Chapter 10

COMPLEX MENTAL FUNCTIONS: MEMORY, LEARNING, MENTAL SET, AND PERCEPTUAL TASKS

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Among the clinical claims that have been made concerning the function of the intact frontal lobes are that within them are "centers" in which are organized perception and learning processes, together with the maintenance of direction of activity and goal seeking. Presumably, injury or surgical ablation of parts of the frontal lobe should lead to interference with these functions. Previous experimental studies of brain tumor and psychosurgery patients yielded no substantiation of these claims, but they still persist in many quarters partly because of the long tradition behind them and partly because it is much more difficult to disprove a hypothesis experimentally than to propose one. It is clear that pure tasks of each of these capacities can be constructed only with great difficulty since perception and learning enter into almost all mental tasks, and maintenance of set is a factor in all mental activity. Nevertheless, tasks can be found that may be regarded as dependent primarily on learning and relatively free of other psychologic functions. Similarly, tasks can be found for testing perception and mental set that are relatively free of other functions.

More than 10 tasks were developed to sample the areas of learning, memory, mental set, and perception. In general, new tasks not previously included in earlier studies were selected or developed and the leads provided by these studies served as a guide. Each of these areas of investigation will be described separately.

The tests were administered approximately 10 days before operation and again about 90 days after operation. The preoperative data are designated as -10A and the postoperative data as +90B. It had been intended to retest the patients several times before operation so as to be able to estimate the degree of intraindividual variability to be expected from mere repetition of a test, but this could not be done for a variety of reasons. After operation, too, it did not prove feasible to test the patients more than once. Since it was not practicable to prepare comparable forms of each of the tests for postoperative administration, the tests used preoperatively were repeated. This introduced the uncontrolled variable of familiarity with the test as well as practice effects, but it seemed safer to run this risk than to utilize new tests.

The composition of the patient group varied for the different tests,
and for this reason the patients included in each test procedure will be described for each test.

THE TESTS

Memory and Learning

Retention of learned material over extended periods (3 weeks to 3 months) was studied exhaustively in the first Columbia-Greystone project (Stauffer, '49), but the function of immediate memory was touched upon only lightly. In the present study immediate memory was subjected to closer scrutiny. The tests used were: (1) incidental memory, (2) sequential delayed reaction, (3) verbal directions, and (4) the learning task.

INCIDENTAL MEMORY. It seems likely that the grosser features of memory functioning are usually untouched by frontal lobe surgery but that the more subtle aspects of memory such as incidental memory or span of memory might be impaired. Thus an operated patient may be able to recall material to which his attention had been directed but might be unable to recall the more incidental memories which accompanied the perception of objects or events in the focus of his attention. In order to examine incidental memory the following technique was utilized. A picture was exposed for 2 seconds after the patient's attention had been directed to a special feature in the picture. Then he was asked to recall not only the special feature to which his attention had been directed, but also several other incidental features which had not been called to his attention. Two pictures were used: (1) Chinese Grandfather, Son, and Grandchildren (Perry, '40) and (2) Card No. 2 of the Thematic Apperception Test (Murray, '43). The directions for the first picture were as follows:

I am going to show you a picture for a short period of time. Look at it carefully because when I take it away I am going to ask you how many people you saw in it.

After a 2-second exposure, the patient was asked how many people were in the picture. In addition to this, he was asked how many children and how many adults were in the picture. He was also asked to tell whatever else he could remember. The second picture was presented after a brief interval. The directions for the second picture were similar to those given for the first except that the patient's attention was directed to what the people were doing and the incidental memories dealt with the number of men and women in the picture and whatever else he could recall.

SEQUENTIAL DELAYED REACTION TEST. The delayed reaction experiment which has been investigated in animal experimentation on
cerebral ablations has seldom been tried with patients. The technique adopted in the present study utilized 6 wooden boards, on each of which were fastened 12 playing cards. Six were aces and 6 were nines and tens. The cards were placed in random order so that no 2 boards were alike. Each playing card was covered by a piece of stiff, gray cardboard hinged to the wooden board so that the playing cards could be exposed by lifting the lid for a brief exposure.

The patient was seated in front of the first board and instructed as follows:

Beneath these cover lids are playing cards. There are aces, and nines and tens. I am going to show you the aces and I want you to remember where they are.

The examiner exposed the first 2 aces and asked the patient:

Show me the first ace I showed you; just the first one.

After the patient indicated the first ace, the examiner exposed the third ace. The patient was then asked to show the examiner the second ace that had been exposed. The examiner kept one ace ahead of the patient. This procedure was followed for the first 2 boards. If the patient was successful with this part of the experiment, he was given 2 more boards. This was essentially the same as the single delay sequence, except that the examiner allowed a lag of 2 aces between the patient’s uncovering and his own. If the patient completed this, the examiner continued with triple delay, allowing a lag of 3 aces between the patient’s uncovering and the examiner’s exposure. In this manner, the nature of the delay was graded in difficulty. Each ace was exposed for approximately 2 seconds.

VERBAL DIRECTIONS. One of the important elements in efficient social interaction is the capacity for understanding directions for carrying on everyday activities. In the first Columbia-Greystone project (Stauffer, ’49), this type of test was used as a learning task to see how many repetitions were required before an entire set of directions could be mastered. The results indicated that the ability to learn such directions and to retain them was not impaired by topectomy. In the present study, this test was used not as a learning task but as a means for testing immediate comprehension and retention.

A list of simple directions was read to the patient and he was asked to repeat it. Credit was given for the recall of a memory item even when the patient did not repeat verbatim the original words, provided he recalled their intended meaning. The following directions were given:

I am going to read you some directions on how to do certain things. Listen carefully and then repeat the directions in your own words. For example; here are the directions for “Going to the movies”: (1) Go to the ticket booth, (2) Ask for a ticket, (3) Pay for it, and (4) Give it to the ticket collector as you walk in.
If the patient could not repeat the above directions or recalled only one item, he was given another set of simple directions on "Sharpening a pencil." If these 2 were failed, the test was terminated and recorded as a failure. If the patient succeeded in the first set of directions, the examiner proceeded to the main experiment which consisted of 2 sets of directions, one for "Ordering an overcoat" and the other on "Learning how to swim."

LEARNING TASK. In the first Columbia-Greystone project an attempt was made to study meaningful and semi-meaningful material to see whether psychosurgery affected the learning of the various materials differentially. No striking changes were noted in this respect. The present study was limited to semi-meaningful material and dealt with the more intricate aspects of learning rather than the grosser aspects covered in the previous study. Instead of the paired associate method utilized previously, serial list learning was chosen as the learning task. This has the advantage of requiring greater interitem organizing ability on the part of the subject and of permitting a closer analysis of the learning process with special reference to the effect of serial position, retroactive, and proactive interference, and other learning phenomena which can be measured directly. In order to render the task as meaningful as possible for the patient, the lists consisted of the names of pseudo radio stations in various cities. The pseudo radio stations technique has several advantages. First, it provides a quasi-meaningful approach which the patients accept readily. Previous attempts at teaching mental patients nonsense syllables proved it to be a task for which the patients were insufficiently motivated, whereas the radio station idea seemed to appeal to them. Secondly, the syllables are spelled rather than pronounced, thus removing differences in pronunciation as a possible source of error in recording the learning process. The use of spelled rather than pronounced syllables was introduced by Witmer ("35), who has determined the associative value of 4534 3-letter nonsense syllables constructed from 19 consonants of the alphabet. In the present study only syllables with a 50 per cent association value in Witmer's list were included.

Since several studies (Ach,"35) have shown that some types of individuals respond differently to tasks in which the tempo of work is more or less under their spontaneous control, in contrast to those in which the tempo is fixed by external means, the learning task was administered under these 2 conditions of spontaneous or "free" tempo vs. "forced" tempo. For the "forced" tempo a memory drum was used in the standard fashion with a 6-second interval between exposures, while for the "free" tempo the patient himself actuated the memory drum by means of a microswitch which could be pressed down to move the drum to the next position.

The method utilized in this experiment was to have the patient learn a list of either 4 or 6 pseudo radio stations to a criterion of 2
correct successive repetitions. The syllables were learned in a serial
order by the anticipation method under massed practice conditions.
They were mounted on a continuous paper band on a memory drum
and were presented in pica type capital letters on heavy paper. They
were exposed through a window 6 cm \times 1 cm. Bright illumination
without glare was provided by a light behind the patient. At each pre-
operative testing session the patient was presented first with a prac-
tice list of 4 syllables. This was followed by a forced tempo list of
either 4 or 6 syllables, and finally by a similar free tempo list. The
practice list, which consisted of genuine radio stations in the New York
area, was given to acquaint the patient with the task, and to supply the
examiner with a gross estimate of the patient's learning ability. On
the basis of this information, lists of either 4 or 6 units were utilized
in the main experiment. At each postoperative test session, too, the
patient was first presented with the practice list. Then the free tempo
list was given, followed by a forced tempo list. (The order of free and
forced tempo was reversed from the preoperative test to the postoper-
ative test.)

The following directions were given for the practice list:

I would like to see how quickly you can learn the names of the radio sta-
tions in New York. Read the names as they appear in the window.

The examiner then demonstrated how the memory drum operated and
instructed the patient to anticipate the syllables before they appeared
in the window. If the patient was able to anticipate this list correctly
to the criterion of 2 successive errorless repetitions in 20 trials or
less, he was given a 6 syllable list in the main experiment; if he re-
quired more than 20 trials, he was given 4-syllable lists.

After the practice list was learned, the patient was instructed:

Now I want to see how fast you can learn a list of radio stations for the
city of Boston. Read the names as they appear in the window.

Each syllable was exposed for a 6-second interval, and was followed
immediately by the next syllable. Between successive presentations
of the list there was a 12-second pause.

After forced tempo learning was accomplished to a criterion of 2
correct successive repetitions of the list, the patient was instructed:

This time we are going to do it differently. You can move the list your-
self. . . (Examiner demonstrated manual mechanisms)... Read each station
as it appears in the window and then press down on this bar to get the
next station. This is a list of the radio stations from the city of Chicago.

This was continued until the patient mastered the list to a criterion of
2 correct reproductions in sequence. (The investigators are indebted
to Mr. Charles Lothridge for his assistance with this part of the ex-
perimental program.)
Mental Set

Mental set has been defined as a condition of readiness for some specific type of mental performance. A mental set can be initiated either spontaneously or in response to someone's command or request. It may be temporary or it may last for a longer period. Furthermore, a mental set may involve such tasks as sorting, in which a categorical attitude is required for correct performance, or it may involve simpler activities such as counting. Since an individual in the waking state is rarely completely inactive, the initiation of mental sets usually involves a shift from a previous set to the new one. Goldstein (1936), among others, has expressed the opinion that mental set depends on the integrity of the frontal lobes. For such reasons an attempt was made in this study to examine some of the mental set phenomena which had not undergone close scrutiny in the first Columbia-Greystone study.

The tasks for measuring mental set utilized in this study were as follows: (a) interrupted set (counting and reciting the alphabet and names of the months), (b) interrupted task, (c) directional set (street map mazes), (d) the word selection set, and (e) the sustained task technique (Kraepelin, 1925), in which the patient is required to add continuously for a 15-minute period. Each of these set experiments will be taken up separately.

**INTERRUPTED SET.** (Counting and reciting the alphabet and the names of the months.) In this task, which requires the ability to maintain a set in the face of distracting circumstances and to shift from one set to another, the patient was instructed as follows:

I'd like you to start counting aloud, 1, 2,...Stop. Now I'd like you to recite the letters of the alphabet, A, B,...Stop. Tell me the months of the year, January, February,...Stop. Now I want you to start counting again where you left off last time...Stop. Tell me the letters of the alphabet starting with the letter you left off with last time...Stop. Now tell me the months of the year starting with the month you left off with last time...Stop.

The counting was continued for 7 to 11 digits each time and the alphabet and month recitation was continued for an equal series. When the end of the alphabet was reached the patient was told to begin over again with A, and similarly when the end of the months was reached he was told to start over again with January. This change from numbers to letters to months was repeated 3 times at each testing period.

**INTERRUPTED TASK.** The interrupted task technique has been utilized on both normal subjects and mental patients. In general it tends to differentiate between these 2 groups. Ach (1935) has explained the effectiveness of the interrupted task on the basis of his "will" theory, while Lewin (1935), who originated the method, explained it on the basis
of "unresolved tensions." The procedure was to give the subjects a series of tasks, about half of which were permitted to go on to completion while the other half were interrupted. There were at least 3 ways of measuring the effect of the interruption: (1) recall method, (2) resumption method, and (3) substitutive method. The recall method consisted essentially of having the subject attempt to recall the entire series of both completed and incompleted tasks. He usually recalled the incompleted tasks more frequently. The resumption method consisted of exposing the subject, after the interruption had taken place, to the materials of both the interrupted as well as the completed tasks to see which type of task was resumed. Here again the incompleted task had the advantage. The substitutive method of Lewin presented a new task immediately after the interruption to see whether the "unresolved tension" would expend itself on the substitute material. The specific method utilized in this study was the resumption technique.

The patient was given a simple 25-piece jigsaw puzzle. When the puzzle was half completed, it was taken away and the patient was given some of the pieces of the Lowenfeld Mosaic test (Kerr, '39) and asked to make a design. He was told that he might use as many pieces as he liked and might make any kind of design he wished. The incompleted jigsaw puzzle and a deck of playing cards were placed within reach on the table. After the patient had completed the mosaic design to his satisfaction, the examiner told him that he might do anything he liked while waiting for the next task, because the examiner had to complete his notes. (The examiner had been taking notes throughout the procedure.) If the patient did not resume the puzzle after 2 minutes he was reminded that he might do anything he liked. If he did not resume after 5 minutes the experiment was terminated.

DIRECTIONAL SET. (Street Map Mazes.) One characteristic feature of some schizophrenic and neurotic patients is the degree of rigidity or inflexibility they exhibit in performing simple tasks. This type of rigidity leads to stereotyped behavior which is characterized by the maintenance or adoption of mental sets that are not suitable to the task at hand. Many of the chronically ill patients included in this study exhibited this form of stereotypy during the period of preoperative testing. We wished to determine whether such behavior would be disturbed by the various operative procedures and whether patients who did not exhibit such stereotypy might begin to exhibit such behavior after psychosurgery. In order to examine these phenomena experimentally an attempt was made to establish a fixed directional tendency in the patient. Then the degree of pressure required to alter this directional tendency, or to break the previously established set was measured.

The patient was given a series of mazes, set up as street maps and was instructed as follows:

I am going to show you some street maps. At the bottom of each one you will see a car. You are to drive the car to the park. You must remember that you should stop at the stop sign and that you cannot go through a dead-end street. Trace the route that you would take to get to the park.
In the first series of 5 mazes, the only correct solution was to turn to the right. The next series of mazes was basically similar in design to the first, but it gave the patient the opportunity to break the set spontaneously. He could take the previously established route to the right, or take the shorter route to the left. He was then given a third series of mazes, where the only correct solution was to take the left, or the shorter route. The patient was thus forced to break his previous set in this last series of mazes, if he could not break it spontaneously in the second series of mazes.

WORD SELECTION SET. One method of testing the capacity of maintaining a mental set is through the controlled word association technique. In this technique the patient is given the set to respond with antonyms or synonyms or some other type of association when the stimulus word is presented. An adaptation of this controlled association method was made to set the level of functioning of the chronically ill mental patient studied in this investigation. In order to remove any obstacles to response arising from unfamiliarity with the stimulus words, only words of the Thorndike A level (Thorndike and Lorge, '44) were used. Instead of the more difficult task of supplying the correct association to the stimulus word, the patient was asked to recognize the correct response from a pair of words presented tachistoscopically. There were 3 levels of the task; the single set, double set, and triple set. In the single set, the patient was required to select from the pair of exposed words the word that designated part of the body. The pairs of words (one distractor and one correct choice) were presented tachistoscopically first at an exposure of 10 milliseconds. This was done 3 times and then the time of exposure was increased stepwise to 20, 40, 100, 200, 500, and 1000 milliseconds until the patient made a correct selection in accordance with the set established by the instructions. The double set consisted of selecting out of the pair of words the one word which designated either a part of the body or a food. Only 2 words were flashed on the screen (a distractor and the correct choice) and the exposure intervals were the same as for the single set. The triple set consisted of directions to select the one word in the pair which designated either a part of the body, food, or color.

A record was kept of the exposure interval at which the correct choice was made, and whether it was the first, second, or third exposure at that interval. The degree of certainty of each judgment was estimated by a rating ranging from complete uncertainty to complete certainty in 3 steps. The various misrecognitions which were given by the patient before he recognized the word correctly were also noted. In this way it was possible to measure the ability of the patient to maintain a single set, double set, and triple set.

THE SUSTAINED TASK. Kraepelin ('25) showed that one of the distinguishing characteristics of mental patients, especially schizophrenics,
is their lack of capacity to maintain efficiency in a prolonged task. While tasks of short duration may not reveal a difference between normals and mental patients, a task continued for a long time is likely to show a much greater decrease in the patient than in the normal individual. The task utilized in this study was the same as that utilized by Kraepelin, namely, continuous addition of simple numbers. The purpose of this technique was to determine whether the frontal lobe operations tended to alter the efficiency of mental patients in long continued tasks. H. E. King ('49), after applying the "Continuous problem task" which involved the learning of complex positional light patterns, concluded that there might be a deficiency in this function in the topectomy patients. Instructions were given the patient as follows:

I want to see how fast you can add. When I say "Ready, go"... begin to add these figures as fast as you can and continue until I tell you to stop. When you come to the end of one page do not stop; but go on to the next page. Ready, go.

The patient was given a soft pencil with an eraser. Constant bright illumination without glare was furnished by a floor lamp stationed behind and to the left of the patient. The examiner's stopwatch was concealed from the subject.

A notation was made of the patient's progress per minute in terms of his position on the additions sheet, from which a minute-by-minute work curve was later obtained. The test continued for 15 minutes.

The patient was then presented with 5 sheets of 2-digit addition problems, each sheet containing 90 additions in which the patient had to "carry" from the first to the second column. "Carrying" was introduced to note whether the extra effort involved would tend to introduce errors as the work continued. The patient was instructed as follows:

Now I would like to see how fast you can work adding these figures. Add the problems on these pages as quickly as possible.

Notation was again made of the progress per minute. This test continued for 5 minutes.

Perceptual Tasks

The first Columbia-Greystone study had utilized the following projective techniques; the Word Association test, the Rorschach test, and the Levy Movement Blots. No demonstrable changes occurred in the word association test as a result of the operation. The Rorschach test performance was analyzed individually as well as statistically but only one significant finding emerged, namely, the reaction time to the first response was reduced.
DIGIT PERCEPTUAL SPAN AND WORD RECOGNITION TEST. The word association technique was modified so as to remove certain of the difficulties which might interfere with the analysis. The important element in the word association technique for our purpose was the stimulus word, which we thought might prove to be either of neutral or emotional significance for the patient. In previous studies neutrality or emotionality was judged by examining the type of response given; that is, whether it was an expected or unexpected word, whether it had a long or short reaction time, or whether it showed any other indications of being complex-bound. The difficulties inherent in making such judgments were thought to militate against an accurate evaluation of the results. Since the emotional tone is set off by the stimulus word, it might be better to study the impact of the stimulus word directly rather than through the response word which is elicited.

One way of studying the emotionality that attaches to the stimulus word is to determine its ease of recognition under tachistoscopic conditions. Presumably a word that is emotionally charged may require a longer time for recognition. One study (Bruner and Postman, '47) utilizing this method indicated that, in college students, words which seem to be emotionally tinged tend to have longer recognition times and give rise to many misrecognitions during the trial-and-error period. The manner in which a subject misrecognizes a given word sometimes indicates the emotionality that attaches to the word. This technique was adapted to the need of the patients in the following manner: first, the digit span of the patient was determined by exposing one-digit, 2-digit and 3-, 4-, or 5-digit numbers at 10 milliseconds. This served both as an introduction to the perceptual tasks as well as a means of determining perceptual capacity. Then a series of neutral words selected from the Kent Rosanoff list was presented one at a time at a 10-millisecond exposure. Each word was shown 3 times in succession and the time required for response, the actual response given, and a judgment as to certainty of response was recorded. If the subject failed to recognize the word correctly the procedure was continued with longer exposures of 20, 50, 100, 250, 500, and 1000 milliseconds with 3 exposures at each interval until the patient made a correct recognition of the word. A similar list of emotional words selected from the Orbison list (Rappaport, et al., '46), and a list of words culled from the patient's case history on the basis of their likelihood of arousing complex-bound associations was also used.

RESULTS

Memory and Learning

INCIDENTAL MEMORY. The incidental memory test was administered to 18 patients preoperatively, 14 in the operated group and 4 in the control group. Since the test contained 2 aspects of immediate memory, a direct item to which the patient's attention had been called and
 incidental items to which the patient's attention had not been called, 2 scores were available. Standards for these 2 scores were established on the basis of the preoperative data. The modal response to each question was accepted as correct. Thus, a response of either "7" or "8" persons was accepted as correct for the direct memory item to Picture I, while answers in excess of 8 or below 7 were scored as errors. Responses of "3" or "4" children were accepted as correct for the indirect memory item. Similarly, the answers such as "farming" or "cultivating" were accepted as correct for the direct item to Picture II, and "one or 2 men" and "one or 2 women" were accepted as correct for the incidental items in the picture. Any response that differed from the standard was scored as an error. The number of errors in the 2 contrasted groups, operated or control, is shown in Table 26 for the direct and incidental items combined, since no differences were obtained between them.

Table 26

TOTAL NUMBER OF ERRORS IN THE TEST OF INCIDENTAL MEMORY IN THE OPERATED AND CONTROL GROUPS

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>-10A</th>
<th>+90B</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operated</td>
<td>14</td>
<td>9</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Control</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>11</td>
<td>13</td>
<td>24</td>
</tr>
</tbody>
</table>

It may be concluded that as far as immediate memory is concerned, of both the direct and incidental types, no significant changes attributable to psychosurgery were demonstrable. This test was in the process of development during the preoperative test sessions. Conditions under which it was administered and the directions for giving the test were modified and revised. Because of these modifications in administration there are too few comparable cases. It is felt, however, that the rationale is essentially a sound one, and that with more standard presentation methods, this easily administered test might prove to be a valuable tool.

SEQUENTIAL DELAYED REACTION. There were 23 patients in this experiment; 19 were in the operated group and 4 were controls. All of the patients were tested 2 weeks preoperatively and 3 months
postoperatively. The records were scored in terms of errors in identifying the aces. Every time the patient uncovered a card that was not an ace an error was registered on his record. The data are shown in Table 27. In general, no striking differences were obtained from the

<table>
<thead>
<tr>
<th>Operative Technique</th>
<th>N</th>
<th>-14A</th>
<th>+90B</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL</td>
<td>10</td>
<td>2.08</td>
<td>1.92</td>
<td>0.17</td>
</tr>
<tr>
<td>TO</td>
<td>5</td>
<td>3.06</td>
<td>3.30</td>
<td>-0.26</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>2.33</td>
<td>2.49</td>
<td>-0.16</td>
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<tr>
<td>All</td>
<td>19</td>
<td>2.37</td>
<td>2.40</td>
<td>-0.03</td>
</tr>
<tr>
<td>Control</td>
<td>4</td>
<td>1.24</td>
<td>2.21</td>
<td>-0.97</td>
</tr>
</tbody>
</table>

preoperative to the postoperative testing. Both the operated group and the control group showed a slight tendency to make an increased number of errors in the second testing session. The group of venous ligation patients showed a contrary trend, however, their errors decreasing slightly in number postoperatively. Because the technique was not standardized until later, and because of the possible effects of interexaminer differences, these observations should be regarded as only tentative.

The ability to perform sequential delayed reaction problems, as measured by the materials used in this experiment, was not at a very high initial level in these patients. The variability in the results, and the lack of consistency within the operated groups, make it difficult to interpret the losses and gains in terms of the operative procedures. If this test is to be used in future research both the test materials and method of procedure should be changed.

VERBAL DIRECTIONS. This test was administered to 20 patients; 16 operated cases and 4 controls. Since the 2 repetitions of each test yielded approximately similar results, the sums of the items recalled on both repetitions were totalled and considered as one score. The average number of items recalled on the 2 forms of each test is shown in Table 28. The 2 tests differed in their susceptibility to practice
NUMBER OF MEMORY ITEMS RECALLED ON THE VERBAL DIRECTIONS
TEST BY THE OPERATED AND CONTROL GROUPS

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Form A (Overcoat Order)</th>
<th>Form B (Swimming Lesson)</th>
<th>Gain</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pretest</td>
<td>Post-test</td>
<td>Pretest</td>
<td>Post-test</td>
</tr>
<tr>
<td>Operated</td>
<td>18</td>
<td>8.6</td>
<td>9.6</td>
<td>7.9</td>
<td>7.6</td>
</tr>
<tr>
<td>Controls</td>
<td>4</td>
<td>7.3</td>
<td>9.8</td>
<td>10.5</td>
<td>10.3</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>8.3</td>
<td>9.6</td>
<td>8.4</td>
<td>8.1</td>
</tr>
</tbody>
</table>

effects, Form A showing a gain of 1.3 points while Form B showed no gain. It is interesting to note that the control group gained 2 1/2 times as much as the operated group on Form A, but because of the small number of patients in the 2 groups no valid statistical comparison could be made. Nevertheless, the material interested the patients and was responded to adequately by those whose capacity was equal to the task. If it is to be used in future work of this sort it should be revised, expanded, and extended.

LEARNING TASK. There were 9 patients on whom sufficient records were obtained, 7 operated and 2 controls. The means for the +10A testing and the +100B testing for the forced and the free procedures are shown in Table 29.

Table 29

MEAN NUMBER OF TRIALS REQUIRED FOR LEARNING
BY THE FREE AND FORCED PROCEDURES

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Forced Tempo +10A +100B</th>
<th>Difference</th>
<th>Free Tempo +10A +100B</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operated</td>
<td>7</td>
<td>20.7</td>
<td>15.9</td>
<td>4.8</td>
<td>15.9</td>
</tr>
<tr>
<td>Control</td>
<td>2</td>
<td>10.0</td>
<td>9.0</td>
<td>1.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>18.3</td>
<td>14.3</td>
<td>4.0</td>
<td>13.7</td>
</tr>
</tbody>
</table>
The forced procedure seems to show a greater practice effect than the free and this was especially marked in the operated group. In the free procedure the operated group shows a slight loss while the control group shows the normal effects of practice.

Clear-cut interpretations of these data are difficult to make in view of certain deficiencies in the experimental design and other testing irregularities, namely:

1. No second postoperative retests were given. This was contemplated in the original design of the experiment (but not carried through) in order to evaluate the influence of the mutual interaction between forced tempo and free tempo lists by alternating the sequence of presentation. Consequently the effects of the operation are confounded with the forced-free effect.

2. The same lists were given preoperatively and postoperatively to assure a constant level of difficulty of material, but this also confounds the variables of remote retention and learning ability.

3. All scores were recorded in terms of number of trials, but since the patients controlled the rate of syllable presentation of the free tempo procedure, this measure does not accurately reflect the speed of learning. It would have been desirable to record the time required for free learning in addition to the number of trials.

4. Some patients were given lists consisting of 6 syllables, while other patients were presented with 4-syllable lists because it was found that they could not master the 6-syllable lists within a reasonable number of trials. In comparing the results of the 4- and 6-syllable lists certain extrapolations had to be made, the validity of which is questionable. There is no consistent significant change from before to after surgery in the relative difficulty of the syllables within the lists. Thus, we find no support for the contention that brain-operated cases show a greater susceptibility to intraserial interference as was claimed by Malmo (’47). Similarly an analysis of the oscillations in correct response after the criterion of learning was met showed no changes which could be related to the effect of the operation.

**SUMMARY.** Although the memory and learning tests did not indicate any definite changes attributable to the operation in this study, it may be concluded that these tests and techniques reflect patient behavior in such a consistent manner that when modified they can be utilized to advantage in future studies. The Verbal Directions test for measuring immediate retention and the free and forced techniques in learning lists of nonsense syllables seem especially suggestive for further study.

**Mental Set**

**INTERRUPTED SET.** (Counting, reciting alphabet and months.) The number of errors in counting and in reciting the alphabet and months
of the year was noted and a total error score obtained for each patient. Since there were 2 interruptions in each task, the maximum possible number of errors for each of the tasks was 2, or a total of 6 for the 3 tasks combined. Whenever the patient resumed the counting at or near the point which he had reached when he was interrupted, the performance was considered satisfactory. If, however, he lost his place completely or started at a point 2 or more digits (or letters or months) away from the stopping point, it was regarded as an error. The mean number of errors in the operated and control groups is shown in Table 30.

Table 30

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>-10A</th>
<th>+90B</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operated</td>
<td>14</td>
<td>1.71</td>
<td>1.63</td>
<td>-0.08</td>
</tr>
<tr>
<td>Control</td>
<td>4</td>
<td>2.00</td>
<td>0.75</td>
<td>-1.25</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>1.78</td>
<td>1.46</td>
<td>-0.33</td>
</tr>
</tbody>
</table>

There was a definite improvement due to practice in the control group, but the operated group as a whole did not show such improvement. Analysis of the performance of the venous ligation group of 8 patients indicated that they showed relatively more practice effect than did the control group. The transorbital group of 4 patients showed a tendency not to benefit from practice.

There were some operated and some control cases in which performance in this task improved slightly at +90B testing, and there were also some operated and some control cases in which performance was poorer at +90B. In no case was there evidence of gross improvement or gross deterioration in this test, nor was there a significant difference between the control and operated groups.

In view of Malmö’s (47) report of a similar technique applied to one psychosurgery patient we had expected this test to be of greater usefulness than it was. In contrast to his finding of a large increase in errors postoperatively, our patients showed a decline in number of errors.

With regard to the use of this test in future work it seems doubtful that it will ever serve in its present form as a profitable part of a test battery since patients usually perform the task quite well initially and little opportunity is left for subsequent improvement. Hence, it can prove useful only for very deteriorated patients.
INTERRUPTED TASK. There were 24 patients to whom this task was administered preoperatively. The tasks selected for this experiment did not hold equal interest for all patients. Some thought the jigsaw puzzle childish and refused to continue, while others thought it fun. It was felt that in some cases the non-resumption of the task after the interruption was a function of lack of interest, rather than lack of tension toward completion of the interrupted task. The selection of materials for this type of task for use with mental patients is a source of difficulty that we have not been able to overcome. It is for this reason that no postoperative data were obtained. If adequate testing materials can be devised this area of study might be of interest in a future study.

DIRECTIONAL SET. Data were obtained for this test on 22 patients, 18 operated and 4 controls. All but 2 of these patients were tested 3 times—twice preoperatively (−60A, −30B) and once postoperatively (+60C).

This test was aimed primarily at determining whether the right-turning habit established in the first 5 mazes induced a rigidity of performance that prevented spontaneous shifting to the shorter left-turning route. For those who did not make a spontaneous shift, a further opportunity for breaking the right turning habit was provided by the last 4 mazes in which the patient was forced to shift to the left. The number of errors which he made before turning leftward was a further measure of the degree of rigidity.

One of the most striking findings is the consistency of performance found in the 2 preoperative administrations. The patients usually repeated the same pattern of behavior on the second preoperative testing. Instead of the usual practice effects there was a preoperative rigidity. Of the 22 patients 14 could only take the shorter route when forced to do so on the last 4 street maps. These patients behaved as if they were suffering from psychic blindness extending over the left field of vision. After having established a right-turning habit, the shorter left route, seemed completely out of the realm of their perception. After the operation, 3 of these patients showed even a greater inability to relinquish the right-turning habit. One patient improved, being able to break the set spontaneously although unable to do so before the operation; the remaining 8 patients performed exactly as they had done before the operation. Of the latter 8 patients, 2 were controls.

Table 31 shows the pre- and postoperative performance of the operated and control groups with regard to spontaneous shifting. If a patient was able to shift spontaneously either at −60A or −30B he was considered as having shifted spontaneously preoperatively. In the group as a whole, 18 of the 22 patients did not alter their performance postoperatively, 13 remaining incapable of making the shift and 5 performing the shift spontaneously both times. Four patients altered their performance, one for the better and 3 for the worse. The control groups showed no changes from pre- to postoperative testing.
### Table 31

**SPONTANEOUS SHIFTING OF SET (+) IN THE OPERATED AND CONTROL GROUPS FOR PREOPERATIVE AND POSTOPERATIVE TESTING**

<table>
<thead>
<tr>
<th>Operative Technique</th>
<th>Pre+ Post+</th>
<th>Pre- Post-</th>
<th>Pre- Post+</th>
<th>Pre+ Post-</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL</td>
<td>11</td>
<td>3</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>TO</td>
<td>5</td>
<td>3</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>TH</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>All</td>
<td>18</td>
<td>3</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Control</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Eight patients out of 22 were able to change their set spontaneously before the operation. There were 6 operated and 2 controls in this group. After the operation 3 of the 6 operated patients could take the left route only when forced, although they were able to change their set before the operation; 3 remained unchanged. The 2 control patients also remained unchanged.

In order to get an estimate of the rigidity or flexibility exhibited by the patients, a clinical estimate was made of the quality of their total performance, including the spontaneous shift as well as the forced shift. The judgments were made with regard to changes from pre- to postoperative behavior in 3 steps; (1) increased rigidity, (2) increased flexibility, and (3) unchanged.

Table 32 shows the patient who evidenced a greater rigidity, a greater flexibility, or remained unchanged postoperatively by type of operation. Of the patients who showed greater rigidity postoperatively, 2 were venous ligations, 2 were transorbital lobotomies, one was a thermocoagulation, and one a thalamotomy. It is interesting to note, however, that all of the controls remained unchanged. It follows that any changes in performance cannot be attributed to the nature of the operation.

In order to obtain an overall quantitative measure of the performance of each patient, a total score was obtained in which each spontaneous change of set was given a credit of 2, and each error in the group of forced-change mazes was given a weight of -1. These scores for each individual were computed and the 66 scores obtained on the 3 tests were transmuted into a T-scale (Garrett, '47). The
Table 32

INCREASE IN RIGIDITY AND FLEXIBILITY OF SET IN THE POSTOPERATIVE TESTING

<table>
<thead>
<tr>
<th>Operative Technique</th>
<th>N</th>
<th>Increase in Rigidity</th>
<th>Increase in Flexibility</th>
<th>Unchanged</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL</td>
<td>11</td>
<td>2</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>TO</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>TH</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>18</td>
<td>6</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Control 4 4

The performance of each patient was then given its equivalent T-score and the means for the operative and control groups computed as shown in Table 33.

Table 33

MEANS OF OPERATED AND CONTROL GROUPS ON DIRECTIONAL SET TEST IN T-SCORES

<table>
<thead>
<tr>
<th>Operative Technique</th>
<th>N</th>
<th>-60A</th>
<th>-30B</th>
<th>+30C</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL</td>
<td>11</td>
<td>51.36</td>
<td>50.82</td>
<td>50.45</td>
</tr>
<tr>
<td>TO</td>
<td>5</td>
<td>53.00</td>
<td>46.00</td>
<td>45.20</td>
</tr>
<tr>
<td>All*</td>
<td>18</td>
<td>51.00</td>
<td>49.44</td>
<td>47.72</td>
</tr>
</tbody>
</table>

Control 4 52.25 52.75 53.75

*Includes one TH and one TC patient.

It will be noted that the control group increased but slightly from test to test. The operated group as a whole declined from the -30B
testing to the +90C testing 1.72 points. Although this difference was not found to be statistically significant, it nevertheless may be an indication of the general tendency for the operated patients to gain less than the control patients from repeated practice on a test.

A factor that cannot be overlooked, is an inadequacy of procedure which made it difficult to determine the basis of the postoperative changes. Five of the mazes were so constructed that the only correct solution was a right-turning movement, while on 4 others the patient had the choice of the previously established right-turning movement, or a "shorter" left-turning movement. These were given to see if the patient could shift "spontaneously." In the last 4 mazes the right-turning movement was blocked and the patient was forced to move to the left. Because the patients were not "forced" to take the left route in the second part of the experiment, some shifted and some did not. This freedom of choice might serve as a differential reinforcing agent upon the first and the third parts of the subsequent postoperative testing. There was nothing in the directions or the nature of the experiment to insure equality of reinforcement, nor was there any indication that the left route was possible during the second part of the experiment. Greater rigidity in the postoperative performance might be due to the fact that the right-turning tendency had more positive reinforcement through the patient's own choice. In view of this difficulty, the same mazes should not be reused postoperatively and a new type of maze should be utilized for testing for possible changes. Instead of a left-right choice, a top-bottom choice could be used in the postoperative testing. If one maze be inserted between the first and the second part of the experiment, for the purpose of demonstrating to the patient that a movement to the left is possible or calling attention to left-turning movements, it would eliminate the possibility of a "spontaneous" shift on the part of the patient, but it would make the data more amenable to analysis since it would equate reinforcement for all patients.

**WORD SELECTION SET.** The responses in the word selection tasks were scored by means of a T-scale technique (Garrett, '47). This numerical evaluation was obtained by tabulating the total number of correct responses at each exposure-trial per list, and then computing the corresponding T-scale score for each of the successive trials. This scoring method showed that the tests were too easy for the better patients, who had little difficulty in recognizing most of the words with a 10-millisecond exposure. Thus, an artificial ceiling was imposed upon the scores in that there was relatively little possibility of registering any significant improvements which might have occurred in postoperative performance. The data, though unsatisfactory, indicated a tendency towards postoperative improvement for the transorbital and venous ligation groups, but since the controls also show a slight gain in the second testing, a portion of this gain must be attributed to practice effects.

In general, these word selection tests appeared to be useful
instruments for evaluating abilities in set and perception which might afford stable measures under more carefully controlled conditions than we were able to employ.

SUSTAINED TASK. The sustained task was given to 16 patients, 12 operated and 4 controls. The work curves for the operated and the control groups were plotted for the 15-minute work period minute-by-minute. The control group as well as the operated showed considerable variation from minute to minute and no trend was evident. There was a tendency in the control group for a steady rise in output per minute and no indication of any slowing within the 15-minute interval. This held true of both the preoperative and the postoperative test, but the latter in general was on a lower level of efficiency than the preoperative test. The operated group showed a short warming-up spurt followed by a gradual decline. This held true of the preoperative as well as the postoperative test.

In the absence of any significant differences between the operated and unoperated groups, the performances of the individual operated patients were examined for any consistent trends which might be related to the surgical technique employed. No relationship was found.

The findings of Conkey (38) and M. F. Robinson (40) suggested that we might find a change in the ability to sustain performance from the beginning to the end of the task as a result of psychosurgery. However, a comparison of the slopes of the curves of performance from the first to the fifteenth minute for the pre- and postoperative test periods showed some changes in a positive direction and some in a negative direction, which failed to support the Conkey-Robinson hypothesis.

The possibility that the accuracy of performance might change as a result of operation was examined by making a graphical comparison of the preoperative and postoperative error scores. No significant trends were found. The analysis of the data and graphs of the 2-digit additions revealed no consistent tendencies when examined in terms of total number of additions completed, the range of each patient's preoperative and postoperative performance, shape of the curve of performance, and the error scores.

It is to be noted that in the above discussion the analyses have been primarily based on an inspection of the graphical material. In view of the irregularity of the data, refined statistical treatment did not seem warranted. So far as the sustained task method is concerned we may summarize by pointing out that no significant changes which could be ascribed to the operative procedures were found with respect to; (a) total number completed, (b) range of performance, (c) shape of the curve of performance, and (d) total error scores. This was true in both the one- and 2-digit addition tasks.
DIGIT PERCEPTUAL SPAN. The evaluation of performance in this test was made in terms of the maximum number of digits correctly reported at an exposure of 10 milliseconds within 3 successive trials. Comparison of the mean changes in the operative and control groups showed that the operation produced no alteration in this function.

WORD RECOGNITION. Performance on Word Lists A and B was scored similarly to that in the word selection test making use of T-scale values. None of the statistical comparisons of the data obtained from the various subgroups were significant although there was some indication of improved performance in word recognition for the group of transorbital patients. The magnitude of this change was not large. That no type of psychosurgery used in this study improved perceptual span per se was indicated by the absence of any change in the perceptual span for digits.

SUMMARY AND CONCLUSIONS

In the study of the effects of psychosurgery on complex mental functions a battery of 14 tasks was used to measure memory, learning, maintenance of mental set, and perception. Since many of the scales involved were in a preliminary stage of development, an important aspect of the investigation consisted of sifting out the most suitable techniques for further research.

Among the tests which proved adequately reliable and sensitive were: (a) verb and directions, which measures the ability to grasp simple verbal directions; (b) the learning task, utilizing the names of pseudo radio stations; (c) the tachistoscopic tests of digit perceptual span and word recognition; (d) the word selection test, which is a measure of the ability to maintain a mental set; and (e) the sustained task, which requires continuous work at simple addition problems for a 15-minute period.

In general, the data obtained were not sufficient to warrant definite conclusions regarding the effects of psychosurgery on complex mental functions, but some interesting trends were noted. The operated patients tended to perform relatively poorly in the learning task when they were required to set their own tempo, although they showed a slight improvement over their preoperative performance when they learned under fixed speed conditions. In 6 of the 14 tests in the total battery the operated group did not show as much gain with test repetition as the control group.

It is concluded that:

1. Memory, both immediate and incidental, showed no alteration as a result of psychosurgery.
2. Learning ability showed no definite alteration directly attributable to psychosurgery. "Forced" tempo learning seemed somewhat easier postoperatively for most of the operated cases and "free" tempo learning seemed somewhat more difficult for them.

3. In the control group, but not in operated patients, there was evidence of improvement of maintenance of set which we attribute to the practice effect of the repeated testing procedure.

4. Although our technique was not all that might be desired, we must conclude that the delayed reaction phenomena reported in brain-operated animals was not evident following psychosurgery in this group of patients.

5. The verbal directions test here, as in the first Columbia-Greystone project, showed some tendency to change in an unspecific fashion following psychosurgery.

6. Neither interrupted set nor the interrupted task test showed a consistent variation following psychosurgery.

7. The test of directional set, which had been specially designed to bring evidence as to changes in rigidity or flexibility in learning or in mental set, failed to show any consistent change which could be related to psychosurgery. This might be due to inadequacy of materials and method used, although the results were in agreement with the clinical evaluation of the patients.

8. Stimulus word recognition, which was used as a substitute for the word association test, gave an improvement in scores with the transorbital group which paralleled the improvement shown by the control group. This difference between the transorbital group and the other operated patients is not due to differences in visual perception span.

9. The Conkey-Robinson hypothesis that psychosurgery or brain injury results in a loss in ability to continue a sustained mental task without marked decrease in efficiency was not confirmed.

10. Several general tendencies appeared. For example, no striking changes for the worse were noted. Such changes for the worse as did occur reflected not a basic loss, but rather a failure to show improvement with practice. There were 14 opportunities for comparing the effect of practice on the performances of the operated and the unoperated patients. In only 3 of these did the practice benefit the operated more than the unoperated. In 6 of these comparisons the operated trailed behind the unoperated and in the remaining 5 instances no marked differences appeared.

11. During the period covered by these psychologic examinations little or no amelioration in mental illness was evident. The psychologic findings in the first Columbia-Greystone report all pointed to the fact that such alterations (gains or losses) in psychologic test performance as were found were more closely related to "social improvement" than to any other variable investigated. Hence, the lack of regular change in this battery of tests is in all probability a reflection of the lack in amelioration from mental illness. Certainly and positively
there was no sound evidence that the variety of neurologic surgery conducted on the frontal lobes of these 22 patients had any important differential effect on the psychologic variables measured.