological studies by Meyer (1949) and Le Beau (1951). The cerebra of older operated subjects showed more marked degeneration than those of younger operated subjects. After extensive follow-up studies of large numbers of brain-injured cases previously referred to, Russell reported a positive correlation between age and post-trauma symptoms including loss of memory or mental ability and concluded that age of the patient was the most important single factor determining the sequelae of head injury. Age was also cited as one of the first factors determining the effects of diaschisis by von Monakow and Mourgue (1928). A moment's consideration will show that findings of greater loss in older brain-injured subjects are not remarkable. Cajal (1928) has described in detail the "exquisite" sensitivity and more marked vulnerability of nervous tissue when compared to other histological elements.

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Since the effects of age on other human tissues are readily observed in arteriosclerosis (and the critical role of the vascular supply in the brain should not be overlooked), the more pronounced effect of lesions on older cerebra should not be surprising.

In view, therefore, of the supporting neurological and clinical evidence, the meagre data of changes in the Porteus Maze and other measures for a few subjects should not be discarded. Additional data for other comparable brain-operated subjects are required before this finding of the present study can be properly assayed.

Nature of the Measure

The Porteus Maze was one of the four psychological tests (selected from approximately 100 considered for the CG I study) that were employed in all three related projects. Of the 14 individual and four aggregate measures afforded by these four instruments, it was the most sensitive indicator of early and long term post-operative changes. Several individual measures, I.Q.s and Wechsler Deterioration Indices failed to reveal marked post-operative changes. The systematic post-operative changes (i.e. increasing losses by three operated groups and recovery of initial post-operative decrement by the fourth) were best reflected by the successive maze scores. For the group showing the most marked losses, the 17 Superiors, 16 showed long-term decrements, the score of the 17th remaining unchanged. A possible explanation for the differential sensitivity is that Maze performance requires selective capacities that are vulnerable to brain insult. The Porteus Maze Test (1914) is one of the oldest psychological instruments in use today, but despite numerous studies, external validation has not been achieved. The precise dimensions measured by the test cannot be unequivocably defined. However, its sensitivity to initial changes following brain insult has been abundantly demonstrated in numerous other studies of brain insult where other measures were only slightly, if at all discriminating. Further analytic study of the numerous complex physiological, psychomotor and psychological elements involved in maze performance—i.e. vision, perceptual field organization, psychomotor co-ordination, attention, selection of a response in a choice situation, impulsiveness, planning, immediate memory, learning rates, etc., may contribute to the isolation and identification of the nature of the specific components that are affected by brain insult.

The definition of four factors cited above are limited to the present study and its unique population. However, the unusual consonance of systematic changes in maze scores with the findings of independent neurological and clinical studies suggest that the results may be a psychological analogue for similar structural and behavioural changes observed by investigators in other disciplines. In addition to these four factors, the systematic differences between initial and long-term effects of operation are logically consistent with the effects of diaschisis, and differences between initial and residual symptoms observed by von Monakow, Head, Goldstein and Russell cited above.

These findings suggest that the paradoxical and contradictory conclusions of many studies of *apparently* similar populations of "brain-damaged" subjects with the same psychological instruments may be reconciled if the four factors can be taken into account.

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SUMMARY

1. Eight years after the New York State Brain Research project, 27 operated and 23 non-operated hospitalized chronic schizophrenics, of an original population of 44 operated and 24 non-operated subjects, were re-examined with the Porteus Maze, the Wechsler-Bellevue I, revised Capps Homograph and Weigl Sorting Test. Analysis of the results of the Porteus Maze, which best represented the salient changes with all measures, showed systematic differences between initial and long-term post-operative effects.

2. In contrast to conclusions of a "drop and rise" pattern and "no permanent deficits" in intellectual functions by the original and two related Columbia-Greystone studies, scores eight years later showed statistically significant losses for operated groups in the Porteus Maze and seven other of the 14 individual measures.

3. Changes between initial and eight-year post-operative effects were related to four factors (*a*) length of the post-operative interval, (*b*) specific site of surgical intervention, (*c*) age of the subject at time of operation, and (*d*) nature of the measure, Of the four operated groups, only younger subjects with orbital topectomy failed to show successive post-operative losses.

4. The pattern of increasing decrements in psychological test scores is consonant with findings of increasing neurological degeneration reported in studies of cerebra of other subjects with psychosurgical lesions. The rate and amount of degeneration were found to be positively correlated with the factors of length of post-operative interval, site of surgical intervention (posterior lesions result in greater degeneration than anterior lesions) and age of the subject at the time of operation. This consonance suggests that changes in test scores may be the psychological analogue for neuro-anatomical changes due to later secondary degeneration.

5. Differences in long-term effects of excisions of lower (orbital) and upper (superior) portions in the forebrain contradict the theory of equipotentiality of areas in the "frontal lobes".

6. Comparisons of early and later post-operative effects on older and younger subjects with orbital or superior topectomy clearly illustrate the complex and dynamic temporal nature of the effects of "brain-damage". The effects of diaschisis or post-operative shock and the influence of the four factors cited in (3) above indicate that the reliability and validity of findings of any study are limited to its particular post-trauma time span. Results obtained shortly following brain insult are least reliable. The diverse and contradictory conclusions of many studies of apparently similar "brain-damaged" populations may conceivably be reconciled when the above factors are taken into account.

BIBLIOGRAPHY

1. BRAIN, R., and STRAUSS, E. B., *Recent Advances in Neurology and Neuropsychiatry*, 1955. London: Churchill.
2 CAJAL, R. S., *Degeneration and Regeneration of the Nervous System*, 1928. London: Oxford University Press.
3. CROWN, S., "Psychological Changes following Prefrontal Lobotomy. A Review", *J. Ment. Sci.*, 1951, **97**, 49–83.
4. EIE, N., "Macroscopical Investigations of Twenty-nine Brains Subjected to Frontal Leucotomy", *Acta Psychiat. et Neurol. Scandina.*, 1954, **90**, 3–40.
5. FRANK, J., "Clinical Survey and Results of 200 Cases of Prefrontal Lobotomy", *J. Ment. Sci.*, 1946, **92**, 497–508.

https://doi.org/10.1192/bjp.106.444.967 Published online by Cambridge University Press

6. FRANZ, S. I., "On the Functions of the Cerebrum. The Frontal Lobes", *Archives of Psychology*, March, 1907.
7. GOLDSTEIN, K., *The Organism*, 1939. New York: American Book Co.
8. GREENBLATT, M., ARNOT, R. E., POPPEN, J. L., and CHAPMAN, W. P., "Report on Lobotomy Studies at the Boston Psychopathic Hospital", *Amer. J. Psychiat.*, 1947, **104**, 361–368.
9. HEAD, H., *Aphasia and Kindred Disorders of Speech*, 1926. Vol. I. Cambridge: Cambridge University Press.
10. KLEBANOFF, S. G., "Psychological Changes in Organic Brain Lesions and Ablations", *Psychol. Bull.*, 1945, Vol. **42**, 9, pp. 585–623. November.
11. *Idem*, SINGER, J. C., and WILENSKY, H., "Psychological Consequences of Brain Lesions and Ablations", *ibid.*, 1954, **51**, 1–41.
12. LASHLEY, K. S., "Factors Limiting Recovery after Central Nervous Lesions", *J. Nerv. Mental Dis.*, 1938, **88**, 733–755.
13. LE BEAU, J., "The Surgical Uncertainties of Prefrontal Topectomy and Leucotomy", *J. Ment. Sci.*, 1951, **97**, 408–504.
14. *Idem*, "Post-operative Syndromes in Selective Prefrontal Surgery", *ibid.*, 1952, **98**, 12–22.
15. *Idem*, *Psychosurgerie et Fonctions Mentales*, 1954. Paris: Masson et Cie.
16. LEWIS, N. D. S., LANDIS, C., and KING, H. E. (Eds.), *Studies in Topectomy*, 1956. New York: Grune & Stratton.
17. MALMO, R. B., "Psychological Aspects of Frontal Gyrectomy and Frontal Lobotomy in Mental Patients", *Ass. Res. Nerv. Ment. Dis.*, 1947, **27**, 537–564.
18. METTLER, F. A., and CURRY, M. A., "Nature of the Project", *in* Mettler (Ed.), *Selective Partial Ablation of the Frontal Cortex*, 1949. New York: Hoeber, pp. 3–26.
19. *Idem*, *Psychosurgical Problems*, 1952. Philadelphia: Blakiston.
20. MEYER, A., BECK, E., and MCLARDY, T., "Prefrontal Leucotomy: A Neuroanatomical Report", *Brain*, 1947, **70**, 18–49.
21. MEYER, MARGARET, "A Study of Efferent Connexions of the Frontal Lobe in the Human Brain after Leucotomy", *ibid.*, 1949, **72**, 265–296.
22. MEYER, V., "Critique of Psychological Approaches to Brain Damage", *J. Ment. Sci.*, 1957, **103**, 80–109.
23. MILNER, BRENDA, "Intellectual Functions of the Temporal Lobes", *Psychol. Bull.*, 1954, **51**, 1, 42–62. January.
24. PENFIELD, W., "Symposium on Gyrectomy", *Proc. Ass. Rev. Nerv. Ment. Dis.*, 1948, **27**, 519–534.
25. PETRIE, ASENATH, "A Comparison of the Psychological Effect of Different Types of Operations on the Frontal Lobes", *J. Ment. Sci.*, 1952, **98**, 326–329.
26. POOL, J. L., "Topectomy 1946–1951. Report on 106 Consecutive Non-project Topectomy Operations", *Transactions and Studies Coll. Physicians*, 1951, **18**, 49–67. Philadelphia.
27. PORTEUS, S. D., "Medical Applications of the Maze Test", *Med. J. Australia*, 1944, **1**, 558–560.
28. *Idem*, "Some Common Sense Implications of Psychosurgery", *Brit. J. of Med. Psychol.*, 1955, **28**, 167–176.
29. *Idem*, "Recent Maze Studies", *ibid.*, 1959, **32**, 1, 38–43.
30. *Idem* and KEPNER, R. M., "Mental Changes after Bilateral Prefrontal Lobotomy", *Genet. Psychol. Monogr.*, 1944, **29**.
31. *Idem* and PETERS, H. N., "Maze Test Validation and Psychosurgery, *ibid.*, 1947, **36**.
32. Proceedings of the Third Research Conference on Psychosurgery (1951), *Publn No. 221*. Washington: U.S. Dept. of Health, Education and Welfare.
33. RUSSELL, W. R., "After-Effects of Head Injury", *Edinb. Med. J.*, 1934, **41**, 129.
34. *Idem*, "Late Effects of Head Injury", *Trans. Med. Chirurg. Soc. Edinb.*, 1939, 88.
35. *Idem*, "Transient Disturbances Following Gunshot Wounds of the Head", *Brain*, 1945, **68**, 79.
36. *Idem*, "Studies of Head Injury", *Brit. Med. Bull.*, 1954, **10**, 1, 65–69.
37. *Idem*, "Disability Caused by Brain Wounds", *J. Neurol. Neurosurg. Psychiat.*, 1951, **14**, 35–39.
38. SMITH, A., and KINDER, E., "Changes in Psychological Test Performances of Brain-Operated Schizophrenics After 8 Years", *Science*, 1959, **129**, 149–150.
39. VON MONAKOW, C., and MOURGUE, R., *Introduction Biologique a L'Etude de la Neurologie et de la Psychopathologie Librairie*, 1928. Paris: Felix Alcon.
40. WALKER, H., and LEV, J., *Statistical Inference*, 1953. New York: Holt.
41. YAKOVLEV, P. I., "Fronto-pontine Bundle and Associated Projection Fibers of the Frontal Lobe Following Frontal Leucotomy", *Trans. Amer. Neurol. Ass.*, 1953, **78**, 286–291.
42. *Idem*, "Anatomical Studies in Frontal Leucotomies", *ibid.*, 1954, 173 (a).
43. *Idem*, "Anatomical Studies in Frontal Leucotomies", *ibid.*, 1954, 53–56 (b).

https://doi.org/10.1192/bjp.106.444.967 Published online by Cambridge University Press