AN ANALYSIS OF THE INTEGRATIVE ASPECTS OF THE PERFORMANCE OF NORMAL AND BRAIN-DAMAGED SUBJECTS ON SPECIALLY DEVISED MOTOR TESTS

by

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Chapter I

INTRODUCTION

For a long time certain neurological signs have been used as the fundamental criteria for diagnosis and localization of brain disease. These include paralyses, anaesthesias, abnormal and irregular reflex activity, and visual field defects. At the same time it has become increasingly evident that certain mental or psychological alterations occur in conjunction with these neurological changes, thus pointing to the relationship between structural damage and impaired psychological functioning. The potential value, then, of investigating these changes accompanying cortical pathology would seem considerable in supplementing clinical neurological findings for purposes of diagnosis.

Recent developments in clinical psychology indicate that intelligence tests are not adequate for this purpose. In a review of the literature on psychological changes following organic brain lesions and ablations, Klebanoff (46) points out that the conventional tests of intelligence have not proved to be sensitive enough for measuring functional losses which occur as a consequence of brain damage. This statement is based upon the results of psychological examinations before and after the removal of brain tissue.

In the area of projective techniques a study by Diers and Brown (20) using the Rorschach as a diagnostic technique for "organic signs" revealed that the validity of the sign approach is open to question, and they suggest that the use of Rorschach "signs" at present be restricted to exploratory and experimental purposes.

There have also been a number of studies which have attempted to relate psychological impairment to specific areas of the brain. Although some of the studies (46) report such relationships, the results are somewhat equivocal. The extensive research of the Columbia-Graystone Associates failed to demonstrate, with an exhaustive test battery, permanent impairment of intellectual functions in a group of psychotic patients after removal of different specified anatomical areas from the cortex (topectomy.) (54) These investigators did not compare mental functioning in "normal" and "organics." Instead, they studied patients with already existing psychopathology and superimposed cortical defects. It would appear simpler and more fundamental to investigate systematically the performance differences between "normals" and "organics." This would lead to a better analysis of such differences in psychological functioning and to conceptualizations which could be validated with objective techniques.

Attempts to measure changes in intellectual functioning connected with somato-physiological variations of aging or with structural pathology or the brain have been made by several investigators who analyzed the score patterns on the Wechsler-Bellevue scale. These analyses deal with effects noted in both the full scale and the subtests. Many valuable qualitative observations have been included in these reports, but not in terms of scoring. In his critical evaluation of such attempts Rabin concluded in 1945:

> "From the findings of these investigators, one cannot agree that these findings establish the Wechsler-Bellevue as a reliable instrument in the diagnosis of brain damage. All that can be said is that some psychologists acquainted with clinical signs of organicity may be able to make a diagnosis of brain damage while using the Wechsler-Bellevue test." (60) (p. 420)

It is important to learn why some of the most valid intelligence tests should often show no effect of injury to the brain. Hebb (37) reports that the effect of a clearcut removal of cortex outside the speech area is often astonishingly small; and at times no effect whatever can be found; intellectual functioning is usually affected by any large brain lesion--yet the results of our present-day tests indicate sometimes that it seems not to be. High I. Q. scores have been reported on patients after lobotomy and even lobectomy.

Halstead (31) reports that a patient with a high Binet score and a normal Rorschach, nevertheless showed disturbance in conceptual (abstract) behavior. Nichols and Hunt (55) found failure on the Vigotsky concept formation test in a patient with bilateral lobectomy who had an I. Q. of 120. One explanation proposed by Hebb is this:

> "The level of intelligence-test performance is a function of the concepts a patient has already developed. Once developed, a concept is retained despite a brain damage that, if it had occurred earlier, would have prevented the development. The patient with brain injury at maturity may contine to think and solve problems normally in familiar fields, although his intelligence would have been far from normal if a similar injury had happened at birth." (37) (p. 2)

There has been much said for and against this viewpoint. In any case it points up the apparent deficiency of our present intelligence tests to adequately indicate organic involvement. One of the controversies bearing on the question which Hebb raised concerns the familiar hypothesis of Baboock. In essence, this hypothesis also asserts that past experience and knowledge in terms of "older associations" may camouflage existing organic defects on verbal tests. From this hypothesis the familiar criterion of higher verbal scores and lower performance scores in organics was developed. Basing his conclusion on similar considerations, Wechsler proposed his distinction between "hold" and "don't hold" items as diagnostic criteria for organicity.

Anderson (15) found neither the Wechsler index of deterioration nor the Reynall index to be very useful in detecting brain damage in fifty-five male veterans with verified brain-damage. Rogers (15) and Kass (44) found Wechsler's index a fallible instrument in distinguishing between brain-injured patients and neurotics and other groups. The only promising technique seems to be the use of a series of ratios based on different combinations of Wechsler-Bellevue subtest scores, which were developed by Hewson. According to Challman, these ratios are sufficiently helpful to warrant their use together with other psychological tests and clinical procedures.

Goldstein, Yacorzynski, Scheerer, and Feifel have maintained that a more careful analysis of verbal performances does not support the Babcock hypothesis that older associations are longer preserved. Feifel and Lorge found that lack of a refined scoring procedure led to the artifact of the apparent intactness of older associations, since responses on an inferior (concretistic)level received the same credit as those on a higher (conceptual) level. (21) Also there is a significant difference between the responses given by younger children as against those used by older children, if they are qualitatively analyzed with more care.

The studies by the aforementioned authors and also by Capps (14), Cleveland and Dysinger (16), and Ackelsberg (2) established the fact that words which are used with a conceptual meaning by normal adults may carry a rather restricted and concretistic meaning in the usage by cortically impaired patients, by individuals suffering from senile deterioration, and by young children. Going beyond these negative strictures, the investigations by neurologists and psychologists, such as Goldstein and Gelb, Henry Head, Werner and Strauss, Goldstein and Scheerer, Bender, Armitage, and many others have introduced specialized tests for investigating psychological functions in patients with diseases or lesions of the brain. These attempts have clearly demonstrated the need for and the positive value of such specialized testing methods, though a complete validation of their diagnostic differential value for every case of brain injury has not been attained.

A number of experimental studies have been devoted to the performance of brain-damaged human beings and animals on tasks of varying difficulty and complexity. Lashley's research, for example, on animals with surgically produced brain defects suggests that there is a relationship between the ability to perform complex tasks and the amount of brain damage. (48) Some authors like Goldstein and Scheerer apparently find in brain-injured human beings a relationship between cortical dysfunction and impairment of the more complex psychological functions, i.e., abstract behavior.

This theoretical position can be considered an outgrowth from certain principles which Hughlings Jackson and Henry Head developed. These principles are based on a conception of a hierarchial organization of nervous function. Accordingly, cortical impairment in particular would lead to a deficiency in the more complex psychological functions and a reduction in the evolutionary and ontogentically more recently acquired abilities. To this view, Goldstein and others added the concept of reorganization of mental operations to a more primitive level of functioning, and this led to the emphasis on concept formation and sorting tests in the recent two decades in research on brain injury.

The tests for abstraction, namely, the concept-formation tests like those by Vigotsky, Goldstein-Scheerer and Shipley Hartford may pick up deficiencies in severe impairment, but in cases where the impairment is mild, they do not suffice. Moreover, the performance on the concept-formation tests by schizophrenics further clouds the picture. There is often confusion as to what is organic and what is schizophrenic. However, these methods mark a decided step in the right direction, and their trend has been extended in the present battery in an attempt to pick up the more subtle impairments.

In summary it may be stated that even though the techniques in testing for psychological changes in brain damage have become increasingly specialized and have contributed considerably to the qualitative description of deficits, no real validation has been achieved, either in pattern analysis of intelligence test results or in qualitative analyses of specially devised test situations.

In view of the various controversies, we propose to use specialized and relatively simple motor tests as a diagnostic medium for the following reasons: First, the use of language is unnecessary for the solution except for understanding the easy instructions; second, the required motor activity stimulates simple tasks in everyday life situations. Though voluntary control of muscle co-ordination is required, this does not exceed that for manipulative actions under "natural" life conditions. Third, performance on these motor tests seems to be free from <u>specific</u> past experience or specifically acquired skills. On the other hand, these motor tests require a level of aptitude which is independent of individual differences in motor capacity. This fact had already been demonstrated by Van Der Lugt and the writer in control studies of normal individuals of average I.Q. where the performance proved to be independent of previous training and intellectual ability. Fourth, though it is obvious that cognitive functions enter into any motor activity, the motor tests do not focus on "intellectual" abilities in the usual sense. They tap rather such organizational aspects of behavior where perceptual motor integration is at least as essential as the cognitive factors involved and where the manipulative emphasis in behavior permits easier analysis of the nature of this integration. It is therefore hoped that the brain function required for these performances may be more directly tested than in the tests dealing with intelligence level alone, either through I.Q. or specialized qualitative methods such as sorting tests and others described by Goldstein and Scheerer and Rapaport. In this respect it may be noted that Malmo in a recent article points out the neglect of the motor aspects of behavior in most studies dealing with personality and especially with pathological personality manifestations. He says:

> "The strong emphasis on perceptual aspects of behavior (as in Rorschach) in the field of personality analysis has undoubtedly been amply justified but it would seem that more attention should be directed toward motor phenomena in this field." (52) (p. 547)

Fifth, following the pioneer studies and methodological axioms expounded by Goldstein and Scheerer and also Werner, it is expected that these tests will yield information on how the organic patient arrives at his goal in the event that his mode of functioning has become changed from his customary manner of functioning. This may be done through a careful analysis of the processes through which the normal and the organic patient execute the motor tasks. Scheerer rather clearly points this out in his paper on Performance Analysis:

> "We cannot treat wrong responses as minus or zero performances, simply because they are test failures. Ignoring the factual process which leads to failure leaves a scientific gap where positive explanation is called for." (63) (p. 657)

Without entering into a task analysis of these motor tests at this point it should be stated that the proposed motor battery represents an attempt to tap different levels of perceptual motor integration proceeding from more simple to more complex tasks. In terms of increasing complexity, the various tasks used include fine motor control, pressure judgment and estimates of traversed distance in movement, two-hand coordination, anticipation and planning, and simultaneous response to multiple stimuli.

THEORETICAL CONSIDERATIONS

We assume that normal brain structure and function permit sufficient interaction between various areas of the brain so that different processes which enter into a perceptual motor task can be integrated in a harmonious fashion and be centrally directed. Brain damage regardless of the specific locus can interfere with such normal interaction or "communication" and higher central control. This may affect the controlled innervation of finer muscle movements so that more undifferentiated, global muscle action prevails. It may also affect the tempo of the motor performances so that retardation may occur; or it may result in a disturbance of normal figure-ground relationships so that processes which are otherwise subordinate in the course of perceptual motor activity cannot be held under control. It may further result in an insufficient integration of motor activity in that there is inadequate planning or lack of adequate control in the successive phases of the action; or this cognitive control of the action may be lost on the way because the task presented is of too great complexity, namely various subordinate activities have to be engaged in, or "kept in mind" at the same time. The integration of tactual and kinesthetic cues into simultaneous psychological representation of tri-dimensional patterns, may be affected so that recognition of forms on this basis deviates from the normal. Finally, there may be impairment of the ability to utilize the perception of a fixed spatial distance for the establishment of a spatial frame of reference, within which experienced smaller distances have to be gauged during the performance of a motor task.

In summary we will state our hypothesis in this general form: Brain damaged patients will show impairment of integrative functioning on perceptual motor performances. The nature of this impairment will go in the direction of lacking differentiation. This will manifest itself in impaired perceptual motor planning ("idea of movement") such as anticipatory control;* in inadequate temporal coordination of the perceptual motor and various subordinate activities into an orderly course; in a reduced mastery of movements which require finer articulation and precision and finally in an impaired ability to use tactual and kinesthetic cues for integrated form recognition or judgment of spatial distances.

* cf. Liepmann's "Bewegung vorstellung," "Bewegungs entwurf" (movement-design or plot)

The more specific hypothesis to be advanced will be discussed in connection with the specific subtests of the battery.

OBJECT OF THE STUDY

It is our belief that "organicity" may be diagnosed more adequately and economically by studying motor performances than by testing for "intellectual" changes alone; and that the examination of perceptual motor performance may tap the effects of brain injury (particularly of cortical dysfunction) upon behavior more directly than psychological tests of intellectual functions. Therefore, the major objective of the study is to determine what differences will appear in the test performances of brain-injured and normal subjects with the use of specially devised motor tests.

The battery of tests employed in the investigation consisted of seven subtests. In setting up the battery an effort was made to include tests which in the preliminary studies had shown promise of differentiating between brain injured and normal individuals. The following general features were sought in selecting the battery: 1) the subject's motor and manipulative responses should be recordable in direct and carefully controlled behavioral observation; 2) the task and material should be non-verbal, so that verbal ability has little bearing on the type of response produced; 3) apparatus used should be selected to exclude practice and training effects on subjects and should approach natural conditions of everyday life manipulations; 4) the final composition of the battery should meet the criterion that the battery should be applicable without essential alteration of instructions or technique to normal control-individuals and to the brain-injured patients, while an attempt should be made to maintain a constant motivational appeal; 5) the patients should not show any apractic symptoms, since we are not interested in apraxia but the effects of brain injury on motor action in general; 6) the material of the battery should not threaten the subject by its strange appearance, thus avoiding possible emotional complications; 7) each subtest should be of short duration so that the subject is not taxed to the point of fatigue or unduly frustrated; 8) in regard to the above statement, it is particularly important with organic patients that the sessions for individual subtests should be short and applicable at different times, i.e., the entire test battery need not be applied in one full session. The time needed for administration and scoring should also be within limits of practicality; 9) whatever qualitative analysis suggests itself from the expected behavior differences between organic patients and normals, these qualitative performance aspects should be quantifiable and translatable into objective scores.

Chapter II

METHOD

PILOT EXPERIMENT I

The tests were selected on the basis of an exploratory study which was conducted with the following questions in mind:

1) On what tests do patients with brain lesions differ from normal subjects?
2) What hypothesis is most acceptable to explain these differences?

A large number of tests were chosen to be given to brain-damaged patients. These included: Weight Discrimination, Finger Dexterity, Peg Board, Pursuit Meter, Double Stimulation, Formboard, Reversible Figure, Satiation to kinesthetic stimulus, and the following from the Van Der Lugt tests*: Accuracy Steadiness, Pressure Control, Accuracy Precision, Memory Direction, Memory-Spatial, Pressure Reproduction, Coordination-Static, Speed Asynkinesia, Coordination-Dynamic and Speed Prehension. This exploratory study covered a three-month period, and over 50 normal and brain-damaged subjects were tested. Because of the large number of experimental methods with which the patients were tested, it was impossible to test all the subjects with them. For that reason, at times no more than three or four patients were

* These motor tests were purchased through Dr. M. Van Der Lugt, New York University, New York City.

tested by a certain method before discarding it, unless the results differed from those of the normal subjects. In some cases the differences which did appear were so dramatic that they could be detected by using only a few subjects.

As a result of the study sketched above, a great number of observations accumulated, leading to preliminary conclusions and hunches. It became evident early in the investigation that much data would be lost if we relied solely on a quantitative scoring system on whatever tests were finally selected. It also became clear that a thorough study of the qualitative factors had to be considered first in evaluating the differences in performance between the normal and the brain-injured subjects. Wells (69) has called attention to the recent increasing emphasis on qualitative features of standard tests.

> "Such leads need much further development. Practicing clinicians constantly use such hypothesis and ideas in evaluating individual test data. However, we need more explicit use of such hunches and careful research examinations of such apparently meaningful patterns of test responses." (34) (p. 79)

Lois Murphy (34) has pointed out a number of promising personality indicators within the Binet framework. W. A. Hunt complains

> "...that our test manuals give little space to the quality of test responses and their diagnostic significance. Nor is there anything to prevent us from being explicit about the qualitative factors in extending our objective scoring systems to include such indicators. We should rework our tests to obtain items which will yield diagnostically rich, observable material as well as convenient numerical measures." (34) (p. 79)

Even earlier than these writers Goldstein, Scheerer and Werner have pointed out the value of analyzing the qualitative aspects of a subject's mode of approach. Goldstein's criticism of the "plus or minus method" of scoring tests initiated this trend. He states:

> "The older psychopathological investigations usually confined themselves to the question of whether a patient actually gave, or failed to give, the correct response in a task. This 'plus or minus method,' however, is inadequate, no matter whether we are dealing with positive or negative results. If we regard a reaction only from the standpoint of the actual solution of a task, we may overlook the deviations from normality, because the individual completes the task by a detour which may not be evident in the solution." (25) (p. 23)

To adequately understand the capacity of the injured organism and his manner of approaching his problems, more is needed according to Scheerer than a knowledge of whether he passes or fails a test item. In his paper on Performance Analysis he comments:

> "It seems to me that we are still in need of extending to many fields what H. Werner describes as the functional analysis of 'process and achievement'". (63) (p. 656)

He further points out that:

> "Success and failure are only the <u>end products</u> of performing. As such they do not disclose the <u>how</u> of succeeding and the <u>why</u> of failing. Clinical and child psychology abound in instances where results are attained by unexpected round-about means...." (63) (p. 656)

As most of the tests used in the battery are standard tests, but are new in their application to subjects with injured nervous systems, it was necessary to introduce additional scoring methods. The original scoring methods were too gross and concealed important differences. To bring out these differences a qualitative scoring system had to be devised by analyzing the various aspects of the performance on each test.

PILOT EXPERIMENT II

With the main elements for the development of the technique thus being acquired and the less differentiating tests being discarded, a second pilot study was made, using the following battery of tests: the Van Der Lugt Motor Tests, Digit Symbol, Formboard and Double Stimulation. These tests seemed to be the more promising in differentiating normal subjects from those with brain injury. In this pilot study seventeen brain-damaged patients and fifteen normal hospital personnel were used as subjects and all were given the complete test series. Five of the subtests from the Van Der Lugt Motor Test showed so much overlap between the normal and the brain-damaged group that they were dropped from consideration. The Double Stimulation Test was invariably passed by the subjects of the normal group, but was failed by only fifty-five per cent of the brain-damaged group; hence it was discarded.

FINAL SELECTION AND NATURE OF THE ADOPTED TESTS

The results of this study determined the final composition of our battery, which now included the following tests, each of which showed the greatest promise for a differential diagnosis:

1. Five subtests from the Van Der Lugt Motor Tests, including: Pressure Reproduction, Pressure Control, Speed Prehension, Speed Asynkinesia, and Coordination-Dynamic.

2. Stein-Phelps Digit Symbol

3. A modification of the Goddard Formboard (Halstead)

The selected tests present tasks which require the integrated functioning of perceptual motor activity for satisfactory execution. Following is a brief description of the motor task of each test:

1. In the first subtest drawn from the Van Der Lugt scale -- Punchboard Test or "Speed Asynkinesia"--the subject is presented with a plate in which there are one hundred twenty holes arranged in a serpentine pattern. He is given a stylus and instructed to pierce each hole consecutively as rapidly as possible.

2. Double Punchboard--"Pressure Control." The same apparatus used in the Punchboard test is utilized with an added plate. Two recording sheets are placed on the plate with a perforated metal plate an eighth of an inch thick between them. The task is again to follow the pattern by piercing the holes in the top sheet with the stylus, but avoiding the piercing of the second sheet. This is to be done as rapidly as possible with no support for either hand or arm.

3. The third subtest, Ring Test--"Speed Prehension"--consists of three parts. In Part I, the subject is given a pole set in a metal base upon which 15 metal rings are placed. The task is to remove the rings one at a time as rapidly as possible and place them at the right of the base; then the rings are removed again from the pole and placed at the left of the base. In Part II, the pole is removed and the rings are lined up parallel to the base. The task here is to <u>carry</u> the rings across the base, one at a time as rapidly as possible.

When the last ring is carried over, the rings are then brought back to the original side in the same manner. In Part III, the rings are placed in a loose cluster at one side of the base and now the task is to slide the rings around the base, one at a time as rapidly as possible bringing them back to the approximate starting point. Any ring may be used as long as a change of rings is made at the beginning of each trip around the base. Trials are made in both clockwise and counterclockwise directions.

4. Plunger Test--"Pressure Reproduction." The subject while blindfolded, pushes a plunger down with his forefinger until the experimenter asks him to stop and remove his hand. Immediately following this, the subject has to push the plunger down again to the same point, so that still blindfolded he has to reproduce from memory the previous traversed distance, while at the same time encountering pressure cues.

5. Marble-Peg Test--"Coordination-Dynamic." The task is one of the most complex of the series. In this instance the subject is required to simultaneously place a marble with the left hand and a peg with the right hand in the hollows and holes of a plate, while following a designated pathway. The subject is directed to always use the right hand for the pegs and the left hand for the marbles, and to cross hands whenever necessary to simultaneously place the pair.

6. Digit Symbol. This is modification of the Digit Symbol test devised by Kenneth B. Stein and developed by the writer. The

subtest presents the subject with a blank, on the top of which is printed a sample line with the numbers from one through nine. Below each number is an unfamiliar form to be used as a symbol for that number. The blank also contains 64 empty squares each of which bears any of the numbers from one through nine in random order--as is typical of the digit symbol test forms. The subject has to write into each empty square the symbol which is associated with that particular number.

7. Formboard--Tactual Performance Test first used by Halstead. The subject is blindfolded and given ten figures which he has to place into the corresponding openings on an upright formboard, using both hands. Before the blindfold is removed, the board is moved out of the subject's sight. He is then asked to reproduce each figure and its position on the board by a drawing.

POPULATION

A total of 70 subjects were used in the investigation; 35 normal subjects and 35 brain damaged subjects. The normal and brain damaged subjects were matched in as many respects as possible. The battery of seven subtests was given to each subject individually. Administration and scoring of these tests averaged about two hours per subject and all examinations were conducted by the writer. Testing sessions with the normal subjects were approximately of an hour's duration, while the sessions with the brain-damaged subjects were broken up into twenty-minute periods and usually lasted a little over an hour.

Control Subjects

These 35 subjects were chosen from the medical and nursing staff and the ward personnel of Winter Veterans Hospital. As a group, they ranged in age from 21 to 58 years and averaged 33 years. Each was induced to take the battery of tests without compensation. Eighteen of the group were females and 17 were males. Detailed inquiry failed to reveal any history of actual or probable exposure to the possibility of brain injury. Mild degrees of anxiety were present in three of the subjects of the group. The others appeared relaxed and well motivated during the test procedure. All the subjects were regarded as having normal personalities and as being reasonably well adjusted.

Experimental Subjects

In general all patients were selected after consultation with two staff neurologists* who screened the patients as to a definite diagnosis of cerebral pathology. The criteria for the diagnosis were based on:

1.	Clinical symptoms of neuropathology	8
2.	Spinal tap (paretics)	3
3.	X-ray findings	10
4.	Encephalographic reports	8
5.	Pneumoencephalographic reports	3
6.	Operative findings (before testing)	3
		35

* Dr. Maurice Walsh and Dr. Leon Bernstein

The diagnosis based upon these findings presumably offers no doubt as to the cerebral pathology in these 35 cases. In addition other selective considerations were set up. Excluded was any patient suffering from any symptoms of paralysis, from psychomotor seizures, convulsive disorders, aphasic or apractic disturbances, and psychotic involvements. All cases had to be considered past an acute state by the neurologists, including the brain tumor cases which were under constant observation for their stationary nature. Although no ratings were obtained from the neurologists as to the severity of the organic involvement, the aforementioned selective considerations and the clinical judgment of the neurologists definitely places all the chosen cases in the classification of "mild." For example, the two post-encephalitic patients had served in the Army, in spite of their childhood encephalitis. These along with the two multiple sclerotic patients were only hospitalized for a periodic checkup. None of the cerebrovascular patients showed specific handicaps. All patients, moreover, were in the process of discharge from the hospital within a month after the testing except for one brain tumor patient who was subsequently operated upon. According to the social worker's report all but the brain tumor patient, one head injury patient, and two vascular patients returned to their former or equivalent occupations.

The average age for the group was 35 years and the age range was from 20 to 58 years. There were 19 males and 16 females. The following table gives the breakdown of the neuropathology of the subjects.

Analysis of Neuropathology in Subjects

Disorder	Duration	Number
Cerebrovascular Insult	11 mos. to 2 yrs.	10
Head injury	1 yr. to 18 mos.	11 (5 fractures, 6 closed)
Brain tumor	1 Stationary, 1 preoperative	2
Paresis	Arrested following treatment	6
Multiple Sclerosis	About 5 years	2
Monoxide Poisoning	16 mos. to 18 mos.	2
Post encephalitis	5 and 8 years	2
		35

Table 1

The intelligence range was determined by the administration of a Wechsler-Bellevue to each subject. This range as shown in Table 2 was from 92 to 125 for both groups. A breakdown of each group shows that 23 of the normal subjects have I. Q.'s falling between 99 and 115 and 25 of the brain-damaged subjects have I. Q.'s within the same range. There are ten normals in the I.Q. range of 115 to 125 compared to three brain-damaged subjects; two normal subjects and five brain-damaged subjects have I. Q.'s between 96 and 98, while two brain-damaged subjects have I.Q.'s of 92 and 94.

The following table presents a summary of the age ranges and the intelligence range of the subjects studied as well as their distribution according to sex:

From Table 2 it will be noted that both the normal and the brain damaged groups offer comparable diversity in age and intellectual range. The age distribution with a range for both groups of from 20 to 58 can be broken down in the following manner.

Intelligence Range, Age Range and Sex Distribution of Control and Experimental Subjects

	Normal		Brain Damaged
Intelligence (W-B)			
Full Scale I. Q.			
Mean	111.1		105.6
Range	96-125		92-125
Verbal I. Q.			
Mean	112.3		109.8
Range	94-128		94-130
Performance I. Q.			
Mean	108.4		103.8
Range	93-120		87-119
Age			
Mean	32.8		34.7
Range	21-58		20-58
		10-year periods	
	13	20-29	13
	15	30-39	13
	5	40-49	5
	2	50-59	4
Sex			
Male	18		19
Female	17		16

Table 2

Twenty-eight of the normal group were below 40 years of age, while 26 of the brain-damaged group were below that age. Two of the normal subjects were above 50 compared to four of the brain-damaged subjects. Further breakdown indicates that the latter group has a greater concentration of ages in the lower part of the 30-39 and the 40-49 age ranges than the normal.

PROCEDURES

I The tests were administered individually in a testing session by the writer in the following order:

1. Punchboard test
2. Ring test
3. Double Punchboard test
4. Plunger test
5. Marble-Peg test
6. Digit Symbol test
7. Formboard

On tests Nos. 4 and 7 the subject was blindfolded. The testing rarely lasted over an hour and rest periods were frequent.

II The two groups were compared with each other for performance on each of the tests and the particular performance on each test by each group was analyzed qualitatively and quantitatively.

III The qualitative analysis was also converted into quanitative (penalty) scores. The rationale for the degree of penalty expressed in point scores was as follows: For each test performance the normal and abnormal subjects were compared with regard to behavior characteristics which hampered adequate solution, and their frequency determined in each group. The less frequent such actions occurred in the normal group, the more penalty points were allotted to these now termed deviations. Characteristic behavior forms which were absent in the normal group were not necessarily given the highest penalty, however, but weighted according to their interference effect on performance in the brain-injured group. Other comparisons as germane to the nature specific tests were also made, for example, in terms of learning, speed, retention, etc., and utilized for further quantitative evaluations.

IV. Critical ratios (t-tests) were computed to determine the significance of the obtained differences for both types of scores separately and combined.

In the following chapter each test and the results of the test will be discussed separately. In the discussion the normal subject will be interchangeably referred to as the normal or control S and the brain-damaged subject as the brain-injured—B-I; brain-damaged—B-D; or the experimental S—EXP. S.

Chapter III

TESTS AND RESULTS

SINGLE PUNCHBOARD TEST—"Speed Asynkinesia"

Description of Task

The task demands from the subject rapid and precise movement co-ordination. The subject has to punch holes on a punchboard in a consecutive pattern, starting with the hole in the upper left-hand corner and continuing until time is called. He uses the hand of one arm placed on the table while the other hand is used for stabilizing the plate. In this action, muscle co-ordination is required not only of the "executive" hand and arm but of the other parts of the trunk as well.

Apparatus and Test Instructions

The punchboard consists of a metal baseplate, above it a tracing sheet on which the holes actually punched will appear, and a top metal plate with the pattern of the holes to be punched. The stylus used for punching has a cone-like shape, widening from the point to the handle so that a deeper punch leaves a large hole in the tracing sheet. (See Fig. 1.)

The subject is comfortably seated when the punchboard is placed before him. The stylus is inserted in the hole at the upper left-hand corner of the plate.

Instructions to subject

Pierce each hole with the stylus and be sure not to miss any, Work just as rapidly as you possibly can. You may hold

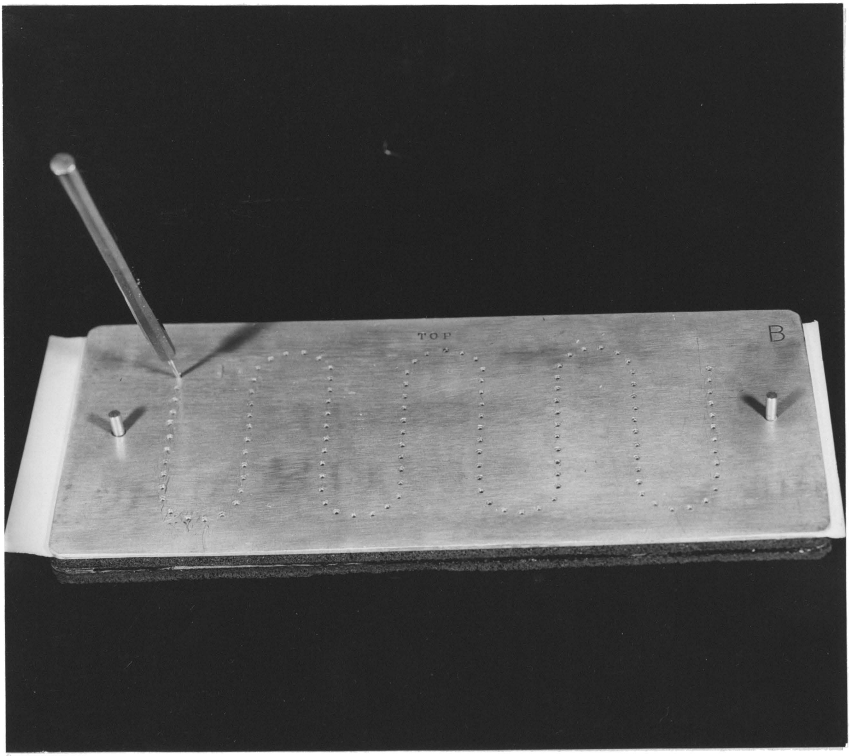

Fig. 1

the stylus in any position and at any point on the handle. Rest your hand, wrist, and forearm on the table or on the plate, if you wish. You may steady the plate with your other hand. Begin in the hole directly beneath the stylus and continue until I say 'stop'. Do you understand? Ready, begin.

Behavioral and Performance Analysis

Though this test is considered the most simple of the battery, it requires a planned voluntary movement sequence executed with both speed and precision. Diverse perceptual motor acts must be integrated. Speed demands that each hole be punched with a light, deft stroke and the stylus be raised just enough to clear the plate before inserting it into the next hole. Precision is necessary in "hitting the target"--the hole--and controlling the just necessary strength of the punch. A smooth and economic carry-over from hole to hole has to become almost automatic in its execution. Any inco-ordination pf vpluntary muscular control or timing results in a retarded and inadequate performance.

Aside from inco-ordination, a difficulty in rapid execution may stem from the subject's cognitive approach: The subjects respond to each specific hole to be punched as an individual task with a total stab reaction. The cone-shaped stylus is pushed down as far as it will go, so that it penetrates through the tracing sheet to the base plate. Time is thereby lost both in pushing the stylus down to the base--farther than necessary--and in extricating the stylus from the deep punch. Time is also lost in this approach of punching discrete, individual holes by coming to a halt after each completed punch, pausing as it were before initiating the next.

In order to avoid this, the sequence of hole punching has to be anticipated, so that each hole becomes a subtask in a larger whole. At the same time the depth of the punching movement must be planned with "intentional" control of the hands and fingers, guided by vision and supported by kinesthetic and touch pressure cues coming from the paper resistance and that of the base plate. As the performance progresses the subject normally learns from these cues to avoid overshooting the mark and to eliminate waste movements, attaining a more accurate and effective control of his movements.

The performance of the experimental subject on the Punchboard Test, when compared with the normal subject, shows overtly the following: First, the normal range of volitionally innervated movements has shrunk. There appears a reduced control of the individual digits as to flexibility and accuracy, together with a marked dimunition in the normally present variety of smaller movements; secondly, all such movements are markedly slow in initiation and execution; thirdly, the diminution of the normal range of voluntary movements manifests itself in an abnormal uniformity in the patterning of hand and finger activities. The result is that the B-D subject is only able to punch fewer holes in the allotted thirty seconds, not because the ability to punch holes has dropped out, but because he apparently must use a more gross movement and lacks refinement and precision. Fourth, there appears cognitively the aforementioned lack of plan regarding the sequential punching of holes which plan the normal adopts as a task goal in which the individual hole punching is subordinate to the sequence. The B-D subject tends to deal with each specific hole as one discrete punching task; fifth, owing to the same cognitive deficiency the B-I easily loses his whereabouts in the pattern sequence of punching holes, so that he will repeat the punching of a hole already pierced or inadvertently skip holes in the sequence. His restricted scope of dealing with each hole individually, together with the absence of a projected plan as to organized sequence, therefore expresses itself also in a difficulty to keep accurate check of the last hole punched; sixth, in contrast to the normal, who quickly adapts to the cues of pressure resistance, thereby learning to avoid overshooting the mark, the B-I typically fails to do so. This is manifested in two ways, namely, unevenness in tempo such as erratic bursts of speed alternating with halting hesitation, and in the fact that overshooting the mark appears as much toward the end of punching as in the beginning on the tracing sheet. In contrast the normal Ss show a steady decline of these errors.

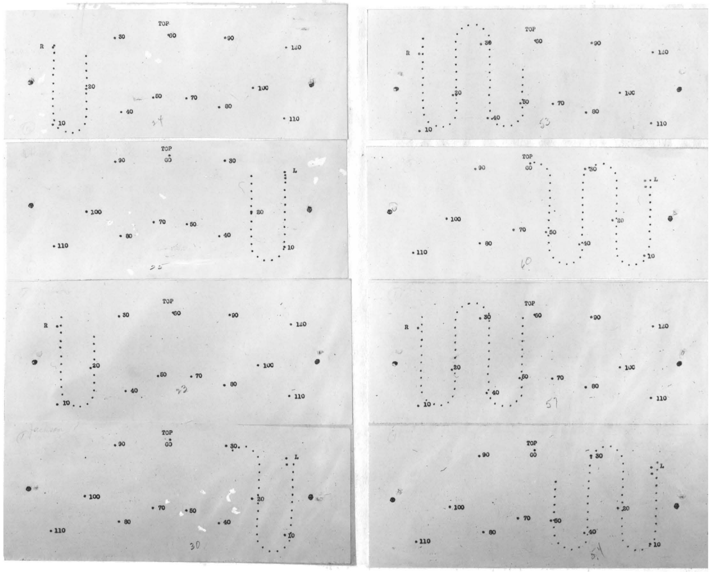

Fig. 2

Figure 2 shows some examples of the performances of the B-D and of the normal Ss. Samples from two B-D Ss appear on the left--the upper two show the performance of one S when he first punched from the upper right and then from the upper left; the lower two show the same kind of performance of a different B-D S. On the right of the figure is the performance of two normal subjects, showing the two performances of each--one from the upper right hand corner and the other from the upper left hand corner. The samples show clearly the fewer number of holes punched by the B-D Ss. The numbers on the tracing sheet indicate the total the Ss attained in 30 seconds. For the B-D Ss, the best score is 30,or one hole per second, while the normal attains a high score of 60, or two holes per second. On the tracing sheet, another fact stands out; most holes are larger in the case of the B-D, indicating that the stylus has been pushed through the sheet to the larger end of the punch.

Method of Scoring

Qualitative

The present investigation emphasizes the qualitative differences also in motor performances between the normal and B-I groups. Hence an attempt has been made to quantify these differences and thus give a behavioral index of the way in which the subject approached his task. A qualitative deviation score is set up as a measure of this index and is recorded on the scoring sheet. (See Fig. 3.)

Qualitative Scoring (Penalty scores by subtraction)

1. Stylus pushed through to base-for each--1
   (This manifests itself: a) by a larger hole in the paper sheet; b) by the sound of the stylus striking the base.)

2. Each hole missed--1

3. Punching again a hole once pierced--2

4. Erratic burst of speed and subsequent slowing down--1
   (same score whether once or repeated)

5. Head movement with arm motion--1
   (same score whether once or repeated)

   In clinical neurology such accompanying movements which the normal adult has outgrown are called "associative movements." From our point of view following the theories of Goldstein, Koffka, Lewin, Werner and Piaget in this area, the "associative movements" are expressions of a lack of differentiation in motor activity. They may either occur during immaturity in the infant or young child where global movements precede the individuated "single" innervations (59) or they occur when a normal adult operates on a more primitive level owing to a difficulty in mastering a task. For example, the uneducated man who reads silently but must move his lips.)

<u>Scoring Sheet</u>

Punchboard Test

a ____ b ____ Total ____

Penalty Score

1. Stylus pushed through to base ____
2. Holes missed ____
3. Repunching hole ____
4. Erratic burst of speed ____
5. Head movements ____

Deviation Score ____ Total ____

Fig. 3

The scores for slips in execution and fluctuations in manner of approach are summed to obtain the qualitative deviation score. This penalty score is then added to the quantitative score and the result is the total score for the test.

Quantitative

A time limit of 30 seconds is allowed for each part--the first part beginning at the left-hand corner, the second at the right-hand corner. The number of holes punched is recorded on the aforementioned sheet beneath the plate. The quanitative score is determined by counting the number of holes punched on the tracing sheet in the allotted time. This score is based on the Van Der Lugt system.

Results

Statistical Procedure

The F-test was made for a ratio of the variance of the means. This yielded 1.69. The ~~5%~~ 1% point is 2.30 and the ~~1%~~ 5% is 1.80, so that the difference of variance is not significant and the t-test was used.

In comparing the scores of the control and experimental groups, as presented in Table 3, it may be seen that despite some overlapping, there is a highly significant difference between the means of the two groups.

Quantitative Scores of the Normal and Brain-Damaged Groups on the Single Punchboard Test

Statistic	Normal		Brain Damaged
N	35		35
Range	90-133		16-110
M	108.9		67.9
S.D.	16.6		21.6
Mdn.	110		64
σM	2.84		3.70
σDm		4.66	
Dm		41	
C.R.		8.79	

Table 3

An analysis of the distribution of scores shows further, that none of the normal group has a score below 90, whereas 30 of the B-I remain under 90. The remaining five B-D Ss score between 90 and 110 in the following way: Four scored between 90 and 95 and one scored 110. This is the only B-I S who scored above the mean of the normal group. The mean scores of the two groups appear to be highly differentiating, even when considering the quantitative scores alone. For example, none of the scores in the normal group approaches the mean of the B-D group. Furthermore, as seen in Table 7 the mean difference between the two groups of 41 proves to be highly significant with a C.R. of 8.79 which is beyond the 1% level of confidence.

The qualitative deviation scores are presented in Table 4 below. In the normal group only five of the 35 Ss had a penalty score and of these, none had a score above 3. In the B-D group on the other hand, all 35 subjects were penalized and had penalty scores ranging from 1 to 53, with an average of 17.4 per subject.

Qualitative Scores of the Normal and Brain-Damaged Groups on the Punchboard Test

Statistic	Normal	Brain Damaged
N	35	35
Range	0-3	1-53
M	.31	17.4
Mdn	0	12
Dm	17.09	

Table 4

The only five instances of error scores for the normal group occurred when the subjects punched too lightly so there was only an impression made but the sheet was not pierced. In the error score for the B-D group, 83 per cent of the subjects—29—punched through to the base; ten missed holes entirely or punched again holes which had already been punched and five subjects showed accompanying head movements with each punch. From this it is apparent that the greatest penalty score for this group derives from the stylus being pushed to the base.

An inspection of the tracing sheet further shows that this overshooting the mark (in terms of the larger holes of stylus penetration) is rather uniformly distributed over the punch pattern. In order to quantify this impression, the following analysis was carried out. The holes punched by each subject were counted and divided half and half, so that one could compare the first half with the second half in time. The errors in punching to the base were then counted in each half and averaged. Even without this averaging, however, the count yielded no errors in the second half for any normal subject, while twenty-nine Ss of the experimental group had 295 errors. The average in the latter group was 10.1. The average ratio between first and second half errors for the B-I group was 9.1 to 10.1. In addition only the B-I showed interspersed erratic bursts of speed in cases where the stylus was not inserted deeply enough or one of more holes were skipped on the sheet. From this we draw further support for our conclusion that the B-D Ss actually did not learn during their performance, in comparison to the normals and that they also operated to begin with, on a level of sensory-motor primitivation--below that of the normal subject who though starting initially slow, picked up speed to learning, on his level, a more efficient coordination.

With the addition of the qualitative scores to the quantitative findings the differences between the performance of the two groups becomes so marked that an F-test yielded 2.65. Thus the difference in variance is significant. In order to test for the difference of means with different variance the Cochran and Cox method was used.

Combined Qualitative and Quantitative Scores of the Normal and Brain-Damaged Groups

Statistic	Normal	Brain Damaged
N	35	35
Range	90-133	0-102
M	108.2	50.8
Mdn	110	48
S.D.	16.2	26.30
σM	2.77	4.51
σ Dm	5.28	
Dm	57.4	
C.R.	10.8	

Table 5

The subtraction of the penalty scores have little appreciable effect on the scores of the normal group. The range is unchaged and the mean drops but .7 of a point. The B-I group on the other hand shows a considerable change. The range changes from 16-110 to 0-102 and the mean drops from 67.9 to 50.8, a total of 17 points. The difference between the means becomes greater and the critical ratio, which was 45.8, becomes 49.4. It is clearly evident that there is practically no overlapping between the two groups--

the one exception, with a score over 90 in the B-D group is the score of 102 for one subject, which falls in the normal range. We interpret these results to indicate that our hypothesis has been proved, i.e., that a difference exists between the performance of the brain-damaged and normal groups on this test.

Discussion of Underlying Processes and Pathology

Some Explanatory Hypotheses

Such planning and well-adapted movements as are necessary in the execution of this task depend on a normally functioning cortex for complete integration of the activity. It is the interruption of this integration which is responsible for the retarded and sometimes erratic performance we find in the patient with a brain injury. A voluntary movement is initiated and controlled from its start to its consummation by the integration of two processes: 1) innervation--co-ordination of various muscle groups based on a preconceived "plan" or idea of movement (49); 2) a constant stream of sensory in-put from diverse sources, reaching the cortex (feedback). From our point of view the whole cortex is here involved and it is this communicative integration which functionally permits a measure of precision, fineness of adjustment, timing, and a capacity for variation. Lack of integration (owing to isolation of parts of the brain from the rest through a lesion) leads to interference in the integrative process and results chiefly in two modifications of normal motor activity: 1) a dedifferentiation owing to which the more isolated voluntary movements become more difficult and a lack of precision is observable; 2) a certain rigidity and lack of flexibility owing to which adaptability and variability of the movements suffer. This gives rise to retardation in tempo because the subtler movement cannot be steered accurately and the command over gross movements is reduced as well, so that these get easily out of hand and are sometimes even unduly accelerated (the clumsiness of the quick--inaccurate person). Either of these two factors will contribute a low achievement score within the time limit.

The observed piecemeal manipulation of punching each hole as an individual discrete task and coming to a halt after each completed punch suggests a restriction on the cognitive level. The approach appears not to integrate and subordinate the punching of each hole to the broader task of "punching as many holes as rapidly as possible". The same cognitive restriction seems to underlie the failure to learn from experience during the repetition of the individual punchings. The absence of manifest improvement in terms of benefiting from errors during the course of the performance appears to result from the operation of two factors: 1) The processes which underlie forced responsiveness and stimulus-bond are expressed in the piecemeal approach. These processes are either the direct expression of cognitive restriction--which leads to restricted scope towards the task--or they are coping mechanisms of the organism in trying to deal with the task and with this restriction at the same time; 2) The cognitive limitations prevents the necessary interaction and carry-over from a preceding error experience to the later following punches so that no principles or generalizations are "grasped" or developed. Other writers have pointed out the lack of self corrective behavior in more severely B-I patients on more intellectual performances, such as concept formation tasks and story retelling. It is conceivable that the lack of self-correction evidenced on our test performance has common roots with the above-mentioned phenomenon, namely, a lack of cognitive scope.

DOUBLE PUNCHBOARD TEST--"Pressure Control"

Description of Task

The subject has to pierce consecutive holes on the punchboard, while the hand and arm are unsupported, and the amount of pressure exerted on the stylus must be accurately controlled and gauged. The task this time is to pierce only the top sheet of two sheets of paper inserted between the metal plates and avoid hitting the bottom sheet.

Apparatus and Test Instructions

The same punchboard is used as in the Single Punchboard Test, with the following modification: On top of the base plate is a <u>seaond</u> tracing sheet, covered by a pierced metal plate. On top of this lies the <u>first</u> tracing sheet, which is again covered by the same metal plate with the same punch hole pattern as in the previous test. The second sheet indicates whether the stylus was inseeted too far beyond the first tracing sheet. (See Fig. 4.) The punchboard is again placed before the subject with the stylus placed in the hole at the upper left-hand corner.

Instructions to subject

There are two sheets of paper between these plates. You are to pierce each of the holes consecutively, but the stylus is to go through the top sheet only, and you must try not to puncture the bottom sheet. You may hold the stylus at any point on the handle, but be sure to hold it in an upright position. Do not rest your

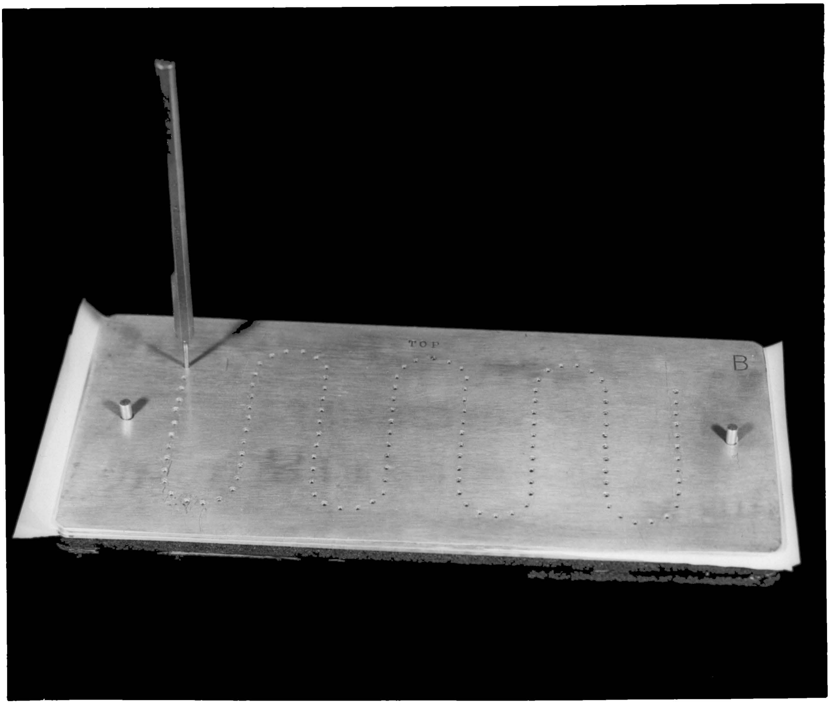

Fig. 4

your working arm or wrist on the table. Only one hand should be used, but you may steady the plate with your other hand if necessary.

Begin at the perforation directly beneath the stylus and work as quickly and carefully as possible. Remember that you are to pierce the top sheet only. Do you understand? Ready, begin.

Behavioral and Performance Analysis

While an emphasis on speed and co-ordinated precision is essential, this task specifically requires continuous voluntary control because of the necessity of gauging the pressure exerted. Initially the performance may be one of caution until the subject gets the kinesthetic cues which inform him of the necessary distance he must punch and the amount of pressure he must exert. Hence, we should expect errors to occur at the beginning of the performance in excess of those made on the previous task. However, as the normal S learns to profit by these cues, the errors will become fewer, and the tempo of the performance will increase. Thus success on the test implies good visual motor co-ordination, with an ability to arrest a movement once initiated, before its completion. It is perhaps this last aspect of the performance that greatly differentiates the normal group from the B-D group. The B-D patient seems to meet with pronounced difficulty in arresting the downward stroke of the stylus in time to avoid penetrating to the second sheet. If on the other hand, he concentrates on this aspect and accomplishes it successfully, there is a considerable loss of speed. For example, an Exp. S may develop a round-about method to by-pass the difficulty of timing the pressure on the stylus, by turning and twisting it slightly during insertion without actually pushing it down. This is done by a gross extensive forward movement of the thumb rolling the stylus--a behavior in which no control S ever engaged.

While the nature of the task calls for a certain degree of repetitiveness in its execution, it also calls for a constant shifting in position of the unsupported hand in moving from one hole to another. The control subject seems to be able to anticipate his next move while completing the stroke of his punch. This leads to a smooth rapid performance.

This cognitive factor appears to have suffered in the Exp. S, inasmuch as he has either difficulties in the required anticipation or, if he attempts to plan ahead, he cannot hold in mind other aspects of the task, such as not resting his hand or arm on the table while punching. In addition, there is again a tendency in the experimental group to respond to each hole as a discrete task. Hence the performance is executed with individual punches separated in time by coming to a halt between each punch. Also some of the B-I may complete the test and be totally unaware of the number of times they have pierced both sheets; others may verbally indicate that they knew they had punched too far but had been unable to halt the process of completing the downward stroke.

In the same context as described in analyzing the Single Punchboard Test performance, we do find an unintentional skipping or repeated punching of holes in the experimental group. Both groups, however, though with different frequency, commit the error of sometimes punching too lightly, so that only an impression is made on the first tracing sheet instead of piercing it. This lapse results apparently from an attempt toward speed or an over-cautious approach. Since the time scores clearly indicate a much slower performance in the B-I, this error is caused by the over-cautious behavior in these subjects, who seem to alternate between lack of control in gauging the punch and over-control. The tendency toward alternation may lead in some Exp. Ss to an all or none reaction, so that these subjects become compulsively cautious throughout, performing in an abnormally slow rate without ever increasing their tempo. This may result in the paradox that a B-D S may show no punch-through errors at all, while at the same time, he accomplishes fewer punches than the normal and even fewer than his own group.

Both types of behavior, lack of punch control and over-control, differ entirely from normal behavior inasmuch as no improvement is manifest in the course of the performance. In contrast, the normal control group gives evidence of profiting from experience with the task in the decrease of punch-through errors and over-control. They also give evidence of being aware of errors as they occur.

It may also be pointed out that over-control is a rare exception in the normal group. The occurrence of an impression on the first tracing sheet made by the normal Ss is rather the result of a tendency opposite to over-control, namely, lack of thoroughness in over-hasty consecutive punching. This conclusion is again borne out by the greater total speed in this group

Method of Scoring

Qualitative

Qualitative aspects which may be recorded by a check or penalty score on the scoring sheet--(see Fig. 5)--are:

1. Number of errors in the second half of the performance which exceed that of the normal group average (3 errors*)--1 for each. (This is manifestation that the subject has not been able to profit by pressure cues and hence has not learned to avoid overshooting since he has not been able to correct and thus reduce his errors as he progresses.)
2. Resting hand or arm for support on the table--contrary to instructions--1 for each time admonished.
3. Stylus pushed through both sheets to the base--1 for each (contact producing audible sound as basis for score)
4. Each hole missed or just an impression made on the first sheet instead of piercing it--1
5. Punching again a hole once pierced--2
6. Head movements accompanying arm motion--1 (explanation given in previous test)
7. Manner of approach--S appears cautious or appears "driven" by an impulse to punch the greatest number of holes as rapidly as possible at the expense of adequate pressure control--check

Total score is quantitative minus the qualitative penalty score.

---

* This number was determined by statistical computation.

Double Punchboard

a_____ b_____ Total _____

Approach: Cautious _____

Driven _____

Penalty Scores

1. Occurrence of Errors

Beginning _____

Random _____

End _____

Number second half _____

2. Support of hand or arm _____

3. Stylus pushed through to base _____

4. Each hole missed _____

5. Punching again hole once pierced _____

6. Head movement with arm motion _____

Deviation Score _____ Total _____

Fig. 5

Quantitative

The quantitative scores are recorded in terms of the number of holes punched on the two sheets upon which the subject works. He is allowed 60 seconds to punch as many holes as quickly as he can. The total number of holes punched is recorded, and from that total is subtracted the number of holes appearing in the second or bottom sheet. This is the score based on the Van Der Lugt system.

Results

The results of the quantitative scores are given in Table 6. The mean scores of the two groups appear to be highly differentiating where a mean difference of 10.3 proves tobe significant. These mean scores also point up the fact that the normal subjects,with a score of 65.5 in 60 seconds punched almost twice as many holes with no punch-throughs as the brain damaged Ss who achieved a score of 33.4. An overlap in the ranges of 34 to 86 for the normal and 5 to 53 in the B-D group, is present with regard to the range from 34 to 54. Here should be noted that 31 of the 35 normals had a score of 54 or more, which is above the highest score attained by any subject in the brain damaged group. The four remaining subjects had scores below 54 as follows: 52, 49, 38 and 34. (In one case--score of 49--extreme caution was used and no errors were made. This care in execution, however, penalized the S in terms of quantity and the score suffered accordingly. In the other three cases, the total number of holes actually punched ranged from 60 to 72, but by putting emphasis on speed the subjects were not careful about punching through and lost credit points, although all were aware of the number of times the second sheet was perforated.) In summary, then, in the "overlapping" normal group, only one normal S had a score between 50 and 54 and only three had scores below 50.

In the case of the B-D group, 30 of the 35 subjects had scores below 50. The remaining five attained scores between 50 and 54 as follows: 50, 50, 52, 52, and 53.

Quantitative Scores of the Normal and Brain Damaged Groups on the Double Punchboard Test

Statistic	Normal		Brain Damaged
N	35		35
Range	34-86		5-53
M	65.5		33.4
S.D.	11.6		14.01
Mdn	66		37
σM	1.98		2.40
σDm		3.11	
Dm		32.1	
C.R.		10.3	

Table 6

A comparison of the two groups in terms of the total holes punched, disregarding the number punched through, shows the following: 34 of the 35 normals punched 60 or more holes, (the 35th S making the aforementioned 49 score without penalty) while only six of the 35 B-D Ss punched that amount.

The qualitative deviation scores are presented in Table 7 below. In the case of the normal group, eight of the 35 Ss had a penalty score of zero. This was not due to a very cautious approach as each of these eight obtained quantitative scores above the mean of 65--three were above 80, two in the upper seventies and the remaining three in the upper sixties. Hence though these Ss never pierced the second sheet they were in the top bracket of speed in performance. Twenty-two normals had penalty scores below 10 and four had scores from 10 to 13.

Qualitative Scores of the Normal and Brain-Damaged Groups

Statistic	Normal		Brain-Damaged
N	35		35
Range	0-13		0-52
M	2.8		13.9
Mdn	1		11
Dm		11.1	

Table 7

In the B-D group two Ss committed no errors, thus having a zero penalty score. However, one obtained a quantitative score of 14 and the other a score of 35, a speed at which one would not expect errors and which fits our above-mentioned statement about errorless performance without learning.

The total numbers of punch-throughs for the two groups were 300 for the normal and 461 for the B-D group. Of these total numbers, the normal group had only 99 punch-throughs in the second half, whereas the experimental group had 248. Thus the normal group averaged approximately 3 errors on the latter half of the performance, in contrast to approximately 7 errors for the B-D group. (These errors are of course the basis for the qualitative penalty score for punch-throughs.) In addition the B-D group had penalty scores for other slips in execution totalling 177. The normal group had eight. Analysis of the distribution of these penalty scores discloses the following: The experimental group had penalty scores of 20 for supporting the hand or arm; 17 for punching again the same hole; 5 for head movements, while the control group had none. For missing a hole or just making an impression on the sheet, the Exp. group had penalty scores of 135 and the control group had 8.

These results are all the more striking when we take into consideration that the normal group punched twice the number of holes as did the brain damaged group so that the chance for error was greater. For example, the 300 punch-throughs in the normal group have to be assessed in relation to the total of 2895 punched holes, whereas the 461 punch-throughs in the B-I group has to be related to the total of 1628 holes punched. Hence, there is a ratio of one error in eight punches for the normal or 1 to 8 and a ratio of one error in every four punches or 1 to 4 in the B-D group.

Examples of Brain Damaged and Normal Subjects' Performance

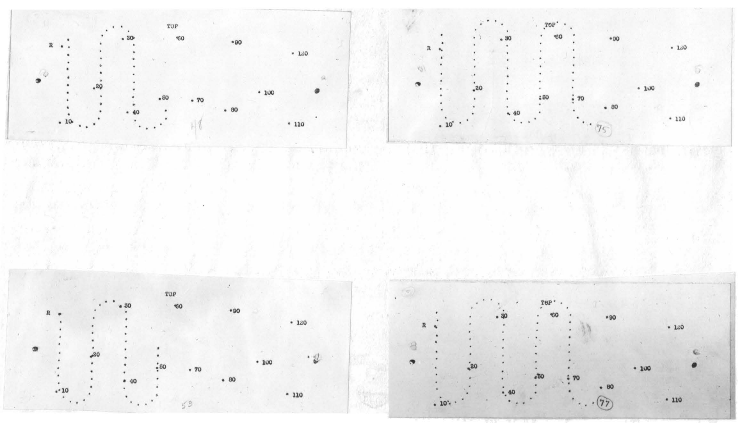

Fig. 6

Figure 6 shows clearly the rate of progress made by the B-D and the normal Ss. The tracing sheets on the left are the recorded performances of two B-D Ss, while the normal Ss' performances appear on the right. Irrespective of the errors made, in every case the normal Ss are able to pierce many more holes than the B-D. In the normal group the errors generally occur at the beginning of the performance, with only an occasional punch-through as progress is made. The experimental group, on the other hand, shows a high error score which is randomly distributed through the performance. In some cases as many as 80 per cent of the holes were punched through both sheets by subjects of this latter group.

Two methods of attack seemed to be used by the normal group. One, in which the subjects attempted to use care and proceeded with a moderate speed attaining a total number of about 55 holes punched. In the second method, the S attempted to first get the "feel" of the amount of pressure needed, necessarily making some errors and thereafter utilizing the cues to the fullest extent and executing the task at greater speed. Good examples of learning, we believe, are indicated in the following normal Ss. A subject putting great emphasis on speed punched a total of 97 holes, committing 17 errors, all of which occurred in the first 30 holes punched, and the next 67 were free of error. In another case where a S punched a total of 74 holes, committing 7 errors, all of the errors but one occurred in the first 20 punches. Another subject punched 83 holes, committing 5 errors, with all five occurring within the first ten punches. Only two of the normal subjects had random errors, with equally as many appearing in the second half as in the first half of the performance.

The B-D group resorted to many different methods in an effort to perform the task, ranging from violating the instruction to keep the hand unsupported to inserting the stylus and giving it a slight twist, thereby by-passing the need to control the pressure on the stylus. There were also evidences of a carry-over from the previous test. In spite of instructions to the contrary, five subjects attacked the test in the same manner as on the previous test and punched the stylus completely through to the base. The fact that over half of the punching through errors occurred on the latter half of the test seems to indicate that the B-D group were not able to profit by the errors at the beginning of the performance and hence, little learning was evident.

If we consider the quantitative and qualitative scoring together, more differences between the groups become apparent. The combined scores are shown in Table 8.

<u>Combined Qualitative and Quantitative Scores of The Normal and Brain Damaged Groups</u>

Statistic	Normal		Brain Damaged
N	35		35
Range	24-86		0-51
M	62.7		20.1
S.D.	14.05		18.15
σ M	2.40		3.11
Mdn	63		26
σ Dm		3.92	
Dm		42.6	
C.R.		10.8	

Table 8

The subtraction of the penalty scores from the quantitative score resulted in some shifting in both groups. The means show that the B-D group as a whole was able to punch correctly one-third the number of holes that the normal group punched. In terms of scores, 30 of the normal group have scores from 50 to 86, while three have scores of 45, 47, 48 and two of 24 and 26. These latter two subjects showed random errors in the early and later part of their performance and attained scores well within the range of the B-D group. However, no penalty scores other than punching through were assessed against the two Ss. In the B-D group 29 Ss have scores below 40. Twelve of these 29 now attain only zero scores, which means no credit at all. The remaining six Ss in the group of 35, have scores within the range of 40 to 51. Evidence of overlapping therefore appears in that the three normal Ss who scored 45, 47, and 48 are in the upper range of the B-D group, while two of the B-D Ss may be said to be in the lower range of the normal group with scores of 50 and 51.

It appears that the B-D group shows the most change with the addition of the qualitative scoring; however, the normal group is also penalized and their scores reflect this change to the extent that the significance of the difference between the group means shows but a slight increase.

Discussion of Underlying Processes and Pathology

Some Explanatory Hypotheses

We stated the hypothesis (page 10) that adequate integration of normal cortical functions is required for precision, adjustmental variability, and timing in motor co-ordination; that brain damage interferes with this integration, resulting in an impairment of isolated voluntary movements, i.e., dedifferentiation. The same lack of integration will delay the interaction of the different processes, so that the tempo of the performance is retarded. The latter also manifests itself in the cognitive handling of the task and in behavioral regidity, in the sense of stimulus bond--the piecemeal response to the holes. The added difficulty in this test is that anticipatory planning of the pressure to be exerted in punching is necessary along with adequately timed control, in order to prevent the punch from going too far. Since this process repeats itself at each hole, the accumulative experience of inadequate and adequate pressure controls is either translated into learning of adequate pressure for the subsequent punches or there is failure in this aspect. In the latter case, no dimunition of double punch errors would occur. The B-D fails in both requirements, namely, the anticipatory planned control as well as in the acquisition.

One of the reasons for the non-acquisition may be the lack of integration (or isolation of parts) in the cortex, which may interfere either with adequate discrimination or with the cognitive evaluation of the kinesthetic cues. The performance of the task then proceeds with little or no correction for errors and no improvement in technique. This lack of normal communication between different brain functions will further retard the learning process.

RING TEST--"Speed Prehension"

Description of Task

Three aspects of prehension are tapped: first, the precision in grasping and removing individual metal rings from a pole; senond, precision in rapidly picking up rings and carrying them across a plate--the base of the pole--and returning them to their original side; and third, accuracy in grasping and sliding the rings around the plate, first in a clockwise and then in a counter-clockwise direction. par.

Apparatus and Test Instructions

The plate with a pole inserted is placed before the subject. Fifteen metal rings are placed on the pole. (See Fig. 7.)

1. Instructions to subject

a. Rest your (preferred) hand on the table. As soon as the signal to begin is given, remove the rings, one at a time, as quickly as possible. Grasp them firmly and place them flat on the table to the right of the base. Do not attempt to arrange the rings in an orderly fashion, but be sure to place them, never throw them. If a ring should fall from the table, do not attempt to pick it up as there are enough other rings there. Remember you are to work as quickly as possible. Do you understand? Ready, begin.

b. Same as above, except the rings are to be removed and placed at the <u>left</u> of the base.

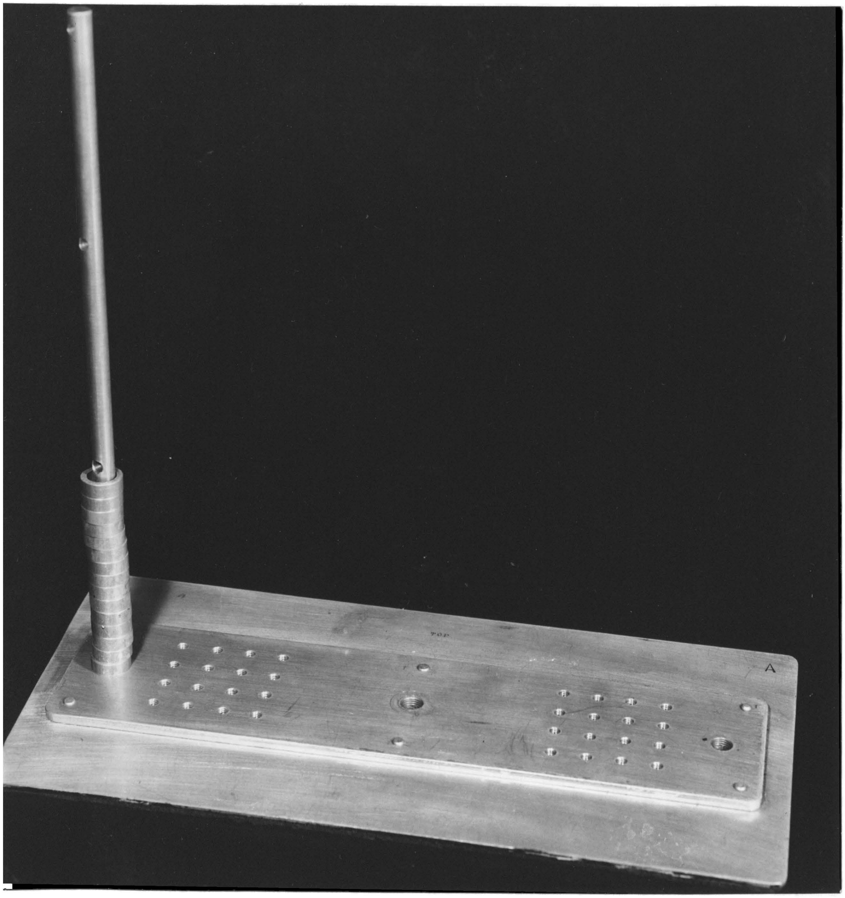

Fig. 7

2. Instructions to subject (after removal of the pole from the base):

a. Rest your (preferred) hand on the table. As soon as I tell you to begin, pick up the rings, one at a time, and carry them across the base as quickly as possible. (See Fig. 8). Grasp them firmly and place them flat on the table to the right of the base. After you put the last ring down, bring them all back to the left of the base in the same manner. You do not have to line them up. Remember you are to work as quickly as possible. Do you understand? Ready, begin.

b. Same as instructions above except rings are carried across the base away from and toward the body.

3. Instructions to subject: (Rings placed in a cluster by the plate. See Fig. 9).

a. Rest your (preferred) hand on the table. As soon as the signal to begin is given, you are to slide the rings, one at a time, around the base in a clockwise direction (demonstrate) and return them to the approximate starting point, as quickly as possible. You may select any ring at random provided you do <u>not use the same ring</u> you have just released. Remember you are to work as rapidly as possible. Continue until I say 'stop.' Do you understand? Ready, begin.

b. Same instructions for counter clockwise direction.

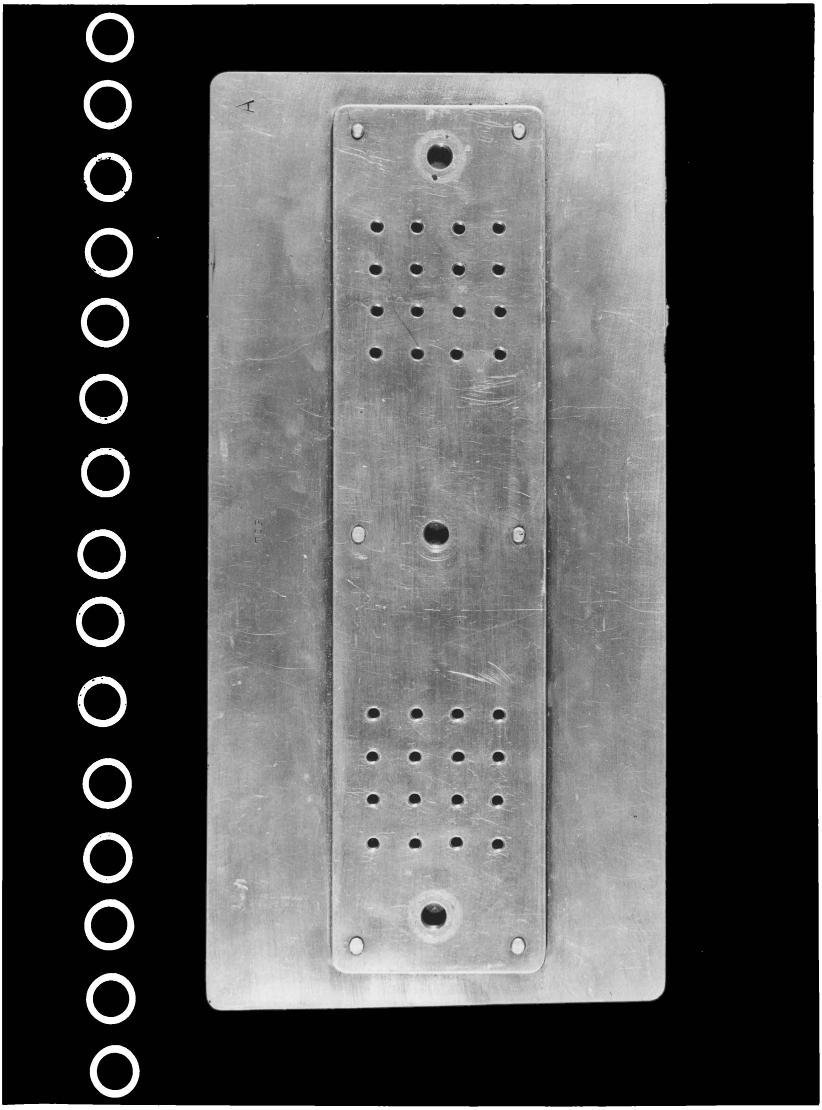

Fig. 8

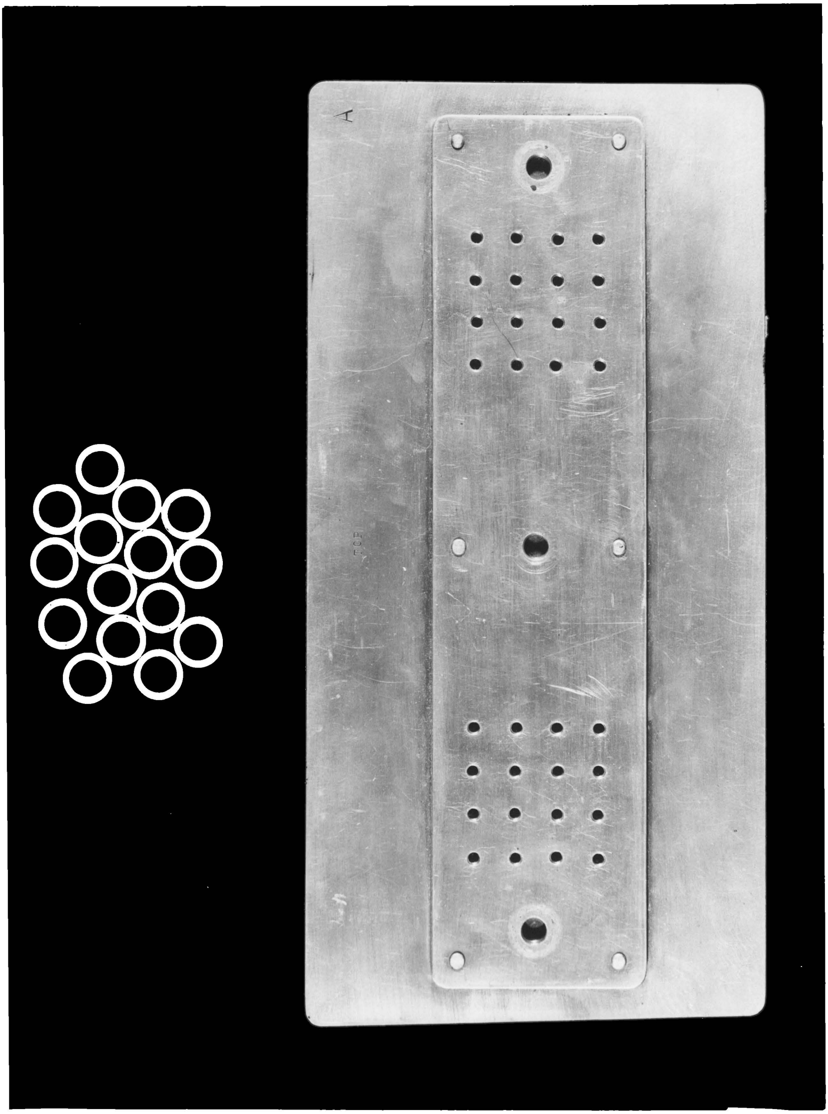

Fig. 9

Behavorial and Performance Analysis

On the one hand the task is one of accurate but relative gross manipulation; on the other hand, more enters into an adequate execution than motor dexterity. Though the S carries his task to completion with no time limit, he is asked to perform as rapidly as he can. This requires anticipatory control of movements to be executed in timed coordination and avoidance of superfluous motion. It requires cognitively a flexible planning expressed in rapidly varied motor actions. The presence or absence of this flexibility or shifting may at times be inferred from verbal tests alone, but here it can be concretely demonstrated in manipulative behavior.

A comparison of the behavior manifest in the B-D group and in the normal group may further help the analysis of the performance on this task. 1) The normal S lifts each ring up without contacting the others and moves it to the desired position with little or no lost motion. The performance of the B-D S is slow and appears retarded in point of time and number of units accomplished. Nevertheless, he does not proceed with fewer movements than the normal but uses many more movements than are actually necessary. There is a great deal of wasted motion which appears especially in the placement of each ring, as if this were not irrelevant to the task. Thus each ring is set down with meticulous care, as if it had to "find" its particular place. The inadvertent result is a commonly lining up of rings instead of random placement.

2) The B-D S, intent on quickly removing the rings from the pole,is likely to do so by a swaying motion of the whole trunk and tends to begin taking the ring off the pole before he has reached the top of the pole, thereby unbalancing the latter and often dropping the ring. This would seem to indicate that anticipatory judgment is being interfered with, by the other aspects of the task. Also his attempts at speed easily bring about the slipping of a ring from his grasp, or the grasping of more than one ring at a time, often without the subject's appearing to notice this.

3) In addition there seems to be very little "learning-carry-over" of what was "learned" in dealing with one ring to the manipulation of the next one. In contrast, the normal is able to constantly improve and correct his judgments of distance and spatial directions, so that the execution of the task movements become more and more co-ordinated as he progresses on the test.

4) Further the lack of flexibility mentioned above becomes evident in the following ways: a) The instructions are interpreted literally and the S deals with each subtask, i.e., the individual ring manipulation, as a discrete, separate task in itself. In accordance with such a tendency, each ring is dealt with individually, namely, as a "thing" put in a special place, so that all the rings are lined up in a compulsively appearing order often parallel to the edge of the plate. This behavior is observed, though Instruction 1.a explicitly states, "Do not attempt to arrange the rings in an orderly fashion...," and the S is asked to work as rapidly as possible; b) moreover, all the

rings which have been used are placed separate from the unused rings in spite of the Instruction 3.a., "You may select any ring at random provided that you do not use the ring that you have just released," again requiring speed; c) finally, the task of Instruction 2.a.--where the S has to carry each ring across the base and when finished bring them all back--is typically carried out in the case of the B-D S by breaking up the total task into two discrete units with a distinct time interval between each. In contrast, the normals carry out the task smoothly without any comparable pause between the two sub units.

There are several other characteristic performance differences between the two groups. In order to avoid repetition, they will become obvious in the qualitative scoring section.

Method of Scoring

Qualitative

The qualitative as distinct from the quantitative scoring is concerned with errors in manipulation, execution, and planning. The scoring consists of a system of penalties which are recorded following slips in execution. These are totaled giving a qualitative deviation score for the test.

Qualitative Deviation Scoring (penalty scores by addition)

Part I a and b (removal of rings from pole)

1. Number of times the S attempts to pull rings off the pole too early, unbalancing pole and/or losing ring because the height of the pole is incorrectly anticipated--1 for each.

2. Number of rings dropped from grip--1 for each

3. Number of times more than one ring is removed--2 for each

4. Meticulously lining up one ring after the other in a row along side of the base plate, instead of placement without specific order as instructed--1

Part 2 a and b (carrying rings across baseplate and back again)

1. Meticulous lining up of rings in a chainlike fashion contrary to instructions--1

2. Number of rings dropped--1 for each

3. Time interval--whenever the subject has completed one trip in transporting rings to one side and then pauses before returning rings to the original side--actual time paused in seconds equals the number of points added.

4. Deviant thumb-index finger opposition in grasping the ring, so that both fingers grasp sideways instead of with fingertips--1

5. Head movements accompanying hand motion--1
   (explanation given in previous test)

6. Order of bringing rings back across the plate--last to first or first to last--1 for first to last order.

   (Since the subject is asked to do the task as quickly as possible, it is assumed that the shortest method will be employed to comply. If S returns the ring in the same order in which they were initially taken across, his hand has to move from the place of the last ring transported to the place of the first ring, then the second and so forth. This indicates a forced orderliness and rigid structuring of the task, leading to wasted motion and retardation which are normally avoided by picking up the rings at random, without specific order.)

Part 3 a and b (sliding the rings around the plate)

1. Effort to use each ring only once--1

(The subject is instructed to use any ring so long as he does not immediately use the one just released. If he follows this instruction with understanding, he can succeed most economically in rapid execution by using only two rings, avoiding the last transported and selection another--and then alternating between the two. Or the S may select <u>any</u> of the unused rings not caring specifically which one as long as the last released ring is avoided. If he follows this instruction, by using <u>every</u> ring only once, he is forced into trying to keep track of the rings used and into the difficulty of knowing "which ring is which" between returned and unused rings. Since the two previous tasks actually involved the use of all rings, several alternatives in describing this behavior exist: One, the subject cannot cope with the task of avoiding the use of the just released ring and therefore avoids the use of every used ring compulsively; two, he perseverates in the use of all rings as done previously; three, the behavior is a contamination of both the above tendencies. These alternatives are not explanatory but descriptive, because they refer to behavior--or psychological--categories, not to underlying brain processes.)

2. Separation of used and unused rings--1 whether once or repeated. (This is a more compulsive solution to the difficulty encountered above in No. 1.)

3. Number of times the base is contacted--1 for each contact

4. Lifting the ring from the table--2 for each (This is contrary to instructions and more significant, since an actual demonstration has been given.)

Penalties for errors on each part of the test are computed. The three parts are then totaled for the qualitative deviation score. This score is added to the quantitative score for the total score. No criticism of the performance is made by the examiner, nor are any instructions given other than those set forth in the testing procedure. It should be emphasized that in this scoring each of the above-described deviations must be recorded and scored. For an example, if the subject, while sliding the ring around the plate should contact the plate with his finger or thumb, the prescribed penalty score is assessed; or if two rings are removed to the top of the pole and one is dropped back on the pole, the penalty score is given.

Quantitative

The results can be recorded during the testing period on a scoring sheet shown in Fig. 10. The time for completion of each of the three parts is recorded and summed, and this is the total quantitative score for the test. This score is based on the Van Der Lugt system.

Scoring Sheet

RING TEST

1. a____ b____ Total____

Penalty Score
1. Height of pole misjudged ____
2. Rings dropped ____
3. Removal or more than one ____
4. Lining up of rings ____

Deviation Score ____ Total ____

2. a____ b____ Total____

Penalty Score
1. Lining up of rings ____
2. Rings dropped ____
3. Pause time ____
4. Head movements ____
5. First to last order ____
6. Use of other than tip of forefinger and thumb ____

Deviation Score ____ Total ____

3. a____ b____ Total____

Penalty Score
1. Use of all rings ____
2. Separation of used and unused ____
3. Contacts ____
4. Lifting ring from table ____

Deviation Score ____ Total ____

Quantitative and Qualitative Total ____

Fig. 10

Results

As can be seen from Table 9, the results generally confirm our hypothesis: B-D Ss require a longer time for completion of the tasks than normal Ss. This time difference is statistically highly significant.

Quantitative Scores of the Normal and Brain Damaged Groups on the Ring Test

Statistic	Normal		Brain Damaged
N	35		35
Range	111-171		172-396(566)
M	142.8		230.7
S.D.	15.9		80.5
M	2.72		13.6
Mdn	143		200
Dm		13.78	
Dm		87.9	
C.R.		6.38	

Table 9

The group means for each performance are 142.8 for the normal and 230.7 for the B-D Ss. The weighted t-tests which were applied to test the significance of the differences between these means give a critical ratio of 6.38, which is beyond the .001 level of confidence. The results in the table further indicate a bi-modal distribution, since the range of the two groups do not overlap. This precluded the use of the usual t-test and the test by Cochran and Cox was used. The range of the B-D group is very wide and the standard deviation of 80.5 shows the extreme variability of the performance within this group. In addition one S had a score of 566, due to extreme caution and slowness. This score was omitted in the statistical computations as it would have given an untrue picture of the group performance.

Qualitative deviation scores further accentuate the difference between the groups.

Qualitative Scores of Normal and Brain Damaged Groups on the Ring Test

Statistic	Normal	Brain Damaged
N	35	35
Range	1-8	2-67
M	2.9	15.6
Mdn	2	15
Dm	12.7	

Table 10

The results shown in Table 10 do not yield a bi-modal distribution but indicate a highly significant difference between deviation scores of the groups, yielding a difference in means of 12.7

An analysis of the errors scores in Table 5 indicates that for the normal group the highest error score attained was 8 and the average for the group was 2.9. Four of the normal Ss had no errors, fivehad one error and ten Ss had two errors. Thus 19 or 54% of the normal Ss had an error score of 2 or less. The remaining 16 Ss had error scores as follows: Five had a score of 3; three had a score of 4; three had a score of 5; two each had scores of 6 and 7 and one had a score of 8.

In the majority of the Ss, these errors occurred in Part 3 of the test, where the normal Ss attempted to slide the rings around the plate in the least possible time. In speeding up they reduced the arc of their swing and contacted the plate. After such contacts occurred the arc of the swing was usually widened and subsequent contacts became less frequent. Five of the Ss used all 15 rings in this part.

On Part 2, three of the normal Ss started to line up the rings but abandoned this action spontaneously. Only one normal S had an error score on Part 1. This occurred when a ring was dropped.

In the B-D group the highest error score was 67 and the average for the group was 15.6. All Ss in the group had an error score. Three of the B-D Ss had scores of 2, 4, and 5 respectively; three had a score of 6; two had a score of 7 and three had a score of 8. The remaining 24 Ss or 68% had scores of 10 or more.

The errors of the B-D group were scattered throughout the three parts of the test. In contrast to the normal group oerformance on Part 3, the B-D group followed the contour of the plate and contacts were numerous. In order to avoid these contacts, the rings were lifted up in four instances. The rings were separated into two groups--used and unused--by 20 Ss and ten Ss lined up the used rings. All of the B-D Ss used all 15 rings. On part 2, 26 Ss lined up the rings and of this number, 12 Ss used the edge of the plate as a guide for the lining up. The task of carrying the rings across the plate and back was broken up into two discrete tasks by 19 Ss of the B-D group, eight of whom paused at least two seconds before returning the rings to the original side. (None of the normals interrupted the continuity of their established rhythm.) On Part 1, the lining up of the rings was not as frequent as on Part 2, but the dropped rings, removal of two rings at once and the accompanying head movements accounted for a high error score in the performance of 23 Ss.

As Table 10 indicates, there is some overlap between the scores of the two groups. However, if a cut-off point is made at 6, three

B-D Ss--9 per cent--fall below this point and three normals--also 9 per cent--are above it. It might be well to point out that the three B-D Ss who had error scores of 2, 4, and 5 had time scores well beyond the range of the normal group. The difference between the performance of the two groups is thus pointed up both behaviorally and in completion time.

Combined Qualitative and Quantitative Scores of the Normal and Brain-Damaged Groups

Statistic	Normal		Brain-Damaged
N	35		35
Range	115-177		179-432(570)
M	145.7		246.2
S. D.	15.5		48.5
Mdn	145		214
σM	2.65		8.31
σDm		8.72	
Dm		100.5	
C.R.		11.5	

Table 11

The qualitative deviation scores do not appreciably change the picture of the normal group as is shown in Table 11. Its mean has increased by 2.9 points from 142.8 to 145.7 and the range from 111-171 to 115-177. The B-D group shows considerably more change. The mean increased over 15 points, from 230.7 to 246.2 and the range from 172-396 to 179-432. (Oddly enough, the S with a score of 566 had only four error points. His extremely meticulous care and constant repeating of the instructions aloud to himself precluded many infractions.) The significant increase in the difference between the means of the two groups also increased the critical ratio from 6.38 to 11.5.

Discussion of Underlying Processes and Pathology

Some Explanatory Hypotheses

I. The control of finer movements in the distal parts of the limbs has ostensibly suffered, e.g., the primitive form of grasp with the fingers and the tendency to involve the trunk or head in the finger use. There is also a strikingly reduced control in the precurrent or anticipatory steering of the longer complex movement sequences. This function, necessary for initiating and directing an ordered course of motor acts under conditions of speed, is diminished. The reasons for these two changes may be: That the integration has levelled off from its normal articulation to a more diffuse spread of excitation; that the integration of the sensory appraisal--the feedback--and of the motor steering is temporally out of step. At the present state of our knowledge it is futile to speculate on whether this lack of integration is caused by: 1) A "reduced vigilance" in cognitively interpreting the sensory feedback; 2) less distinctness in the feedback itself; 3) reduced articulation on the motor side, i.e., unprecise innervation. Any one of these losses would affect the normal integration of sensory-motor "impulses" or constituent functions necessary for willed movement. Whichever of these constituent functions has suffered more than the others or whether they all have suffered, we do not yet know. The performance picture of the B-D S, however, provides sufficient evidence to conclude that the normal communicative interaction between different brain functions requisite for coordinated motor performance is impaired. This lack of adequate integration has also been described as dedifferentiation of the formal aspects in the organization of brain processes.

II. That we are also dealing with a cognitive disturbance expressed in the so-called rigidity of behavior seems evident from the following: The main task goal of either taking the rings from the pole or bringing them across the plate and back, etc., includes several necessary sub-goals or secondary aspects of the task execution. Such are, not to grasp more than one ring at a time, speediness, to avoid touching the plate in transporting the rings and to avoid using a ring just previously used. The B-D Ss appear to have difficulty in subordinating these secondary aspects of the main task execution. The entire manipulation with the rings seems to be executed on a level of concrete interpretation of the task, namely dealing with rings as individual objects--"things," each of which has equal independent valence but is not a part of a larger task.

The ability to function simultaneously on two or more aspects of a given problem seems to be impaired to the extent that the main task aspects, e.g., "bringing rings across" can only be carried out at the expense of other also necessary task aspects--speed and smoothness. If the S focuses on speed, this aspect commands the foreground at the expense of others and he grasps two rings or drops rings, or in sliding the rings around the plate rapidly, he hits the plate. If he focuses on not using the last ring released he does it at the expense of speed and rigidly lines up each ring against the edge in an overly orderly fashion. If he focuses on transporting the rings across the plate in one direction, he loses sight of the total task of bringing the rings back in the other direction after taking them across, thus losing time in pausing after completing the first part, as if he had to re-orient himself again for the trip back. This impairment of simultaneous functioning in several overlapping regions of behavior also accounts for the described lack of flexibility and shifting.

There is further evidence of a lack in self correction following failure. This seems to be linked with a lack of learning from the experiences gained during the various performances in each of the three situations. One of the reasons may be the above mentioned impaired communication. This would hinder transfer of learning and also account for the constricted mental functioning which blocks the B-I from viewing the individual ring tasks as parts of a continuous larger task whole and lead him instead to deal with them as discrete and separate.

MARBLE-PEG TEST—"Co-ordination Dynamic"

Description of Task

The task is to place two objects—a marble and a peg—into different holes, always using one hand for each (hollows for marbles and holes for pegs), and in doing so, to follow a designated path along which the holes and hollows are arranged on a metal plate. This path consists of rows in which the holes for peg and marble placement alternate their position in a left-right sequence. Thus the S has to cross hands every other row. Every placement must be executed with both hands simultaneously, crossing them as necessary; this involves repeated acts of anticipation whenever the crossing is imminent and when it is not, and to carry out these planned actions with the necessary shifts in set and movement control that permit smooth simultaneous placement of peg and marble as well as prevent the dislodgment of those already placed in preceding rows and adjacent positions.

Apparatus and Test Instructions

The plate with the rows of hollows and holes is placed before the S. The marbles are in a container on the left side of the plate and the pegs are on the right side. The paths of the rows have been modified from the Van Der Lugt arrangement, and pointing markers have been placed on the plate to indicate the changing path. This was done in order to increase the frequency of shifts in orientation and to make the task more complex in simultaneous aspects. (See Fig. 11.)

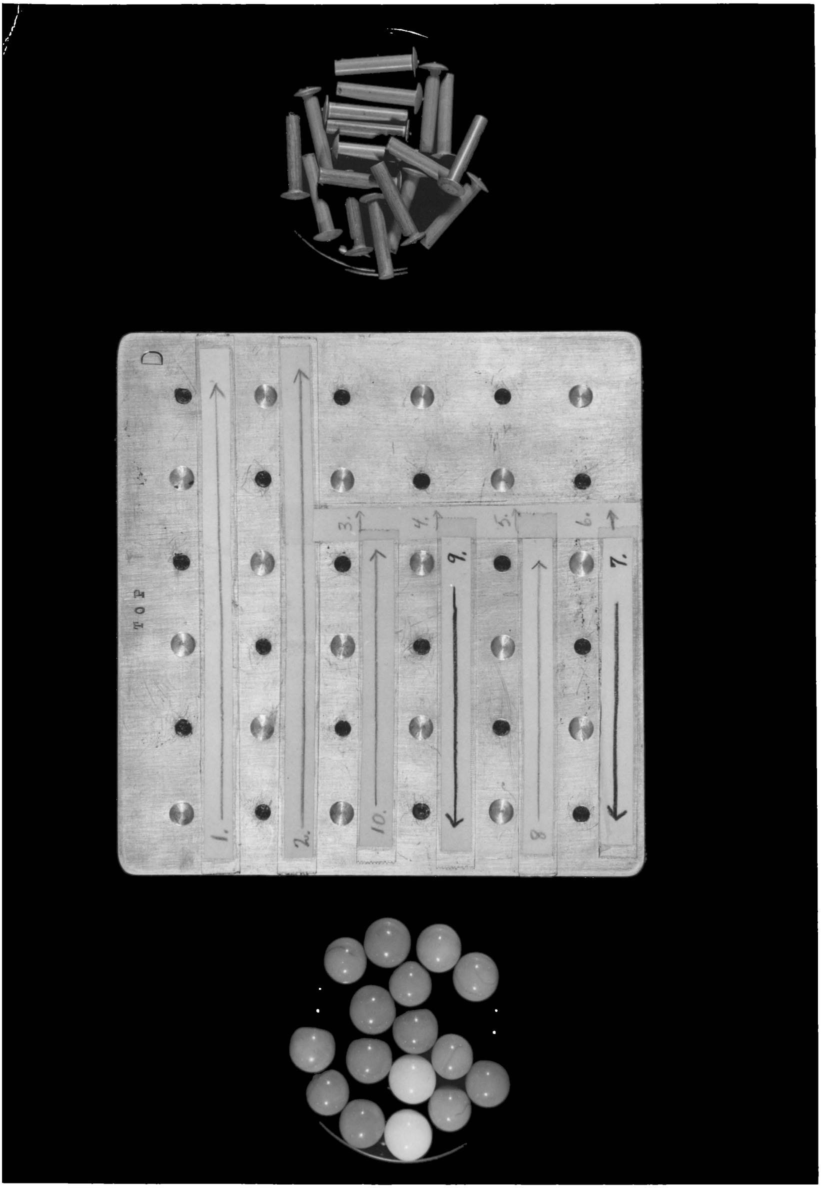

Fig. 11

Instructions to Subject

Your task will be to fill the hollows with the marbles and the holes with the pegs. But always use both hands and always pick up the peg with your right hand, the marble with your left hand at the same time. Also take care to place the marble into the hollow and the peg into the hole, one beside the other at the same time.

While you always hold the peg in your right hand and the marble in your left hand, you may cross hands whenever it is necessary, but never transfer either the peg or the marble from one hand to the other.

What it all amounts to, then, is that you place each time a peg and a marble together as a pair side by side into the hole and hollow, even if you have to cross hands to do this. You should not start with a new pair until the previous pair is properly placed. In case it happens that a peg or a marble you have already placed should become loose, be sure to put it back in place before you start a new pair.

Now remember always to use both hands simultaneously when you place the pairs, taking the peg in your right hand and the marble in your left hand. Follow the numbered paths which are drawn on the plate with arrows.

Before we start I would like for you to point out with your index finger, the path you are going to follow, so that I am sure you understand. (Subject traces pathway.) Now put your hands on the table and begin placing the pairs when I say "start."

Behavioral and Performance Analysis

The normal S usually carries out the grasping and placement of both objects with ease throughout the first row, feeling his way at an even tempo. But on the subsequent rows, where the holes alternate position, his tempo may become irregular. He loses time by stopping in mid-air, poising each hand on its respective side while inspecting the holes, as if to "cross or not to cross." This "decision time" indicates an organizational difficulty which results from not having inspected the subsequent row beforehand, so that a necessary crossing can be anticipated. Little or no difficulty is manifest, however, in the execution of crossing the hands whenever the subject finds it necessary, following inspection.

Subsequently, the organizational difficulty disappears as soon as he hits upon the principle of alternation in crossing and non-crossing of the hands. He seems to examine the paths while picking up the marble and the peg, so that, when he comes to place them, his hands are already in the right position. Thus little time is lost in adjusting the position of the hands and the pathway is also followed without time loss and orientation difficulty.

This mode of performing is already the result of learning during the preceding placements and leads to a further behavior change, namely, an increase in tempo of the task execution which is now more familiar as to planning or anticipation and motor coordination. The increased speed leads the S, however, into a new difficulty, since the simultaneous placement becomes less easy, the more rapidly it is attempted. If now, errors are made by the normal S, they are mainly connected with "non-simultaneity" committed in his effort to maintain the pace of a rapid performance. These errors consist chiefly in a slight temporal discrepancy between the two placements by the crossed hands, so that one hand is slightly ahead of the other owing to the pressure of haste. Yet the hand crossing itself is adequately executed and no fixed set for either hand preceding the other is manifest, nor are the errors continuous or frequent.

The B-I S appears to meet with definite difficulties on this test. 1) In the first place he typically does not pass beyond the normal S's first phase of solving the task by inspecting each new row separately. Hence the subsequent phase of realizing the principle of alternation in crossing and not crossing and of attaining practice in anticipation is rarely if ever reached by the B-I. He remains in the "first phase" and even more pronouncedly than the normal, carries out each placement of the two objects as an individual task, inspecting the two holes only after having picked up the marble and peg. In the further course of performance, he then will often manifest the familiar perseverative tendency to repeat the hand position he arrived at the final holes of the last row. This necessitates a re-orientation with each new row "from scratch" as if no previous alternation experiences had taken place, so that no grasp of such a principle is in evidence. What the behavior evinces is rather an effect of the manipulation in the immediately preceding row on the approach to the next, indicating a psychomotor set to repeat, but there is no indication of the acquisition of an alternation set. This results in time loss of crossing when the S should not and of failing to cross when he should. This in turn leads to error scores for lack of <u>anticipation</u> because the S will bring first the marble and peg with each hand to a hole on the wrong side and/or will even make placement trials before realizing that their direction is wrong and only thereafter reach the correct placement.

2) Besides these specific difficulties in the cognitive organization of performance the B-I also manifests difficulties in motor organization. (a) The simultaneous placement is mastered as long as no crossing is necessary, namely, on the first row. From then on, two defects in manipulation appear. The S is hampered in the simultaneous placement of "crossed objects," because the demand for the simultaneity and the hand crossing interfere with each other. At the same time, he may be hampered by the carry-over of the preceding "set" <u>not</u> to cross. This is evident whenever the S has come further along in the new row and has thus been forced into the new set of crossing; while he now crosses the hands accordingly his attempts to do the crossing <u>simultaneously</u> remain unsuccessful for the balance of the row.

(b) The simultaneous crossing in itself requires efforts on the part of the B-D S which the normal S does not seem to encounter. Thus the former may have to execute the crossing with exaggerated flexor movements of both arms, with the elbows lifted in an extended position. This seems parallel to the formerly mentioned associative movements* and also to reflect the previously discussed impairment in the control of finer movement coordination in the individual digits.

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* cf. page 29

In order to obtain (or to release) the necessary bi-manual hand-finger flexion while holding fast peg and marble with the fingers of each hand, the B-D S needs the support of a much grosser total flexion movement of the arm than the normal. This grosser flexion position permits the finer flexion of the hand-finger position to emerge easier, namely, as a natural extension of the flexion of the arm into the fingers, thus reducing the otherwise voluntary innervation in the latter. This can also be considered a detour to perform the simultaneous crossing through abnormal means. (Though the normal also can carry out easier this hand-finger flexion with the arm flexed in a certain angle he does not depend on this "preferred way" of execution.) The B-D, however, appears to be exaggeratedly dependent on these preferred ways as Goldstein (25) has repeatedly pointed out.

(c) Other anomalies in carrying out the crossing task also testify to the difficulty in simultaneous crossing. There is an awkwardness of the hand and fingers posture in the crossed position, particularly when the gross arm flexion has not been hit upon. Furthermore, there are frequent attempts to arrive at the simultaneous hand crossing in the following manner: While the thumb and index finger of the left hand are grasping the marble, they are spread out to form an opening and the corresponding fingers of the right hand holding the peg are squeezed into this opening; even if this direct method of sticking the right into the left hand, instead of crossing them leads to correct simultaneous positional placement, the inserted right fingers fall short of attaining a stable placement of the peg, so that when the hands separate, the peg is unbalanced. Another consequence of the crossing difficulty appears in the increasing "tendency" of the B-D to avoid the simultaneous crossing altogether, so that he falls into an almost rhythmical pattern of "one, two," placing the one object first with one hand and rapidly placing the second with the other hand. This behavior can again be considered a detour in coping with the instruction, though objectively violating them. Psychologically more important, however, is the fact that the task of placing marble and peg with a simultaneous hand crossing is now accomplished by retreating from simultaneity to succession in the motor action. It has been pointed out by Goldstein, and Scheerer, Rottman and Goldstein, that the solving of tasks which require simultaneity, by resorting to successive steps, is indicative of a more primitive organization and of a performance level which is easier--less difficult. This points up again the restricted dependency of the B-D S on preferred modes of behavior in contrast to the normal.

(d) Together with these defects in motor organization, the B-D S dislodges more frequently already placed marbles and pegs during the crossing efforts than during ordinary placement.

3. A third characteristic of the B-D Ss' performance is the following: His performance usually settles into mastering one aspect of the task, i.e., he concentrates on the correct pathway and loses sight of alternation and simultaneity, or he concentrates on the alternation and simultaneity and loses the path, thus incurring panalties on this scale. This restriction in scope of diversity in behavior suggests the difficulty of "holding in mind" simultaneously

several different aspects of the task—often pointed out in the reports on experimental observations of the B-I. Consequently, his performance may erratically fluctuate until he finds one way of execution and then he often becomes fixated on this procedure—a behavior characterized by the terms rigidity and stimulus-bound.

Method of Scoring

Qualitative

The qualitative scoring is concerned with errors of manipulation, planning, and execution. The scoring consists of a system of penalities which are recorded following faulty execution.

Qualitative Deviation Scoring (penalty scores by addition)

1. Non-simultaneity in placing marble and peg—2 for each
2. Each dislodgment of marbles or pegs during subsequent placement—1
3. Motor blocking or conflict in crossing hands—1 (same score whether once or repeated)

   (An attempt is made to cross the hands but the hands block, conflict or interfere with each other so that the final crossing is clumsy and not attained in a normal, smooth manner, e.g., the fingers of the two hands awkwardly interfere with each other, or the crossing is executed with an exaggerated flexor movement of both arms, lifting the elbows in an extended position.)
4. Loss of pathway—2

   (same score whether once or repeated)

   (Subject stops the placement and looks around for the correct path or inquires which path he should take.)

5. Failure to anticipate alternations--1 (same score whether once or repeated)

(Subject has not looked ahead and carries the marble and the peg each in one hand, forward to the placement holes on the wrong sides. He then may stop short and change the hand positions or even make placement trials before realizing that they are positionally misdirected and only then does he localize correctly.)

6. Number of admonitions necessary after S has failed two times on simultaneous placement--1

Quantitative

The quantitative scoring procedure is the number of seconds elapsed between the time the S picks up the first pair--marble and peg--and that of the placing of the last pair. This scoring is based on the Van Der Lugt system.

Qualitative deviation scores are recorded during the performance on the scoring record and totalled at the end, when the total time is also entered. The two scores are then combined. (See. Fig. 12)

Marble-Peg Test

Deviation Score (Penalties)

1. Non-simultaneity _____
2. Dislodgment of marbles or pegs _____
3. Motor blocking in crossing hands _____
4. Loss of pathway _____
5. Lack of anticipating alternation _____
6. Times admonished _____

Total Qualitative Deviation Score _____ Total Time _____

Qualitative and Quantitative Total _____

Fig. 12

Results

The total results in time scores are given in Table 12. Inspection of the data reveals a striking difference between the performance of the experimental and that of the control group. The Cochran-Cox method was used in the scoring as the F-test indicated different variances of the groups. The means show that the B-D Ss as a whole required more than twice the time for completion than was needed by the normal Ss. Analysis of the data by weighted t-test shows a significant difference of the two means.

In terms of score ranges in each group, it should be noted that 33 of the 35 B-I needed from 110 seconds to 480 seconds, and 32 of the 35 normals needed from 54 to 95 seconds for the completion of the test. A slight overlapping in the two ranges therefore appears in the three normal Ss who scored 103, 105, and 105 seconds respectively, which places them within the shortest time scores of the experimental group, i.e., at the minimum of their time range. In turn, two B-D Ss scored 96 and 98 seconds respectively, placing them among the longest time scores of the normal group, i.e., at the maximum of their time range. No other overlapping occurred.

The mean time score of 186" for the B-D group as compared with 79" for the normal, is due to the fact that the B-D S has to pause often to check, in order to determine which hand should be on the right and which on the left; to check which direction he should go as he reaches the end of the row; and to replace dislodged pegs and marbles.

Quantitative Results of the Normal and Brain Damaged Group on the Marble-Peg Test

Statistic	Normal		Brain Damaged
N	35		35
Range	54-105		96-480
M	79.3		186.2
S.D.	12.65		67.6
σM	2.16		11.5
Mdn	80		152
σDm		11.7	
Dm		106.9	
C.R.		9.1	

Table 12

Qualitative deviation scores are even more striking. Results shown in Table 13 indicate that the normal group has a mean error score of 2.3 as against an error score of 10.3 for the B-D Group.

Qualitative Deviation Scores of the Normal and Brain Damaged Groups

Statistic	Normal		Brain Damaged
N	35		35
Range	0-9		4-30
M	2.3		10.3
Mdn	2		10
Dm		8	

Table 13

Thirty-one of the 35 normal Ss had qualitative scores below 4; only four had qualitative scores between 4 and 9, which scores fall in the lower extreme of the B-D group's range. These four Ss were penalized chiefly for non-simultaneity because of hastiness, as has been previously mentioned. None of the normal group had penalty scores for loss of pathway and only six Ss were penalized for dislodging pegs or marbles. Fifteen of the group had a score of zero or one.

In the B-D group 27 Ss scored between 10 and 30, i.e., beyond the penalty range of the normal Ss. There were no cases with penalty scores below 4. Eight Ss scored between 4 and 8. Here the overlap consists of four normal and eight B-I Ss in the range of 4-9 deviation scores. Non-simultaneity was penalized in 66 per cent of the cases—23—and 51 per cent—18—were penalized for loss of pathway and dislodging pegs or marbles. It is interesting to note the spontaneous comments by a few subjects of each group. Two Ss of the normal group remarked, after the test was completed, that it seemed so difficult before starting that they did not see how it could be done until they tried it. The behavior of three of the B-D Ss upon experiencing difficulty was to ask the examiner again for directions, to criticize the apparatus, or to spontaneously verbalize reasons for failing and to ignore the instructions.

If we add the qualitative scores to the quantitative scores, the combined differences in the performances of the groups appear greater, and the overlapping of scores seen in the quantative scores in Table 14 is no longer apparent.

Combined Scores of the Normal and Brain-Damaged Groups

Statistic	Normal		Brain-Damaged
N	35		35
Range	55-108		108-495
M	81.6		196.6
S.D.	11.95		77.6
σM	2.05		13.2
Mdn	80		160
σDm		13.3	
Dm		115	
C.R.		8.6	

Table 14

DISCUSSION OF UNDERLYING PROCESSES AND PATHOLOGY

Some Explanatory Hypotheses

We know from the pretest and the test behavior that the B-D S can correctly trace the pathway; also that his prehension is adequate for picking up both the marbles and the pegs; that he understands how to cross his hands and succeeds in the hand crossing when he executes it at the expense of other task aspects, such as simultaneity, alternation, etc. The disturbance, then is not with the motor acts themselves viewed as discrete operations, but in the integration of them into a (sometimes simultaneous) coordinate whole of which these various operations are actually functional "parts." This integration is required on different levels of complexity and difficulty. The simpler one consists of the sensory-motor feedback and coordinated muscle innervation. The complex level involves the cognitive plan of action and its voluntary initiation. In this test, more than in any of the others, the cognitive level is particularly taxed for two reasons: First, in following the instructions many diverse task aspects have to be kept in mind simultaneously, i.e., are not allowed to be lost sight of at any given moment. Such task aspects are: selecting and carrying the marble and peg with the proper respective hand from the start, because transfer from hand to hand at any time is forbidden; the direction of the path; the specific row and holes to be filled; avoidance of dislodging already placed objects; and finally the alternation and crossing of hands. Secondly, an anticipatory alertness for changes in both the path direction and the hand position is needed, if the execution of the task is to be smooth and rapid. This can only be psychologically realized by a continuous shifting of set.

In accordance with our hypothesis any interference with cortical integration will lead to defective sensory-motor performance in both its instrumental and cognitive aspects.

On the first level the defective integration expresses itself in a dedifferentiated motor innervation and coordination of finer movements. The instrumentality of sensory-motor function, be it in terms of sensory-motor feedback, timing or precision, has become more primitively organized (analogous to the motor changes in the Punch-board Test). Behaviorally this leads to the described clumsiness in execution, especially the crossing of the hands under the prescribed conditions of the task.

On the second level, that of cognitive planning, the anticipatory as well as simultaneous function has suffered from the lack of integration. This leads to a cognitive restriction. It expresses itself in a difficulty of combining the required, diversified motor acts into a preconceived unitary plan of action and in a difficulty of continuing to hold them in mind while performing.

It is necessary to recognize that anticipation already involves aspects of <u>simultaneous function</u>. This latter is therefore involved in two ways in motor action: (a) There is already simultaneity operative in the "plan of action" inasmuch as there is <u>now</u> a simultaneous representation--a plot--of the later movement-sequence to be carried out. It is true this representation has a more schematic (outline-sketch) character than detailed completeness in all steps. The specific steps are filled in as the concretization of the plan proceeds in response to and supported by the actual demand conditions during the actions. Yet the studies on apraxia, in particular, have convincingly disclosed that normally such an anticipatory simultaneous schema exists as an "idea" (design) of motor action. Here one has also coined such terms as "ideational plan of movement" or anticipation of "movement-melody."

(b) This simultaneous "ideational plan" represents not only the temporal order of acts in a schema at any time point but it must also encompass the mutual coordination of diverse sub-acts, i.e., different limb and muscle movements. For example, the lighting of a cigarette is preceded by the ideational plan of schematically ordering the temporal sequence: Grasp matchbox--pick out match--strike it--bring lighted match to cigarette tip. This plan is executed <u>while holding the cigarette in the mouth</u> (and maybe at the same time conversing, crossing the street, watching the traffic light, etc.) At each time point, therefore, different simultaneous postural and muscle coordinations occur, while the movement-plot unravels in time. In other words, the ideational plan, the design itself, has to be kept in mind continually at each time point, together with the respectively prevailing changes in limb-muscle coordination. This complexity may be boiled down to a simple statement: Every action demands that we continually do <u>different</u> things at the same time while we follow an anticipated direction towards a goal.

From this point of view the sequel to brain pathology as regards cognitive restriction would lead to the following performance deficits: First, we would expect a less differentiated ideational plan, so that there is relatively less anticipation of specific motor acts. The action plan may have also shrunken in scope so that a complex sequence of manipulations and the total action goal cannot be sufficiently articulated in the schema. We submit that this causes the B-I S to cope with the task of approaching each paired placement of objects as a discrete unit of manipulation, attesting to the absence of a preconceived normally structured action plan. Further, at each time point the reduction in simultaneous function will lead to a difficulty in integrating the task goal with the diversity of other simultaneously called for muscle co-ordinations and action aspects. This may explain the described difficulty in simultaneous crossing of the hands and avoiding dislodgment of already placed objects, etc. It may also account for the tendency to become restricted to one partial feature of the instructions at the expense of the others as described, for example, in the B-I Ss losing sight of the path and concentrating on alternation and vice versa.

The same impairment may also underlie lack of learning, that is of not benefiting from the on-going experience with the task, so as to grasp the principle of alternation and incorporate it into an overall plan of attack. Instead a sort of pseudo-learning occurs, namely, a "falling into a restricted set" which is carried over from the immediately preceding experience with the specific placement sequence in the last row. We thus find that the B-D S either has to reorient himself from scratch with each new row or perseverates in his acquired set of the last row.

The tendency to fixate on a partial aspect of the task, as well as to perseverate in repeating a successful performance has been behaviorally described as a difficulty in voluntary shifting. In terms of our hypotheses and analyses here, we note the multiplicity of factors which enter into this phenomenon of lack of shifting, or rigidity.

It again becomes obvious that an understanding of the modification of function has to go beyond the recording of errors or failure scores, particularly since, despite all the time losses, the B-I Ss are able to complete the test as such. Only an analysis of the type of difficulties these Ss encounter can offer clues for the underlying defect. In this respect one has to include in the rationale, an explanation of some of the round-about methods in which the B-I accomplished the task in relation to their difficulty. First, the difficulty in simultaneous crossing is avoided by these subjects by often converting simultaneity into succession with a one-two rhythm of placing each object with one hand; or by trying to stick the right into the left hand--a behavior exclusively observed in the B-I. Further, the observed gross flexion movement of the arm in order to attain the finer coordination in crossing the hands may be considered a detour in coping with the difficulty of voluntary, more "individuated" innervation.

PLUNGER TEST--"Pressure Reproduction"

Description of Task

The task requires the S to reproduce from memory, while blindfolded, a given pressure which he has once exerted under the experimenter's verbal direction. The S first pushes a plunger down to a certain depth with his forefinger. Following this, he has to repeat his downward push over the same distance from memory. Ten trials with varying distances are given. Since the plunger is mounted on a steel spring inside a cylinder, the plunger offers resistance when pushed down, which resistance naturally increases the deeper the plunger is pushed, so that more pressure must be exerted for greater distance (depth). When the increased resistance calls out increased exerted pressure, the terms "pressure increase" or "pressure resistance" will be used to denote this. The use of spatial cues via touch impressions, kinesthetic sensations, and experiences of resistance enters into this task of pressure reproduction. The distances used in the ten trials in centimeters are: 1, 3, 2, 2, 3, 1, 1, 3, 2, 1, given in that order.

Apparatus and Test instructions

The S is blindfolded. In front of him is the plunger on which a centimeter and millimeter scale is marked off. (See Fig. 13).

Instructions to Subject: I am going to place the index finger of your hand on a plunger. No other part of your hand should touch the material, and your arm should be entirely free during the test performance. When I tell you to begin, you are to push the plunger down with a steady, slow motion until I say 'stop.' Then you are to release it

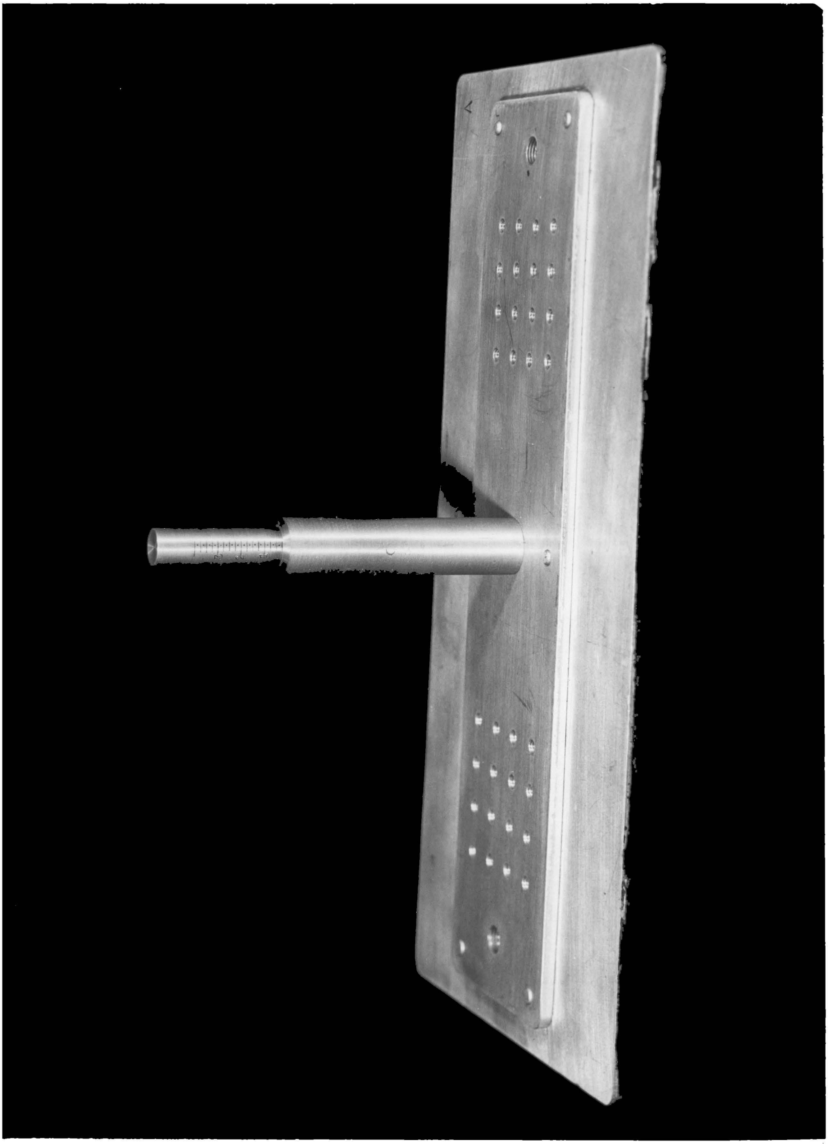


Fig. 13

and remove your finger. You will immediately repeat this performance and try to stop at exactly the same point at which you stopped before. The test will be repeated several times at different levels. Do you understand? Ready, let us begin.

Behavioral and Performance Analysis

The S, without the aid of vision, must make an estimate of how far down he pushes the plunger the first time and then attempt to fit the second downward push to that estimate from memory. Actually the S may not resort to a "consciously" formulated estimate of traversed distance in space or time. Rather he may match naïvely two consecutive units of concrete experience—the experience of the first downward push with that of the second. Each experience unit has two aspects, one along the dimension of increase in "pressure-resistance," the other along the dimension of time, namely the duration of the total movement in the downward push. These two aspects may merge into one unanalyzed total impression, where the increase in "pressure resistance" as based on temporally related kinesthetic and tactual cues and the movement time per se are not differentiated from each other. Each experience unit of pushing the plunger down may in this case be considered a unitary temporal whole comprising the two aspects in one total impression. Consequently, different people in trying to reproduce the first push from memory may solve this task in different ways. Some rely on the aforementioned naïve and unanalytical matching of two concrete units of experience; others may resort to the means of keeping time by verbal counting; while still others may attempt abstractly to isolate out the time factor for estimation; and again others make efforts to visualize their finger positions in the traversed distance of space. If such types of analysis are difficult for a person, he may watch without knowing on what constituent cues his matching is based.

According to which of these cues may have greater figural potency in the total unanalyzed impression for an individual will he depend more upon this cues than on the others, without having an analytical awareness of it. For example, such Ss may depend in their pressure reproduction more on the time factor, more on the spatial-kinesthetic factor, or more on the pressure-increase factor than on the other cues.

Several Ss indicated, for example, that they attempted to count, thus relying onthe temporal cues for their distance estimation and not matching total impressions in the above-mentioned sense. Others indicated that they attempted to visualize the position of their fingers in space, again not proceeding by "matching." Many, however, would give no explanation of how they arrived at their judgment even though it may have been accurate, thereby indicating that "matching" on a naïve experiential basis took place.

The normal S usually pushed the plunger somewhere within the range of the pressure level he was trying to reproduce. This reproduction was just as often apt to be either slightly above as below the level he was attempting to reach again. The B-D S's performance differed in the following ways: He might push the plunger down as far as it would go, no matter what pressure level he apparently was attempting to reproduce; he never underestimated, but pushed either from one to eight millimeters in the direction beyond the required depth; or the greater the increase of pressure--the farther the plunger was pushed down initially--the more likely the B-D S was to greatly overshoot the mark. In contrast to this latter point, the normal Ss performance seemed to diminish little in accuracy as the pressure increased.

Scoring Method

Qualitative

The qualitative deviation scores reflect the departure of the S from the usual method of procedure in executing the task.

Qualitative Deviation Scoring (Penalty scores by addition)

1. Pushes plunger completely down--2 for each
   (This is an expression of either the lack of sensitivity to the spatial and kinesthetic cues or of control in motor innervation)

2. Verbal counting--1
   (Same score whether once or repeated)
   (This appears to be an attempt on the part of the S to translate into a verbal sequence what he cannot accurately estimate. It reflects either a round-about method for solution or a necessary aid for the use of insufficiently evaluated pressure or spatial cues)

Quantitative

Deviations from the centimeter criterion are recorded plus or minus in millimeters for each of the ten trials, on the scoring sheet. (See

Fig. 14) The total arithmetical sum of the deviations for the ten trials is then multiplied by two. This is the scoring for the test by the Van Der Lugt system. These scores are added to the qualitative scores and the results are the total score for the test.

Plunger Test (plus or minus discrepancy in millimeters)

Trial 1____ 2____ 3____ 4____ 5____

6____ 7____ 8____ 9____ 10____ Total ____ X2 ____ Score

Penalty Score

1. Pushing plunger down completely ____

2. Verbal counting ____

Deviation Score ____

Qualitative and Quantitative Total ____

Fig. 14

Results

The quantitative results presented in Table 15 indicate a wide disparity between the scores attained by the two groups. The mean scores show that the B-D group as a whole had a discrepancy score three times as large as that of the normal group. Application of the weighted t-test indicates a significant difference between the means of the two groups. In addition the variability from the mean within the normal group is small--S.D. 5.90--when compared to that within the B-D group--S.D. 20.4 This necessitated the use of Cochran-Cox method as the groups did not have a common variance.

In terms of individual scores, in the normal group 23 Ss had scores within the range of 20 to 28, nine had scores below 20, and three had scores in the thirties—30, 32, and 36. The scores of the B-D group are much more widely distributed, with 31 subjects having a score of 36 or over, and four subjects have scores below 36—34, 32, 32, 26. If a score of 32 can be accepted as a cut-off point, <u>one</u> S from each group falls beyond the range of his respective group, thus reflecting the very small overlap in the score ranges of the two groups.

<u>Quantitative Results of Normal and Brain-Damaged Groups on the Plunger Test</u>

Statistic	Normal		Brain-Damaged
N	35		35
Range	8-36		26-114(238)
M	21.6		62.2
S.D.	5.90		20.4
M	1.01		3.49
Mdn	22		54
Dm		3.63	
Dm		40.6	
C.R.		11.2	

Table 15

The extreme score of 238 in the B-D group (shown in parentheses in Table 15) was attained by a S who pushed the plunger down almost as far as possible on each trial. This score was not used in the statistical procedure, as it would have given a distorted picture of the group as a whole.

It appears that the absence of visual cues greatly reduces the accuracy in performing among the Exp. Ss. Not only do they fail to match the second downward push on the plunger with the preceding standard but they also fail to develop "round-about methods" of coping with the task as compared with the other test situations. Their range of overestimation is from 2 to 11 millimeters. Aside from the one S who deviated over 11 mm. on all the trials, 19 Ss had plus deviations of 8-10 mm. on at least one trial; ten Ss had plus deviations from 5-7 mm. on at least four trials randomly distributed over the ten trials; five had deviations within plus 4 on at least three trials. Only one S in the entire group made one correct matching. With the exception of this S, all the others had no trials without a plus deviation.

In comparison the control Ss seem to be less hampered by the loss of visual cues. They do not show consistent overestimation as their range is plus 5 mm. to minus 5 mm. Twenty-two of the normals deviated within plus or minus 3 mm. in any one of the ten trials; eight had at least one deviation of plus or minus 4 mm.; five failed to match by plus or minus 5 mm. on one trial and did this only at the beginning of the trials but reduced this error to more nearly match their initial push in subsequent trials. All Ss made at least one trial in which they matched the pressure correctly.

Analysis of the scores on the performance of the two groups brings out an important fact. The control Ss had a fairly constant error score at any pressure level, while the Exp. Ss seemed to have a greater error at greater pressure levels. Although there was some variability for each individual S, the majority of the normal individuals did not show as much fluctuation in reproducing any particular pressure level as the B-I. A slight change was noted toward a more accurate reproduction at greater pressure levels, i.e., with greater distances traversed in the normal group. In striking contrast to this, the performance of the B-D group shows a decided shift in the amount of error at different pressure levels. There is a clear increase of errors in direct proportion to the increase in pressure-resistance. Thus 71 per cent (25) of the Exp. Ss had a larger error at greater pressure levels; 20 per cent (7) showed no change and 9 per cent (3) decreased the amount of error, although this error was still larger than that in the normal group. The maximum distance to which the plunger is pushed is 3 cm. and this distance occurs three times, while the smallest distance of 1 cm. occurs four times in the ten trials. Since the B-D group is more accurate at 1 cm., the total group error is less than it might have been, had greater pressure levels been used.

<u>Qualitative Deviation Scores of Normal and Brain-Damaged Subjects</u>

Statistic	Normal		Brain-Damaged
N	35		35
Range	0		0-5
M	0		1.4
Mdn	0		2
Dm		1.4	

Table 16

The results presented in Table 16 clearly indicate that the qualitative deviation scores are all within the B-D group. Nine of the B-D Ss had qualitative deviation scores of zero, while the remaining 26 had scores ranging from 1 to 5. Qualitative scores in themselves are less differentiating in this test than in some others of the battery, but since there is no change in the normal group, when the qualitative scores are added to the quantitative, the combined scores indicate a greater difference between the groups. The results given in Table 17 fully confirm this statement.

Combined Qualitative and Quantitative Scores of the Normal and Brain Damaged Groups

Statistic	Normal		Brain Damaged
N	35		35
Range	8-36		26-118(243)
M	21.6		63.6
S.D.	5.90		19.7
Mdn	22		55
M	1.01		3.38
Dm		3.51	
Dm		42	
C.R.		11.9	

Table 17

Table 17 further indicates the extent of the range of deviation scores within the groups. The normal group range 8-36 is 28 points while the range of 26-118 in the B-D group is 96, when we disregard the extreme score of 243 obtained by one S. As these scores indicate the degree of accuracy for each S in reproducing a given pressure, it gives a fair measure of the inaccuracy of the Ss with cortical pathology on this particular test. The ability of the normal group to more correctly estimate is further reflected in the fact that the actual average error for reproducing a given pressure is 1.1 mm. for each of the ten trials, whereas the B-D group had an actual average error of 3.2 mm. This actual average is computed from the mean of the quantitative score, if that is divided by half and then by ten (trials). (As will be remembered, the Van Der Lugt score is obtained by multiplying the total errors by two, which method we followed in the table on quantitative scores.)

Our hypothesis that a difference exists between the two groups appears to be clearly substantiated by the statistical results, since there is a significant difference between the means of the two groups. This difference is based on the quantitative scores alone, and the added qualitative scores show a slight increase in this difference.

Discussion of Underlying Processes and Pathology

Some Explanatory Hypotheses

We have to assume that this task requires the integration of several processes and functions. First, two types of sensory cues have to be integrated for the experience of traversed spatial distance by the downward movement. These cues stem on the one hand, from the sensory feedback of the combined tactual kinesthetic pressure necessary to overcome the felt increasing resistance of the plunger. On the other hand the cues derive from the kinesthetic experiences during the entire movement as it involves at least the finger, hand and unsupported arm. These cues have to be integrated or related to each other for arriving at a final impression of the traversed distance. However, this is not enough, the integration has to go beyond that of these two cues to a more complex cognitive level. Actually the two types of cues have to be incorporated into the body image of the individual as a frame of reference. No pressure increase or total movement experience can yield any spatial cues of distance or position without becoming related to and integrated with the schema or postural model of the body as Henry Head has called it. The studies on pathology of the body image by Head (36), Schilder (65), and others have adduced sufficient evidence to warrant this conclusion. They have demonstrated the important functional role of the body schema for the normal individual localizing the position of his body in space and of the position of moved limbs as well as touched points on the superficies of the body when blindfolded. In addition to the integration of these functions there is also incorporated the perceived time in terms of the experienced total movement-time.

According to our hypothesis brain damage interferes with normal communication between different functions of the brain, so that inadequate integration ensues. The deviant performance of the B-D in this task gives us only an indication that the integrative process is defective; it gives us no information in which of its specific aspects it is defective. The B-I typically overshoots the mark or even presses the plunger down completely but he never "undershoots" the mark. This defective integration can at this time not be traced specifically. We cannot tell: Whether specific subfunctions such as the sensory-motor feedback itself, or its cognitive interpretation, have suffered; whether the ability to utilize the body schema as a reference frame has diminished; whether the aspect of perceived time, etc., has been affected or whether control of motor innervation is impaired. We cannot even be sure whether the impairment of any such specific functional aspect is primarily causing the defective integration, because of the interference with communication which any such specific impairment would entail. It could also be just as well that a more <u>central</u> integration as such has been affected through brain damage, regardless of specific functional defects. In any event we would expect that either a specific defect or the inadequacy of central integrative process would lead to a change in function and performance of a definite direction, namely, reduced differentiation and behavior primitivation. Nevertheless, this does not explain the direction of the errors in overshooting the mark.

From our hypothesis we would expect abnormal errors in "judgment" of pressure reproduction, owing to faulty integration which may also give rise to cognitive difficulties. We may get a hunch for explaining the direction of the error by examining psychologically the possible cognitive difficulties pursuant to our hypothesis of lacking integration. Such difficulties, for example, would be in the B-I, the task of attributing in the simultaneous final estimate or matching of impressions, a proper and relevant weight to the different cues. Hence, certain cues may predominate unduly in their contribution to his final impression. This could be, for example, the experience of increased pressure-resistance which may become the dominant cue for reproduction outweighing the other cues connected with kinesthesis of the total movement time or traversed distance. These latter would be less in the foreground. In other words, the dominant cue for pushing the plunger down again to the original place, may be the retained impression of pressure increase as a foreground aspect (figure), while other cues are in the background.

Another way of stating this would be to say that the defective integration does not permit the B-I to encompass simultaneously all relevant aspects of a task. Being thus restricted he will respond most readily to that aspect which is the most striking and easiest perceptible to him at the expense of the others. There can be little doubt even from the normal point of view that pressure increase fits this description.

The dependency on this aspect may enter into the reproduction from <u>memory</u> as the chief cue which the B-D S aims to re-experience. What happens precisely and specifically here, we cannot as yet determine experimentally. It is, however, unlikely that the similarity to the Punchboard behavior, where overshooting the mark is also found, justifies the assumption that lack of muscle control is the only factor. The incorrect gauging of the previously experienced resistance at the point where the S stopped is so uniformly and grossly an over-shooting the mark, that we are hardly dealing here with a defective motor component alone. The movement control required is certainly less subtle and fine than in the Punchboard. It seems rather, that the B-I gauges his pressure reproduction in being captured by the aspect of experienced resistance without being able to evaluate the <u>degree</u> of that resistance in more than a global fashion. He thus seems to exaggerate in memory this global impression when he tries to reproduce it.

Cognitively, there may also be a difficulty in acquiring a frame of reference for the various distances traversed in relation to body schema. Such a frame of reference can be built up from the experiences with the trials—a definite range of distance. This range goes from a distance of one centimeter on the first to three centimeters on the second trial with the two centimeter distance mixed in on subsequent trials. In this opportunity for establishing reference points for spatial or temporal judgment, we have a situation similar to the well-known weight discrimination experiments by Zener and others. Here it was demonstrated that normal Ss will establish a frame of reference for their specific weight judgments based on trials with a range of weights. If such a difficulty for the "learning" of a frame of reference would obtain in the B-I, he would not utilize sufficiently the provided reference points for spatial distance during the different trials. This in turn, would make him more exclusively dependent on the experienced pressure increase during each trial, which he may then exaggerate in memory.

Admittedly some of the hypotheses become speculative if they are pursued, as above into more specific functional aspects of the performance impairment. The intriguing question could also be raised whether the pressure reproduction error of "overshooting" could be related to the occurrence of a negative time error in the B-I—which was never present to a comparable degree in the normal Ss. In that case, the negative time error would have to be further explored from such points of view as follows: Is it an error in terms of the reproduction of total movement time or an error in terms of the reproduced resistance. Two further experiments will be reported which were designed to shed further light on the problems raised in our explanatory hypotheses.

Further Experimental Analysis

Even with careful observation, it was impossible to ascertain the many aspects of the "how" of the performance, though a difference between the goups was clearly indicated. In accordance with our hypothesis we believe that when the S pushes the plunger down the first time, aspects of space, time, tactual-kinesthetic and pressure cues must be integrated in experience and, when he tries to push it to the same position again, he must match the new experience with the former on the basis of memory traces. The questions which arise are: How does the deviating S get cues for the first integration? Are the cues correctly received, but, owing to their complexity, an erroneous judgment results in the first place? Is the S, for example, captured by one cue aspect primarily--the resistance and its increase? Does this lead him not to attend to the presence of the other cues, so that he makes an error in judgment of the first position, which misguides the second push--perhaps also aggravated by an exaggerated memory trace? (This explanation would find support in the results where the greatest overshooting of the mark occurred in the greater distances where the resistance was greatest.) Or is the correct co-ordination and the registering of cues initially accomplished but a large negative time error affects the second estimate? This could possibly explain the overshooting of the mark in the B-I group. Instead of speculating on the answer, it seemed advisable to better control one of the variables which might have influenced the experimental group. Since this group overestimated more, as the resistance became greater, we tried to investigate this influence of increasing pressure.

Control Experiment I

It was felt that if the variable of pressure could be held constant or ruled out, the performance under these conditions might throw some light on the above questions. To further test the degree to which pressure cues or the lack of pressure cues contributed to the performance of the groups, the following modification was introduced. A stationary vertical stick, 12 inches long, was now used for judgment of traversed distance, thereby eliminating the encountered pressure with the plunger. (See Fig. 15)

The Ss were blindfolded as before and again told to move their index finger slowly along the stick down to a certain point. The S's finger was then placed again at the top of the stick and he was instructed to move his finger as far along the stick as it had previously moved down. From the graduated scale on the stick, the judgments were recorded. Six trials were given, the order being the same as on the Plunger Test for the first six trials.

The hypothesis was that if the B-D S could successfully perform this task, it would indicate that judgment of spatial distance was intact but interfered with by the increased pressure in the original test. If on the other hand the execution was again inaccurate or close to the prior performance, it would rule out the possibility that pressure was the major factor which contributed to the disorientation.

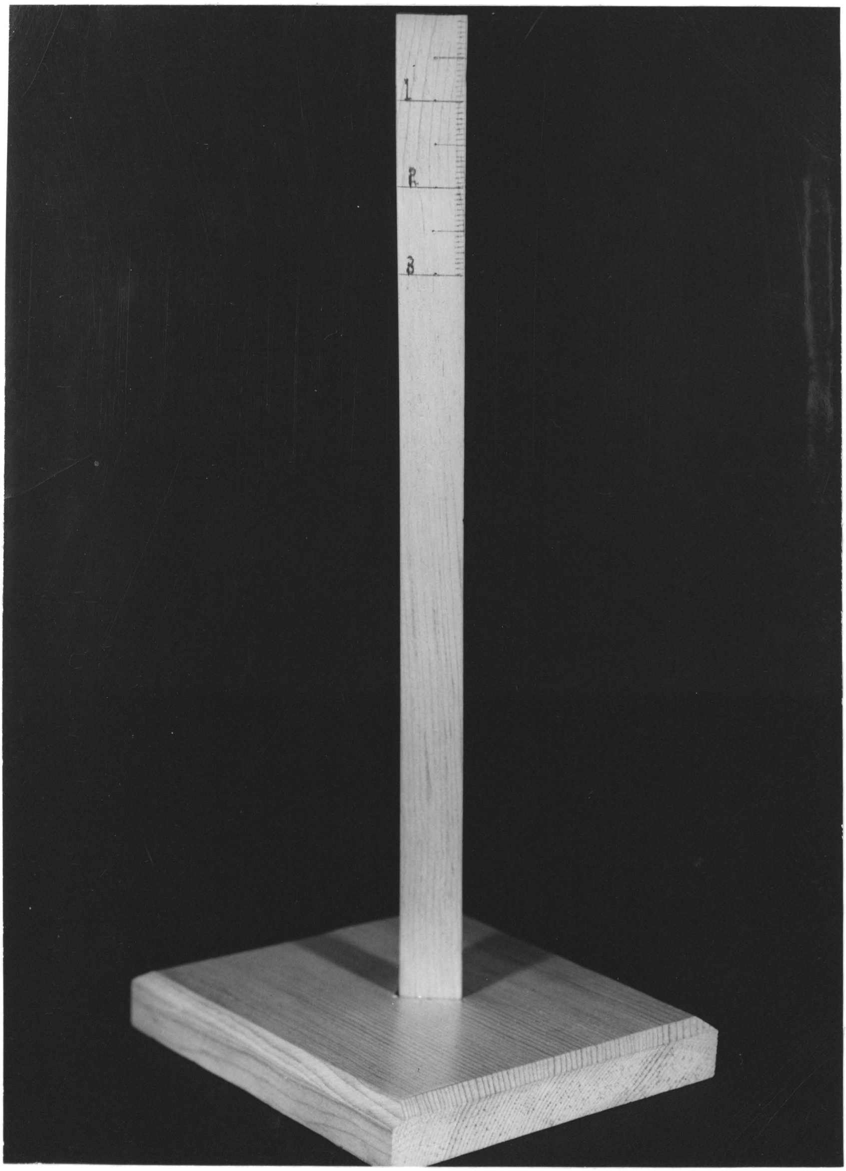


Fig. 15

Fifteen of the same Ss from each group were tested in the experiment with the following general results: The normal group maintained their previous level of performance with some Ss improving slightly. Frequently the Ss commented that they felt that this was an easier task. Their explanation as to the "how" of the performance ranged from "counting" to the "feel" of the position of the arm and hand.

The performance of the experimental group seems to have changed considerably and the results indicate that it begins to approach that of the normal group in the following ways: The consistency in overestimation practically disappears, and the Exp. Ss are just as likely to underestimate as to overestimate. The degree to which the Exp. Ss miss the mark in reproducing the initial position is markedly diminished, hence their error scores are not as large as before, and there is also an increase in the number of correct reproductions.

Specifically, the performance of the normal group in Experiment I remains superior to that of the B-D group. However, the crucial question in the experiment was whether either group improved or became worse in the estimation of distance without pressure increase. The results shown in Table 18 indicate that both groups improved, that is, the number of correct estimations increased with the absence of pressure. The improvement in the normal group is, however, very slight as their group mean on the Plunger Test was 21.9 and their group mean in this experiment is 19.6. The B-D group, on the other hand, shows a considerable improvement with the group mean decreasing from 60.1 on the initial test to 46.6 on this experiment, a drop of approximately 25% in errors.

In the normal group, ten Ss had deviations in centimeters of plus or minus 3 or under; four had deviations of no more than plus or minus 4 and one had deviations of 5. As before, all Ss made at least one or more correct estimates. In the B-D group, of the 15 Ss, 12 made one or more correct estimates, whereas in the Plunger Test only one S had a single correct matching. Four of the group deviated no more than plus or minus 3 on any one trial; eight had deviations not over plus or minus 5; three had deviations of plus or minus 8.

Such a difference in the performance would seem to point to pressure as contributing considerably to the B-D Ss' failure on the previous Plunger Test. Furthermore, in view of the fact that the 15 B-I Ss who were available in this experiment, happen to be among those whose scores had been in the upper error range of the original Plunger Test, the result is all the more striking. The range from which these 15 Ss were taken was 44-106 of the original range of 26-114. (114 being the only score over 106) The range of errors has contracted from 44-106 to 28-60 and the standard deviation has become lower--from 20.4 in the original test to 11.05 in this experiment. The range from which the normal Ss were taken was 10-32 of the original range of 8-36. This range became somewhat lower--from 10-32 to 6-30.

Scores of the Normal and Brain Damaged Groups on Experiment I

(Scores made on the Plunger Test shown in parentheses)

Statistic	Normal			Brain Damaged	
N	(35)	15		(35)	15
Range	(8-36)	6-30		(26-114)	28-60
M	(21.6)	19.6		(62.2)	46.6
S.D.	(5.90)	6.45		(20.4)	11.05
Mdn	(22)	22		(54)	44
σM	(1.01)	1.72		(3.49)	2.95
σDm			(3.67)3.4		
Dm			(40.6)25		
C.R.			(11.06)7.3		

Table 18

On the one hand, the difference in errors between the two groups remains significant--C.R. of 7.3--on the other hand, the results seem to point to the fact that the B-D Ss can more accurately match a given distance traversed when the resistance is removed. The hypothesis that these Ss were particularly captured by the pressure cues on the previous test thus resulting in an overestimation is supported by the present findings.

A statistical analysis was made utilizing the differences in scores between the performance of the two groups on Control Experiment I and the former Plunger Test. The deviations in the scores indicates that the changes in both groups were significant.

Statistic	Normal		Brain Damaged	
	Plunger	Exp. I	Plunger	Exp. I
N	15	15	15	15
Range	10-32	6-30	44-106	28-60
M	21.9	19.6	60.1	46.6
S.D.	4.70	6.45	18.55	11.05
σM	1.25	1.72	5.14	2.95
Deviation Total (X_1-X_2)	34		172	
$\frac{S}{\sqrt{N}}$	9.8		44.4	

Table 19

Though a change in the normal group is very slight it does prove to be a significant change, while the change in the B-D group is highly significant.

With the elimination of pressure, overestimation decreased significantly. There was also no longer an overestimation in correspondence with increased distance, the latter now increasing without concommitant pressure increase. Further the errors in this test distributed in both directions in under and overestimation, in contrast to the first test. Finally the improvement of the normal group in this experiment is strikingly so much smaller than that of the B-I group, that this also points to the pressure factor having influenced the B-I group in the Plunger Test.

Control Experiment II

Notwithstanding the improvement of the experimental group in the reproduction from memory of traversed distance with pressure absent, there still remained a significant difference between the errors of the two groups in Control Experiment I. Therefore, factors other than pressure must have also contributed to the errors in the reproduction of distance on the Plunger Test and on Control Experiment I. The hypothesis suggests itself that this may be a spatial factor, since pressure has been ruled out. To test for this spatial factor we tried to determine how accurate the Ss would be when they would be asked to estimate in inches a traversed distance along the stick. Even if the verbal judgment would be less accurate in both groups than in the direct reproduction of traversed distance, there would still remain this question: Is the spatial judgment of the experimental group less accurate than that of the normal group? In addition, one could determine the spatial factor more accurately by also studying the cognitive aspects. Cognitive support for the individual distance judgments could be ascertained by giving advance information about the total length of the stick. Judgment should improve in accuracy if such information should be utilized.

Accordingly a second experiment was performed using the same apparatus as in Control Experiment I, except that a different side of the stick was used. As can be seen in Fig. 16, the stick is scaled in inches on one side. The procedure in this experiment was to have the S, again blindfolded, run his forefinger a distance along the stick

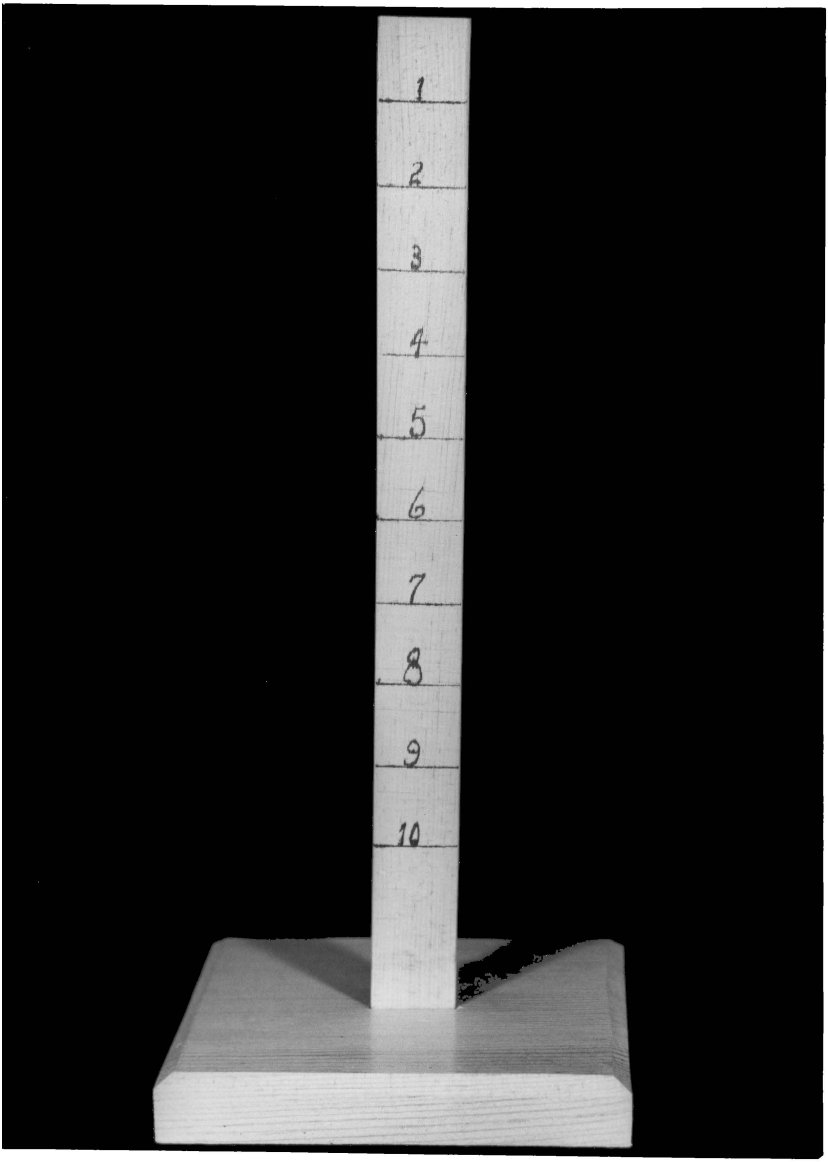


Fig. 16

until told to stop and then estimate the traversed distance in inches. This procedure was alternated with another method used for every other S, where this S was informed about the total length of the stick prior to the trials and then went through the above procedure. The same Ss were employed as in the preceding experiment. Six trials with the following distances in inches, were given in this order: 3, 5, 4, 1, 8, 2.

The general results indicate the following: Those of the normal group who did not know the length of the stick in advance, seemed to use the first estimate as a point of reference and subsequent estimates were determined on this basis. For example, if the S first over-estimated three inches as five inches, his estimates of other distances on later trials would be correspondingly larger. The B-D Ss on the other hand seemed to establish no point of reference and hence estimations seemed to be made for each trial with no apparent relationship to the previous estimate.

Those of the normal group who were told the length of the stick in advance appeared capable of utilizing this as a frame of reference for the six trials. This resulted in more accurate judgments than for the other normal Ss who lacked this information. In contrast the B-I neither improved their performance with this advanced information, nor did they give any other indication of adopting and using the knowledge of the total stick length as a frame of reference for orienting the position of their finger in space. This is borne out by the results in Table 20, where the normals who knew the length of the stick did relatively better in their estimations of each distance, than those of the normal group who did not know the stick length in advance. The two subgroups of the normal group show no overlap in their estimation of any distance.

Estimate of Distance by Normal and Brain Damaged Groups

	Normal			Brain Damaged		
Distance	L. Known	L. Unknown	Av.	L. Known	L. Unknown	Av.
3	3.3	3.9	3.6	4.1	4.2	4.2
5	5.8	6.2	6.0	7	6.8	6.9
4	4.5	4.6	4.5	6	6.1	6.1
1	1.3	1.7	1.5	2.7	2.6	2.7
8	7.9	8.5	8.2	10.3	9	9.7
2	2	2.3	2.1	3.1	3.2	3.1

Table 20

The B-I group on the other hand show no such a dichotomy of the subgroups. On one half of the distances estimated, those who did not know the length of the stick in advance were more accurate than the Ss of the subgroup who had this knowledge. There was also evidence that the Ss in the latter group did not utilize the knowledge of the stick's length. Many gave the same estimate for different distances and further, when an estimate of a greater distance was given, a following estimate of a lesser distance was often reported as the larger of the two. For example, one patient estimated the 3 in. distance as four inches. His estimate on the following distance--5 in.--was also four inches, but the next estimate on the following trial--4 in.--was five inches. It thus appears that the relative distance the finger traveled along the stick could not be utilized for a sound judgment as three inches and five inches were reported as the same distance, and four inches seemed to be greater than five. This behavior was observed in both subgroups of the B-D group but never appeared in either of the normal subgroups.

The range of the two groups and the average estimation of each distance is presented in Table 21. In spite of the fact that the B-D Ss seemed to have no point of reference and apparently no explanation of how thy estimated the distances, the difference between the two groups is much less than on either of the two previous experiments.

Estimate of Distance by Normal and Brain Damaged Groups

Distance	3	5	4	1	8	2
Av. Estimate						
Normal	3.6	6.0	4.5	1.5	8.2	2.1
B-D	4.2	6.9	6.1	2.7	9.7	3.1
Range						
Normal	1½-4	4-9	2-7	1-3	6-10	1½-4
B-D	1-6	3-10	6-8	2-4	10-12	½-5

Table 21

It might be inferred from the results in Tables 18 and 19, that the tendency was for all Ss of both groups to overestimate. The average of the groups would lead to such a conclusion. However, this is not the case in either group. The overestimation was greater than the underestimation and hence, in the average, the underestimation is obscured.

Analysis of the performance in terms of error scores shows that in the normal group 24 correct estimates--27 per cent--were made, with 17 of the 24 being made by Ss with previous knowledge of the stick's length and seven by those who did not know its length. In this latter sub-group of the normal Ss the errors ranged from 0 to plus 4. However, the plus 4 error occurred only once; plus or minus 3 occurred three times, and the remainder of the errors were plus or minus 1 or 2. The Ss of the normal subgroup who were told the length of the stick had no error beyond plus or minus 1. In both subgroups, the greatest error in estimation occurred at the five-inch distance and the least error occurred at the one-inch distance. Ten of the 15 Ss made one or more correct estimates, and two Ss of the informed group made correct judgments in four of the six trials.

In the B-I group only two correct estimates were made and these were Ss in the uninformed group. The latter group made errors ranging from 0 to plus 5. The plus 5 error occurred once; plus or minus 4 occurred four times; plus or minus 3 occurred seven times; and the remainder of the errors were plus or minus 1 or 2. The Ss of the B-I group who knew the length of the stick had a range of plus or minus 1 to plus 5. The plus 5 error occurred once; plus or minus 4 occurred three times; plus or minus 3 occurred seven times; and the remainder of the errors were plus or minus 1 or 2. The greatest error in the informed subgroup was in the five-inch distance, while the greatest error in the uninformed was in estimating the eight-inch distance. Both subgroups seemed to have difficulty in the greater distance--8 inches--as the informed group had an average error almost as great as the uninformed group at this distance.

The results of our two experiments lead to the following conclusions: 1) The elimination of the pressure factor causes a significant reduction of errors in the B-I group. However, this group is still statistically differentiated from the normal group. The pressure factor can therefore account only partially for the errors in the experimental group on the Plunger Test. The findings in the first experiment suggest further that this partial contribution of the pressure factor lies in its effect on the direction of the error, namely, the overshooting of the mark which gave way to errors in both directions. Also inspection of the data on Table 19 reveals: Since all B-D Ss overestimated the distance in the Plunger Test, the score of 60.1 on the Plunger of the 15 B-D Ss available for the Control Experiment I, represents their overestimation score. Considering that the score of 46.6 combined over- and underestimation scores, it is reasonable to assume that the overestimation alone would be actually lower. This would point to the conclusion that the reduction from 60.1 to even less than 46.6 in overestimation, represents the effect of eliminating the pressure on the direction of error.
2) The still persisting amount of error in the B-D group compared with the normal Ss on Experiment II, requires the assumption of other factors. One of these factors must be in the nature of spatial orientation, since the B-D group had consistently larger errors than the normal group and also failed to show any evidence of establishing a frame of reference for their distance judgments. This was observable in both situations of knowing the stick length in advance, as well as judging stick distances without advance knowledge; in the latter

case, no influence of previous judgments on the following judgments was in evidence. Taking these findings in contrast to the normal S's performance, an impairment of a cognitive spatial factor must be assumed in addition to the factor of pressure influence on the judgments in the Plunger Test. 3) These two factors are, however, insufficient to account completely for the inferior performance of the B-D S. The remaining factors, though not as potent as the two demonstrated here, have not been tapped in our control experiments. We might hazard a guess that the next important factor would be a temporal function, which after all is very intimately tied up with the distance estimates in our stick task while being blindfolded.

Since we spoke of different factors influencing the judgments from the point of view of psychological functions and their impairment, we might also speak of the corresponding stimuli which are present in the task situation and require the operations of these functions for adequate response (e.g., pressure, increased resistance, spatial distnace, time intervals between movements, etc.). In terms of response to these multiple stimuli, our control experiments suggest that the B-D Ss are less accurate, the more multiple stimuli have to be dealt with, and that their accuracy increases as the number of stimuli to which they should respond, decreases.

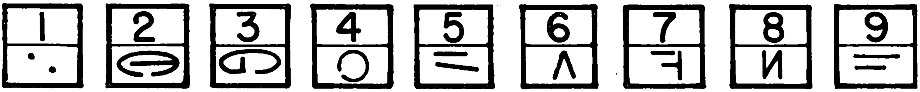
DIGIT SYMBOL

Description of Task

The traditional Digit Symbol or substitution test is one of the best established of all psychological measures, which Wechsler claims indicates intellectual ability along with a deterioration index. For Rapaport it taps visual organizing functions with motor components and a learning process. In our battery the Digit Symbol test as used incorporates the modifications proposed by Kenneth B. Stein, who, however, did not apply them in any specific research. (See Fig. 17.)

For our purposes this particular form of the substitution test has several advantages over many of the others commonly used. The subject is presented with a worksheet on top of which is a key consisting of nine symbols, each paired with a number. He is asked to write the symbols into the (67) boxes below on the sheet, wherever the originally paired numbers appear alone. In contrast to other substitution tests, the symbols are neither familiar letters nor numerals, but rather unfamiliar forms or familiar forms in an unusual setting. All the forms are so designed as to invite perceptual simplification or assimilation to a familiar presentation or perceptual closure. For example, forms are broken up so that the tendency is called out to complete them either by perceptual closure and simplification towards balance or a habitual tendency is evoked to complete and assimilate the forms into a familiar figure. Such tendencies are especially favored if memory enters into the task by way of inserting the symbols on the basis of visual retention. This

SET 1



3	1	2	1	3	2	1	4	2	3	5	2
3	1	4	6	3	1	5	4	2	7	6	3
5	7	2	8	5	4	6	3	7	2	8	1
9	5	8	4	7	3	6	2	5	1	9	2
8	3	7	4	6	5	9	4	8	3	7	2
6	1	5	4	6	3	7					

Figure 17

is either necessitated by shifting the fixation point from the top key lines to the lower part of the page and losing sight of the symbol on the key, or by gradually "learning" what the figure which constitutes the symbol seems to look like.

The Digit Symbol test usually implies following a visually presented sample and visuo-motor reproduction of the symbols; thus, it is also considered a test of visual-motor coordination. Here, however, the factor of resisting completion or simplification tendencies in order to achieve accuracy, is added.

Instructions

You see here in the upper boxes numbers from one through nine and in the lower boxes are symbols or marks for each number. You will notice that each number has a different symbol. Now here below are numbers in the upper boxes arranged in random order, but the boxes below are empty. Your task is to put the proper symbol in the empty box below each number. You can do this by looking up here at the key and putting the symbol below the correct number in the empty box beneath that number. Begin when I say start and go straight across without skipping over any of the boxes. Continue until I say stop. Ready, start.

Behavioral and Performance Analysis

The performance on this particular Digit Symbol test implies a learning process based on visual structuring which has to run counter to the tendency to complete the symbol in accordance with closure or habituated patterns. The learning process, because of the nonsense connection between digit and symbol, remains on the level of momentary retention. Even if learning is attempted, it usually remains abortive, as an ad hoc memorization rather than being integrated with the interests and general memory frame of reference of the individual.

The visual organizing function has here three different aspects: First, in fixating the symbol-form as a visual impression and as the channel of learning and remembering the symbols together with the digits; second, as a guide for the usual checking back and forth between the key symbols and the number on the worksheets, and also for the spatial-motor orientation on the entire sheet; and third, as a control of the executive drawing and writing actions.

The motor activity is of two kinds: First, the head and eye movements used in going to and fro from the key sample to the boxes on the sheet; second, the writing and drawing movements used in reproducing the symbols. These movements seem not to be impaired as such, in the B-D S, but the coordination of more than one of these into one planned integrated action is difficult and leads to temporal retardation.

Finally the ability to resist the tendency to closure and equalization is demonstrated when the S is able to correctly reproduce the sample symbols without loss of speed.

A comparison of the behavior of the B-I and normal S may help to analyze the essential performance characteristics of this test.

The B-D Ss proceeded in a slow, laborious way as if the task were very difficult. They repeatedly referred to the key, more frequently than the normal Ss. In addition they persisted in tracing over with the pencil, the already drawn symbol, as if they were unable to shift and proceed to the next symbol. Another way of describing the behavior is that it gave the impression that this "retracing" produced some feeling of accomplishment while the S reoriented himself before attempting the next symbol. There was no such hesitation on the part of the normal Ss. They proceeded from one symbol to the next and although errors were committed, there was not a single instance of tracing over. Further, there was a marked tendency in the B-D group to assimilate the forms into familiar figures, even in figures which structurally did not offer such opportunities. For example, the symbol for 2 is distorted in the drawing in such a way to make it resemble the upright numeral 3. Thus, the B-D S showed a tendency toward the experience of something familiar to him as stimulated by the symbol, while the normal group did not show any trend in this direction.

The tendency for closure and leveling is present in all Ss, but whereas the normal S could and did overcome it, the B-D S seemed unable to halt the process and as a result his reproductions resembled either concrete familiar objects or simplified forms. When attempts occurred to resist closure tendencies, the Ss of the B-D group typically changed the figure into what one may call a "preferred form" of coping with such a compelling tendency. For example, in dealing with the broken circle symbol (See Fig. 17), the Ss placed a horizontal bar at each end of the missing segment, thus apparently avoiding completion of the circle by anchoring the open ends of the circle; or failing at this they completed the circle each time and then attempted to erase the segment. In contrast, there seemed to be a general tendency in the normal Ss to exaggerate the asymmetry and breaks in the line, thus insuring against leveling and closure.

Scoring Method

The S is allowed 120 seconds for work. Each symbol correctly copied within that period is credited with one score unit. This constitutes the quantitative score. Distortions, and unidentifiable symbols are scored as incorrect.

Qualitative scoring gives us some indication of how the S goes about the execution of his task. It points up the often round-about means which are utilized when the S is unable to perform in his usual manner. The qualitative deviations score is obtained adding the following penalties for deviations in execution:

1. Perseveration in the drawing of the symbols by "retracing" the drawing several times--for each 2.
2. Simplifying the symbol by closure or leveling, but no marked distortion--for each 1.
3. Irregularity in speed of performance--1 (Same score whether once or repeated)
4. First drawing with closure and erasing to arrive at the correct symbol--for each 2.

Results

The results show that there was no overlapping in the scores of the two groups. The testing of our hypothesis involved the determination of which group could correctly reproduce the most symbols in the alloted time of two minutes. Table 22 presents the group means together with the results of the t-test which was applied to test the significance of the difference between these means.

Quantitative Scores of the Normal and Brain Damaged Groups on the Digit Symbol

Statistic		Normal		Brain Damaged	
N		35		35	No. Symbols
Range	No. Symbols	27-65		2-23	Produced
M	Produced	45		15	782
S.D.	1761	9.0		5.94	Av. 22
M	Av. 51	1.54		1.01	
Mdn		45		18	
Dm			1.84		
Dm			30		
C.R.			16.8		

Table 22

As can be seen from this table, the results generally confirm our hypothesis. The means of the two groups did differ significantly and at the same time there is a wide discrepancy in the range and median scores of the two groups. In order to further tease out how these differences came about, an analysis was made of the errors committed by each group on the nine symbols.

A. B-D group

The total number of symbols, regardless of errors, produced by the B-D group ranged from 12 to 39. However, only two of the Ss were able to produce over 30 symbols in the allotted two minutes. In both cases the error score approached 50 per cent, so that the total score was quite low. Three of the group committed less than five errors, but this was done by careful copying of the symbol and the time spent averaged from six to eight seconds per symbol.

In analyzing the results it developed that there were no errors made on the symbols for 6, 8, and 9--with the exception of the symbol for 8 being reversed once. The absence of errors on symbols for 8 and 9 have little significance, since only one S progressed far enough to encounter 9 and only two encountered the symbol for 8. The symbol for 6 was produced from two to three times by most of the group, but always without error. The fact that it may be said to represent a familiar form or a concrete object, whereas none of the other symbols do, may be one reason why no errors occurred on this symbol in the B-D group.

Inspection of the typical errors depicted in Fig. 18. shows that symbols for 1, 5, and 9 lend themselves to leveling or equalization and that the Ss had a tendency to make a balanced, symmetrical symbol of them. Twenty-eight per cent of the group made errors on the symbol for 1 and 53 per cent made errors on the symbol for 5. Symbols for 2, 3, 4, and 7 tend to invite closure and the greatest amount of error seems to occur on the first three mentioned. Sixty-eight per cent of the group have two or more errors on the symbol for 2; 68 per cent have one or more errors on the symbol for 3; 50 per cent of the group had one or more errors on the symbol for 4; and on the symbol for 7, 25 per cent had one or more errors. On Table 23, we give the percentage of errors made on each of the nine symbols. This is calculated as the per cent of the total amount of errors made by

SET 1

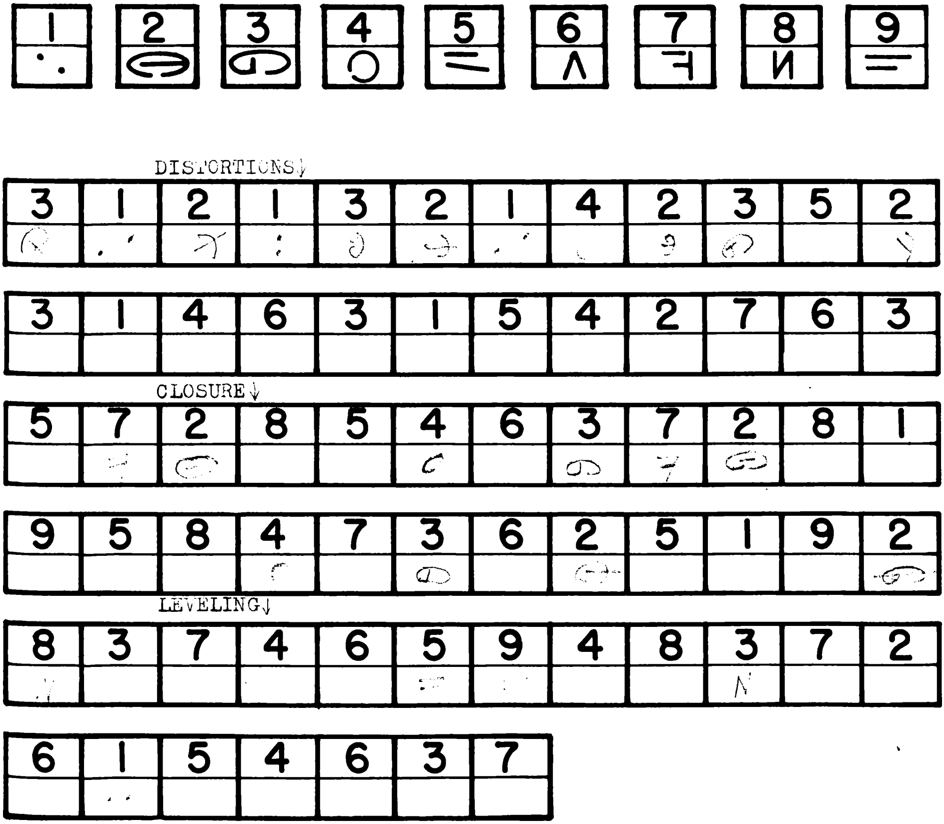


Figure 18

each group on the entire test

Percent Errors of Total Errors Made on the Nine Symbols by the Two Groups

	Tot. N. Sym. Made	Tot. N. Errors	Tot. % Error	1	2	3	4	5	6	7	8	9	Total Error
B-D	782	256	32										
No. Err.				33	87	67	29	32	0	8	1	0	256
% Err. of Tot.				12.9	37.2	26	11.2	12.5	0	.03	.003	0	100%
Normal													
No. Err.	1761	181	10	0	61	43	5	24	0	38	0	10	181
% Err. of Tot.				0	33.7	23.2	2.7	13.3	0	21.6	0	5.5	100%

Table 23

The percentage of total errors indicate that the B-D group made three times as many errors, while productivity was two and a half times less than that of the normal group.

The 35 B-D Ss averaged 22 symbols in two minutes--See Table 22--but as can be seen from Table 23, approximately one third were incorrect in some way. They often began the test by making even the difficult symbol for 3 correctly, but after encountering several other difficult symbols, the next reproductions were made incorrectly. It was as if the Ss were overwhelmed by their difficulty, and the production of most symbols thereafter suffered. For example, even the easy symbol for 1, which initially may have been correct, was later leveled, likewise the broken circle was later closed and the symbol for 5 later equalized. Evidences of difficulty clearly can be seen then, in both the method of execution and the quantitative scores of the B-I Group.

B. Control Group

The range for the normal group for the number of symbols produced is from 27 to 67. Eight of the normal Ss made the symbols without error. Five had error scores above 12 but in each case the number of symbols produced was fifty or above. A breakdown of the performance on each symbol (See Table 23) indicated that the normal Ss also experienced difficulty in making symbols for 2, 3 and 5. Fifty percent of the group made one or more errors on 2; and 42 percent made one or more on 3; and about 23 percent made errors on 5.

Psychologically one of the most important differences emerges if one compares the distribution of errors in temporal sequence over the 67 boxes. Whereas the B-D Ss either persist in their errors or increase them as the task progresses, the control Ss show a decrease in error, i.e., improvement in performance. An analysis of the percentage of errors produced in the two groups along the time dimension of boxes one to 67 yields the following results:

	Box 1-12	Box 13-24	Box 25-36	Box 37-48	Box 49-67
B-D S % Error	39%	45%	13% 4Ss	3% 1 S	0
Control % Error	58%	28%	8%	5% 27 Ss	1% 16 Ss

The general trend of the control Ss is to correct their initial errors and thus achieve a score with few errors later. However, four Ss who produced fifty or more symbols had high error scores. Their performance was not a matter of difficulty in execution as the high number of symbols produced indicates, but the following behavior was observed. After the completion of the first two rows, they no longer referred to the key for the correct symbol, but referred to their own productions on the worksheet and hence, any error made at the beginning was perpetuated throughout the performance.

From Table 23 it would seem that the normal group error on 7 and 9 exceeded that of the B-D group. As has been explained, only one S of the B-D group produced the 9 symbol, versus all the normals; since 7 is the twenty-second symbol to be produced only 25 percent of the B-D group reached this symbol. In contrast to the B-D group, the normal group errors are concentrated at the beginning of the test with a subsequent diminution as progress is made.

Discussion of Underlying Processes and Pathology

Some Explanatory Hypothesis

The most outstanding feature of this test is the extremely wide difference between the quantitative scores of the Exp. and the control groups. We know from the tempo of the performance of the Exp. Ss on the Punchboard test that although there is evidence of motor retardation it is not alone the contributing cause of their poor performance on this test. In this task we seem to be dealing with the following variables, all operating in the direction of modifying the behavior of the Exp. group: 1) The observed behavior in the B-D of tracing over and over a symbol once drawn, suggests a restriction on the cognitive level. The approach appears not to integrate and subordinate the production of each symbol to the larger task of making as many symbols as possible in the allotted time. The same cognitive constriction seems to be basic in the failure to learn from experience during the repeated drawing of the same individual symbols. The absence of manifest improvement in this case, seems to stem from a cognitive limitation which prevents the necessary interaction and carry-over from preceding experience to later productions. Hence, the S does not benefit from the errors committed during the course of the performance, but approaches each symbol as a new experience. 2) While visual perception per se is not impaired for the errors are never 100 per cent, the response to, or the dealing with, the visual impression differs from the normal. We characterize this difference by speaking of an abnormal dependency on the vector forces of dis-equilibrium in the configurational design of the symbols. What the Gestalt psychologists would call asymmetry or lack of pregnanz appears to have a disturbing influence on the B-D S and create stresses and tensions in the S in the direction of achieving "balanced" configurations or "better gestalt". This is particularly evidenced in symbols 1, 2, 3, 4, 5, and 7 as indicated on Fig. 18. The same stress appears to operate on the normals as our percentage analysis of errors showed. However, the same breakdown also demonstrated that the normals were much less affected by the "stress" and were able to overcome it in the course of the performance. Thus this experiment confirms in a new setting what has been considered by many psychologists the old adage of the tendency toward pregnanz responses to forms with disequilibria of forces. The interesting finding here seems to be that the Exp. Ss responded to the stress with leveling and simplification tendencies to a much greater degree than the normals. The latter did not only commit less simplification errors, they even tended to exaggerate asymmetries in the direction of accentuation when producing the symbols correctly.

(a) We may therefore conclude that the B-D are more strongly influenced by the configurational vectors of the symbol-forms. This may be explained as the effect of brain pathology in terms of isolation. As pointed out earlier the lack of integration or communication between different brain functions can lead to forced responsiveness to one aspect or features of the situation. The isolation effect prevents the functioning of the total cortex to be brought into play in dealing with the stimulus situation. Hence, we get either an exaggerated reaction in a part or an exaggerated partitive reaction. In our case this could be, anatomically speaking, either a visual cortex reaction without sufficient support from other controlling factors in the remaining cortex; or, functionally speaking, the excitation process in response to the figure forces, remains more isolated, so that it is delivered to these forces on which the S becomes fixated without bringing other functions to bear. The latter hypothesis need not involve assumptions about specific localized processes in circumscribed areas, but rather assumed patterns of cortical function of different complexity*, affected by isolation from each other. In

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* Lashley has presented a similar view.

any event the isolation would account for the forced responsiveness and stimulus-bond to the figure forces in this case.

(b) The resolution of this stress effect of the figure forces is attained by the B-D on a level of more primitive, undifferentiated organization, namely simplification, leveling and closure at the expense of accuracy. The resolution of the same stress in the normal S is a fluctuation between a similar yielding to closure tendencies, etc., and successful resistance by controlling factors in the direction of sharpening the disequilibria in the drawings. In this direction it is of interest that the Exp. Ss in their attempts to cope with the stress succeeded sometimes by distorting the figures not in the direction of simple closure, but by anchoring the unbalance through self-created preferred form variations (For example, the bars in the open circle.).

(c) Since the task requires a checking back and forth between the model symbols of the key on the top of the sheet and the drawing made in the boxes below, the performance is surely not one of direct X copying a design throughout. Memory factors of visual retention and learning will have to enter. The--even temporary--absence of the perceived model during the drawing may constitute an additional factor of permitting the stress forces to assert themselves in a closure direction which might be prevented in straight copying. (The trace of the visual impression would dynamically correspond here to a "weak gestalt" in Kohler's sense and therefore would be more readily subject to modification.)

(d) It is also possible to relegate the source of the stress as well as of the pregnanz tendency to past experience and habitual ways of organizing visual impressions than to pure Gestalt dynamics. It is not necessary here to raise the issue whether pregnanz tendencies result from generalized habits in past learning or are "autochthounous" and determine habits. The fact remains that the B-D Ss are more bound to these tendencies and in a direction of simplification. The experience factor, however, does seem to play a role in the manner in which these Ss are sometimes assimilating unfamiliar forms into more realistic and concrete forms. Examples of this are the drawings of the symbol for 3 as an upright G and the symbol for 2 as an upright 3. In accordance with this the symbol for 6 was never distorted; it was seen either as an angle pointing up, a roof, or possibly an inverted V. These findings agree with the conclusions by Goldstein and Scheerer in connection with their Stick Test administered to the B-I, who were more severely damaged than our Ss. These authors found that the patients would succeed in reproducing from memory figures which resembled concrete objects, and reproduced "abstract" designs distortedly by assimilating them to concrete meanings, or failed them completely. Thus we have also to recognize the factor of how the Exp. Ss reacted to the "abstract" unreal aspect of some of the figures by trying to cope with them on a more primitive, "thing" oriented concrete level.

Since an adequate performance of the task requires the co-ordination of its many aspects, the B-I S, who in trying to cope with these multiple aspects must restrict his scope, may only carry out certain tasks aspects at the expense of others. For example, if the S concentrates on preventing closure, he loses time by using artificial stops or by erasing, either of which is time consuming. This tendency to fixate on a partial aspect of the task may be described as a difficulty in voluntary shifting.

FORMBOARD TEST

Description of Task

This test requires the S to match and also to identify correctly tri-dimensional forms while blindfolded. Accordingly the test consists of two parts. In the first the blindfolded S is presented with ten different "cutout" figures of equal thickness and asked to fit these figures one at a time into the corresponding ten openings to be found by him on the formboard. In this task the S must therefore match each individual figure with its corresponding board opening exclusively on the basis of touch and kinesthetic cues, i.e., without vision. Naturally, such restriction does not rule out the possibility of spontaneously trying to visualize the form of the object as the S perceives it through non-visual impressions.

In contrast to Halstead's three trials, the S is given only one trial with all ten figures and encouraged to use both hands. (In certain forms of parietal lobe damage, astereognosis or tactual agnosia may be present which would interfere with the performance. This must be ruled out before the test is given.)

In the second task the blindfold is removed and the S now has to visualize the ten fitted figures by making a drawing of each figure from memory; he also has to indicate in the drawing, the location of each figure on the board. Figure 19 shows how the board looks upon presentation to the S.

Procedures and Instructions

I. In front of you on the table is a board. This is the size

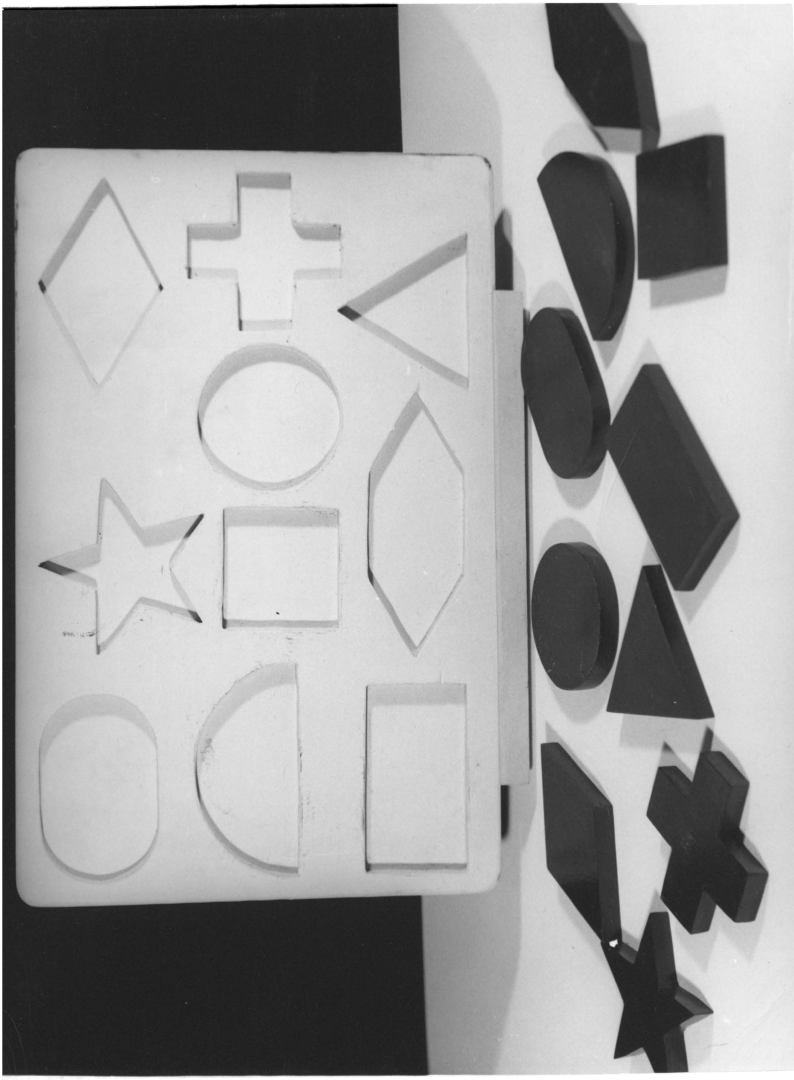


Fig. 19

and the shape of it. (Move S's hand around edge of board) On the face of the board are holes of various shapes and sizes (Move his hand across the face of the board) and here in front of you are blocks of various shapes and sizes (pass his hand over blocks and then place his hand in his lap) which you will fit into the space or openings on the board. There is a place for each block and a block for each opening. You may use both hands to do this task. Begin whenever you are ready.

Two stop watches were used, one started when the S began, for recording the total performance time; the second was used to keep a record of the time spent on each figure. The S is praised for correctly placed figures, especially at the beginning when he is a bit uncertain and nervous. Since the pieces are spread out in front of the S, the examiner pushes the outlying pieces towards the center whenever necessary to keep a supply ready at hand for the S. The examiner also stands ready beside the table to hold the board in case it is pushed over or out of position.

II. When the S has finished, the formboard is first removed out of sight and then the blindfold is taken off. A sheet of white paper and a pencil are placed in front of the S and following instructions given: "Now on this sheet of paper I want you to draw an outline of the shape of the board. On your drawing put in the shapes of the blocks and locate them as you remember them to be on the board. Note that there are three parts to your task; the shape of the board, the shapes of the blocks and their location on the board. Be sure to label the top of your drawing. There is no time limit on this."

The second part of the Formboard Test was designed corresponding to Halstead's procedure and used to determine how many of the figures the Ss were able to recall and how well they could identify, through visualization, those figures they recalled. Allowance for dexterity in drawing could be made by using a scale for distortions from the intended figure which was applied to both groups of Ss equally. What the intended figure was needed only clarification when the drawn figure was unrecognizable to the experimenter and in that case the S was asked to explain; if this did not help, the drawing was not included in the evaluation.

This procedure offered a further opportunity to investigate experimentally whether the S would remember the "simpler" figures more readily than the complex figures, a question not raised by Halstead. This required in turn the experimental control of positional factors which might favor the recall of certain figures irrespective of their simpler or complex form. If, for example, a simple figure, such as the circle would always be found in the position of the center opening of the board, such a central position might favor the recall of the circle, regardless of its simplicity and so forth. In order to control any such spatial variables other than figural memory and <u>actual</u> location, two formboards were used in the experiment. The locations of the figures on the first formboard called A1 in the experiment is shown in Figure 19. In the second board, called A2, the positions of the openings were changed as follows: Top row from left to right, cross, triangle, half circle; second row, circle, rectangle, hexagon; bottom row, diamond, star, oval and square. In addition each board was rotated ninety degrees for each new S. This permitted the presentation of eight different positions for the two formboards. The 70 Ss were divided into eight groups of Ss and each group was presented with a different board position, making 64 Ss. The remaining six were given the same position as the first group of eight. By the above method we feel that positional factors which might influence the recall of certain figures is experimentally controlled. This control was lacking in Halstead's procedure for the control of location of figures since he always used the same board and was not interested in which figures were better recalled than others.

Behavioral and Performance Analysis

In this situation the modalities of touch and kinesthesis are called into play in a "new and strange way." Every S reacts to being blindfolded with some feeling of frustration. The normal S usually begins his matching on a trial and error basis, without yet employing an orderly method of exploring the figures and board openings. His trial gropings may persist as late as the placement of the fifth figure and then he shows a sudden increase in his rate of progress which gives evidence of having hit upon a workable method. He now begins to utilize significant dues afforded by the figures, such as relative size, angles, absence of corners and other total form qualities; he then searches for corresponding features in the contours of the board openings. Speed and total time of the performance thus reflect the extent to which the individual remains bound to the habit of identifying objects visually and has difficulty in adapting to a psychologically "new" task that requires an approach based on cues other than visual.

In terms of evidence from other findings on spatial orientation of blind persons and blindfolded normal Ss, tasks such as these are better performed if the person is able to translate tactile kinesthetic impressions into visual imagery (73). What our tasks then require is first, the integration of the non-visual impressions and second, their translation into some kind of visual image, which in this case, however, does not have its source in the usual direct visual perception.

A comparison of the general mode of solution and the specific procedures used by the normal and B-D Ss reveals the following differences: 1) General approach. a) In contrast to the normal, the B-D Ss rarely seems to integrate his perceptual clues from the figure and those from the contour together. This leads to a piece-meal matching of edges, points or corners and curves of the figure and the contour openings of the board, seeking an experience of "fit" without a "mental" picture of the total form of the figure. Consequently the B-D S manifests repetition of unsystematic trials and error behavior throughout the entire manipulation with the ten figures. Connected with such blind trial and error behavior is another phenomenon. The normal S, in trying to find a contour opening that matches an explored figure, say the triangle, will utilize the encounter with the opening of the circle for his next trial, so that he will pick up the circle next. The B-D S, however, does not avail himself of such clues encountered. He therefore begins with each figure anew as if no experiences with corresponding contour openings on the board have ever occurred. Though this behavior is not included in the scoring, the greater speed in the total performance of the normal is at least in part the result of utilizing his increased acquaintance with the contour openings for fitting subsequent figures.

b) Whereas the normal S threads his way through the various figures, familiar and unfamiliar alike, the B-D S tends to fall rapidly into a fixed set toward the individual figure he is manipulating at the time. This set may persist in the face of mounting contradictory evidence from failures met with in trying to fit that figure into a given contour. Whereas one failure or error is usually sufficient to cause the normal S to shift from one "misfitting" toward another hypothesis for another fit, an initial hypothesis adopted by a B-D S for a given figure may persist and perseverative efforts continue through many failures until he even may entirely "give up" this figure by placing it back on the table with the other figures and try a new one. This behavior generally occurs with the star and the cross, the diamond and the hexagon and the oval and the circle. The shapes of these three pairs of figures are similar enough to cause some confusion, when the board openings are not clearly recognized. Hence, the B-D S used pressure and attempted to force a figure into the board opening, e.g., the circle into the oval board opening. This corresponds to the frequently referred to "forced responsiveness" and "rigidity" in the perseverating behavior in the brain injured.

2) Specific solution procedures and manipulation: a) Since the S is given no definite instructions as to how he should proceed, several methods of attack are open to him. He may first explore the board with both hands and thus familiarize himself with the contours of the openings and then attempt to fit each figure or he may first run his hands and fingers over all the forms and then attempt to locate the proper openings on the board. Either method proves to be satisfactory in arriving at a solution to the problem, providing there is no difficulty in recognizing the form or the contoured opening. The same approach in principle is also applied to an exploration of an <u>individual</u> figure or board opening, followed by the search for its corresponding "individual mate." Any of these methods or combinations thereof are used by the majority of the normal group. We may call this behavior a method of systematic search. It is usually carried out by the normals with the use of both hands, most often one hand exploring the openings while the other follows holding the figure. Both hands will also be used in the fitting of the figure into the openings, thereby permitting more efficient perceptual-motor adjustment of the figure to the contour.

b) On the other hand the execution of the task may be started without exploring either the forms or the board openings, but proceed in a hit or miss fashion. Different figures are unselectively picked up in succession without first exploring their form and then tried at a particular opening--this opening may either be found before or after the picking of the figure; or only one figure is picked up and moved over the entire board in the apparent expectation that it will slide into the proper opening. Typically these manipulations are performed with one hand, while the other hand is unused. This behavior prevailed among the brain injured.

Qualitatively the two last methods are on a lower level of performance since they show a lack of planning and of making optimal use of the available cues. (For that reason such an execution of the task receives a higher penalty on the qualitative score--the system being based on lower scores for the better performance.) We may call this behavior trial and error.

c) Another characteristic of the B-I never found in the normals is the peculiar difficulty he meets in placing the figure, even after the correct opening has been encountered. The previously mentioned lack of integrating the perceptual clues from the figure and from the contour expresses itself here again in a specific performance deviation. The subject is guided by the accidental fitting of one edge or two edges of the figure into the contour which gives him the experience of the right fit, though the figure is positionally askew. Since he does not really grasp the whole of the figure and of the contour, it does not register with him that the two are positionally not aligned. This results in failure to shift the position of the figure in accordance with the contour of the opening which the correct total fit requires; or the S has actually identified the correct board opening as a whole but because he holds the figure in a non-corresponding position, he does not change the position of the figure in alignment with the contour opening, thus giving evidence of a difficulty in identifying the figure and contour when each is in a different spatial position.

d) The normals were always able to recognize the board opening by touch once they identified the shape of a figure through verbal labelling. In contrast, such verbal identification did not aid in or lead to recognition of the corresponding board opening in some B-I Ss when they traced it.

Method of Scoring

I Qualitative

On the basis of the preceding behavior analysis we devised a scoring system which would differentiate between an adequate, efficient planfulness in performance and different degrees of inadequate planning. It should be noted that the criteria for this adequacy are derived from the <u>actual observable manipulation</u>. The appended scoring sheet summarizes the rationale for each score and indicates it. The scores under I and II are based on the described behavioral criteria for planning. The scores under III, IV and V are based on the degrees of failure in form recognition and lack of shifting.

The qualitative deviation scores are totaled. This value gives an indication of how faulty execution and mode of attack have interfered with adequacy in performance.

Qualitative Scoring Sheet

I Is searching done systematically ____ (Subject explores the board-openings selectively, comparing with the figure he has explored; or he explores the figure and systematically compares it with the form of the opening)

Score—0

A. Operates Bi-manually ____ (One hand separately explores the board-openings while the other follows holding the figure. Both hands may be used in fitting the figure into the opening.)

Score—0

B. Explores board uni-manually ____ (While one hand holds the figure the fingers of the same hand explore the board-openings, and the other hand remains unused.)

Score—1

II Trial and Error

A. Piecemeal trial and error ____ (S picks up consecutively one figure after the other without exploring any of them and tries to fit each into the opening by trial and error.)

Score—2

B. Blind matching trials with one hand ____ (Without being explored, one figure ispicked up with one hand which moves it over the entire board in an attempt to find the matching opening.)

Score—3

III Difficulty in placing figure ____ (After correct opening is encountered, S has considerable difficulty in fitting it into opening—does not shift position of figure.)

Score—2

IV Perseveration ____ (When figure is tried at wrong board-opening and some edge happens to fit somehow, S persists. Even when he cannot fit the total figure into the board-opening, he does not desist but continues, using pressure and juggling to force figure into opening.)

Score—4

V Exploration of figure in hand, verbalizing shape, with no recognition when the corresponding board-opening is traced.

Score—4

Total Score ________

Fig. 20

II Quantitative

The quantitative score is the elapsed time from when the S begins the manipulation until he correctly fits the last figure. The scoring of the S's performance begins when he picks up the first figure. The experimenter enters his symbol for the figure on the blank under Trial 1. (See p. 136) In addition the time spent on each individual figure until fitted, is recorded. The sequence in which the ten figures are fitted into the board openings is also marked in the Trial column by entering the symbols for the respective figures.

As the S attempts to fit the figure into various openings an arrow is made in the Location column indicating the different openings in which the S tries to fit the figure. The time spent on each opening is also recorded in the corresponding box under the time column.

If a figure is picked up and an unsuccessful attempt is made to fit it into an opening, the number of seconds spent on this figure is likewise recorded. This occurs when the S tries to place the figure into the wrong opening. He may attempt to force it in the opening, go to another opening or put the figure down. If it is placed back on the table, an arrow pointing downward is placed beside the time spent on that figure in the time column.

When the S returns again to this figure he had placed back on the table, a record is made when in the sequence of trials this occurs and the time he then spends in fitting the figure is recorded and added to the time previously spent on that figure. This sum is entered under Total Time. After completion the Total Time column is summed and this is the total performance time. All behavioral observations are made under the Observation Column.

A sample record on the scoring sheet is shown in Fig. 21. Note on Trial 1, the S first picked up the triangle which he attempted to fit into the square opening on the board. Fifteen seconds were spent in this operation and then the arrow pointing downward indicates that this figure was placed down on the table. The second figure tried was the diamond. Three attempts were made to fit this figure into the opening of the rectangle, circle and rectangle again. The time spent was10, 12, and 13 seconds respectively at each opening. The figure was then fitted into its correct position in 8 seconds--this number was underlined to show a correct fit. Total time for the diamond was 43 seconds. The triangle was again picked up and after two attempts to fit it into the rectangle and hexagon opening, it was correctly placed. The total time for it was 36 seconds. Observations made during the progress of the performance indicate the method of approach of S and the difficulties he encounters. Thus the scoring sheet reveals the manner in which the S executed the task, shows the total time spent on each figure and gives the total time needed to place the ten figures.

III The Recall and Location scores are determined by: a) The number of figures remembered; b) The number correctly reproduced; c) The number correctly located. A record of the sequence of the reproduction is also made. (See Fig. 21 scoring sheet) After the drawings have been completed the S is questioned as to his method of fitting the figures and the cues he has used in matching the figure and the opening.

Sample Record

TACTUAL PERFORMANCE TEST

Name________________________

Board________________________

Position________________________

Trial	Location	Time	Pc Time (On ea. Fig.)	Observations
1 △ △	○ □ △ ◇ D ▭ ⬭ * + ⬡	36"	15"↓, 6" 10", 5"	Explored board with left hand. Explored fig. and searched for opening.
2 ◇	○ □ △ ◇ D ▭ ⬭ * + ⬡	43"	12", 8" 10", 13"	Tried to force into ▭
3	○ □ △ ◇ D ▭ ⬭ * + ⬡			△
4				
5				
6				
7				
8				
9				
10				

Total Performance Time ____________

Fig. 21

Scoring Sheet

Number of figures remembered ________

Number of figures correctly reproduced ________

Number of figures correctly placed ________

Discrepancy score: Correct reproduction over correct placement _____

Sequence of reproduction:

Board number ____

1. Diamond ____
2. Square ____
3. Triangle ____
4. Star ____
5. Circle ____
6. Cross ____
7. Rectangle ____
8. Hexagon ____
9. Oval ____
10. Semicircle ____

After completion of test, the subject is asked:

1. Did you have a picture of the complete form of the piece while looking for the proper opening? ____ (If yes, he is asked why he persisted in a wrong fitting, in the event this has occurred.)

2. When trying to fit the figure, did you get a picture of the whole outline of the openings? ____

3. When did you think that a figure fitted in an opening?

4. Was it by certain edges matching or did you have a picture of the whole figure and the complete outline of the opening?

Fig. 22

Results

The mean time scores in Table 24 show that the experimental group as a whole required more than twice the time the control group needed to fit the ten figures into the board. With a difference between the means of 255 seconds, there is little doubt about this difference being significant.

In regard to the individual time scores, 26 of the control Ss completed the task under 300 seconds, six needed between 300 and 350 seconds and three were above this mark—356, 390, 391. In the experimental group only one S finished within this upper time range of the normal group—355 seconds, all other B-I Ss needing time above that range. There is no other overlap between the two groups, as the range for the 34 Ss of the experimental group is 393-845.

Time Scores of the Normal and B-D Groups on the Formboard Test

Statistic	Normal		Brain Damaged
N	35		35
Range	120-391		355-845
M	238.6		493.9
S.D.	62.8		103.6
σM	11.1		19.58
Mdn	236		503
σDm		21.6	
Dm		255	
C.R.		11.8	

Table 24

In view of the above results our hypothesis predicting a difference between the performance of the two groups seems to be confirmed: Brain Damaged Subjects require a significantly longer time for completion of the task.

The qualitative deviation scores further enhance the difference between the two groups. Results shown in Table 25 indicate that the normal group has a mean error of 2.5, which is very low when compared to an error mean of 14.3 for the B-D group.

Qualitative Scores of the Normal and Brain Damaged Groups

Statistic	Normal	Brain Damaged
N	35	35
Range	0-9	4-31
M	2.5	14.3
Mdn	3	15
Dm	11.8	

Table 25

Of the 35 control Ss, 11 had zero scores; 18 had scores below 4, which is below the lowest score of the B-D group, four control Ss had scores from 5 to 7 and two had scores of 8 and 9.

In the experimental group, 33 had scores above 9, i.e., above the normal group range and 14 of these had scores above 15; the other two Ss had scores of 6 and 4, which are within the normal range. (On the remaining six tests of the battery, however, these tw Ss were in the lowest range of the B-D group)

Five of the normal Ss received penalty scores from 3 to 9 for blind matching trials which occurred within the first three trials; four were penalized for perseveration on the first two trials, achieving scores from 5 to 7. All of these scores, however, were incurred--as has been indicated--at the beginning of the performance, and as soon as a shift was made in the method of attack and a successful method adopted, no further penalties needed to be assessed. In contrast to the normal group, the penalty scores of the B-D group were distributed throughout the ten trials.

In the Exp. Group, 14 of the group made blind matching trials incurring penalties from 8 to 23; 17 Ss showed perseverative tendencies and were penalized from 9 to 16 points; only two made systematic searchings (the two Ss who had scores of 6 and 4). Eight of the B-D Ss incurred penalty scores of 10 or above for the following behavior: The Ss apparently recognized the figure—evident from verbalizations—but had great difficulty in recognizing the board opening when it was encountered and often traced the correct opening again and again without recognition that it was the corresponding for the figure which they held. (See V on Scoring Sheet.)

The following qualitative features not included in the scoring may contribute to the understanding of the "how" of the S's performance: There is a difference in the frequency of false starts, the Ss made in trying to fit the figures into the openings. This should give some indication of how well they were able to visualize the board openings and figures. The control group made a total of 131 attempts to fit the figures in incorrect openings, an average of 3.7 per S. These generally occurred within the first four figures tried and only with the 24 Ss who made incorrect fitting attempts since 11 did not make any. The Exp. group made 357 attempts at incorrect fittings or an average of 10.2 per S. These incorrect fittings occurred throughout the ten trials.

In addition some qualitative aspects may be pointed out by examining a few quotes from both the control and experimental groups in answer to the questions 1-4, asked after the completion of the test. (See Fig. 22) These may give some indication of how the Ss felt and how they thought they executed the task.

Control Group:

1. "I did not find it easy to match from the edges, when I got the complete form, I could match."
2. "The matching was done by the whole form in familiar pieces. I used the edges in unfamiliar pieces."
3. "I visualized the whole piece and opening. I could get a better idea of the whole piece if both hands were used."
4. "I felt for the total geometrical shape."
5. "I matched by total form. Once I got the plan, I know the opening matched when I felt the form."

Experimental Group:

1. "I never did get a picture of the opening—just couldn't tell. The openings felt smaller than the pieces I had."
2. "I tried to get a picture in my mind of the whole thing—the edges helped. The only way I knew it fitted was when it went in the hole."
3. "I couldn't ever be sure, just hoped it was right if it stayed in. Didn't get a picture, just tried every place."
4. "I couldn't exactly tell about the opening until I tried it. Only way I knew it matched was when it went in. The points and corners helped, but I could tell the round pieces."

5. "I got a picture of the form, but the hole was too hard. I counted the corners or points to tell the piece."

Although it has been pointed out that the validity of such introspective methods are open to question, we believe that a certain amount of faith can be placed upon these self-reports. In the first place they seem to be confirmed by the observations made by the examiner and second, they were given immediately upon completion of the task, thus eliminating discussion of the test withothers and also time factors of forgetting.

Addition of the quantitative and qualitative scores are shown in Table 26. Both groups show some increase but from the table and the preceding analysis it becomes evident that the change is greater in the B-D group. The latter had a mean increase of 14 points whereas the normal Ss had an increase of 2.5 points.

Combined Qualitative and Quantitative Scores of the Normal and Brain Damaged Groups

Statistic	Normal		Brain Damaged
N	35		35
Range	120-399		359-861
M	241.1		507.4
S.D.	78.40		92.8
σM	13.45		17.3
Mdn	237		523
σDm		21.6	
Dm		266.3	
C.R.		12.3	

Table 26

II Reproduction in Drawings

A. Recall and Location

Our results show that the B-I group falls considerably below the normal group in both the frequency of correct recall of figures and correct location of them--by 40 per cent for figure recall and 70 per cent for location. The data presented in Table 27 indicates that both groups recall more figures correctly than they can correctly locate. But whereas the normal group is able to locate at least half of the figures recalled, the B-I group does only half as well, locating correctly one-fourth of those recalled.

Recall for Figures and Locations in the Normal and Brain-Damaged Groups

Group	Aver. Recall for Figure	Aver. Recall for Location	Ratio RL/RF
Normal	6.3	3.3	.519
Brain-Damaged	3.4	1.0	.294

Table 27

This difference between the recall and the location scores can be expressed as a Ratio-Recall Location/Recall Figure--which Halstead also computed. Table 27 shows that it is approximately one-half for the B-D group as against the normal group. Hence it would seem that objective experience with the content of the test does not insure a good performance, inasmuch as the normals spend less than half the time on the test and yet corredtly locate, on the average, three times as many figures.

B. Recall of simple vs. complex figures

Further analysis of the data brings out the fact that some figures are more easily remembered than others. In Table 28 the percentage of recall for each figure is shown arranged in decreasing order on the basis of the normal recall. The percentage recallled of all figures is also presented.

Percentage of Recall by Normal and Brain Damaged Groups

Figure	Normal Number	Normal Percent	Brain Damaged Number	Brain Damaged Percent
Circle	35	100	25	72
Square	29	83	17	48
Triangle	25	72	16	46
Rectangle	25	72	14	40
Diamond	25	72	8	23
Star	25	72	11	31
Half Circle	24	69	11	31
Oval	20	57	8	23
Cross	16	46	8	23
Hexagon	1	3	3	9
Total Recall	225	64.3%	121	34.7%

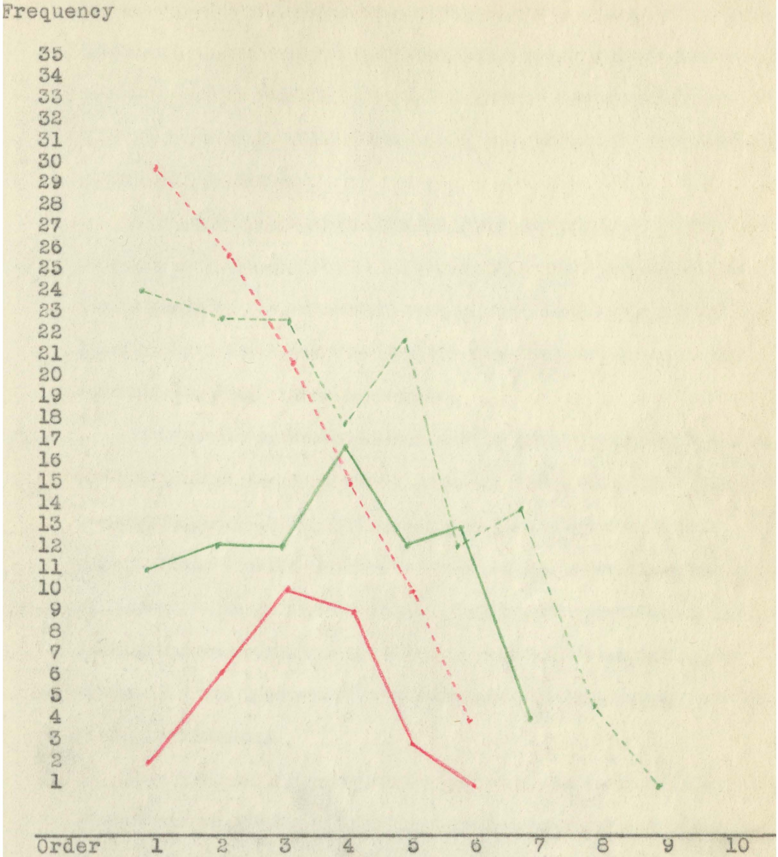
Table 28

Out of a possible recall of 350 figures, the normal group recalls 225 or 64.3%, while the B-D group recalls 121 figures or 34.7%. In terms of actual figures recalled per S it means that each normal S recalled an average of 6.3 figures and each B-D S recalled an average of 3.4. It was our hypothesis that the simple figures would be recalled more often by Ss of both groups and that they would be the first recalled. It is also shown on the table that the first five figures which we will call "simple" were recalled by the majority of each groups more readily than the latter five which we will call "complex"--the only exception being the diamond in the B-D group.

In testing this hypothesis, the following results were obtained; First, of the total number of figures recalled by each group, the normal Ss recalled 139 simple figures of the 255 remembered, or 61.7 per cent and the B-D group recalled 80 simple of the 121 remembered, or 66.1 per cent. The B-D group recalled 41 complex figures, which is 33.9 per cent of the total recalled by the group. Three complex figures were recalled in the entire recall by one S and this was the highest number recalled by any of the B-D group and the only instance of its occurrence. In the normal group, the highest number of complex figures in the total recall was four. This score was attained by four Ss, while fifteen Ss were able to recall three in the total recall.

Second, Fig. 23, shows graphically the order of recall. Taking up the simple figures, we find that 30 of the B-I Ss recalled a simple figure first. Since three of the group failed to recall any forms, it means that 94 per cent had a simple figure on the first recall. Further analysis indicates that 17 B-D Ss reproduced the first three simple. Of these, five Ss reproduce the first three simple and recall nothing else and five reproduce four simple figures first and nothing else. So ten of 17 B-D Ss recall three or four simple forms and recall nothing else. Another way of putting it is: Seventeen Ss recall 30 or 40 per cent of the possible ten figures and <u>all</u> of these 30 or 40 per cent recalled, are simple figures. Thus the recall for these 54 per cent of the B-D Ss is 100 per cent simple figures.

Order of Recall of Figures by Normal and B-D Groups



Simple figures------ B-D Red

Complex ________ Normal Green

Figure 23

In the normal group, 17 recall the first two forms as simple, but they also recall many more. Eleven normal Ss recall the first three forms as simple but also recall many more. This is in contrast to the B-D group wherein 17 recall the first three as simple and ten of whom recalled no other forms. Only two normal Ss recalled four simple figures first.

An analysis of complex figures order reveals: Two of the B-D Ss recalled a complex figure first and only one recalled the first two as complex. In the normal group, 11 of the Ss recalled a complex figure first, while six recalled the first two as complex and two recalled the first three as complex.

In determining whether simple designs were reproduced earlier, the statistical design shown in Appendix B was used. The use of the t-test yielded 5.14 for the normal group and 5.93 for the B-D group. These results confirm our hypothesis. A test for the significance of the difference between the two groups yields a C.R. of 1.01, hence we conclude that there is no significant difference between the two groups—each reproduces the simple designs earlier in the reproduction.

Some interesting points are brought out in the recall by drawing. Distortions and duplications appear in the reproductions of both groups. However, there are no distortions or duplications in either group before the third reproduction. Both distortion and duplication do, however, occur earlier in the B-D group—from the third reproduction through the sixth—whereas they do not appear before the fifth reproduction in the normal group.

It is as though distortions and duplications appear when the S has some vague recollection of more figures than he has reproduced and attempts to recall more. The normal group made six duplications, or 2.7 per cent of their total recall on the diamond, circle, and triangle. The B-I group made 12 duplications, or 10 per cent of their total recall, on the triangle, square, rectangle, and half circle. (One exception not included in the calculation is the instance where one B-D S reproduced the triangle first, and then made eleven similar triangles.)

Discussion of Underlying Processes and Pathology

Some Explanatory Hypotheses

I The initial action is one of exploration. The successively experienced tactual and kinesthetic cues are integrated into a simultaneous form percept and perhaps also translated into a visual conception or image of the figure which cannot be seen. Normally this occurs already when the S investigates the first figure. The various openings in the board are then also explored and from these tactual-kinesthetic impressions the final matching is made and the pieces fitted. What process is occurring here? We may assume that the operation of exploring the figure-object by running the fingers over its surface gives rise to the experience of a boundary that encloses an area and thus leads to the figure-percept of a closed tri-dimensional shape. The reverse, however, obtains for the exploration of the board-opening. In immediate experience the traced "contour" of this opening does not enclose a figure in the same way as the contour of the figure-piece. The contour of the board-opening as necessarily traced along the inside is an ambiguous clue as to what area it is bounding—an "outside" or an "inside" area. The initial tracing experience must be, therefore, ambiguous as to which kind of area the contour is bounding. The S follows the direction of that contour in uncertainty until he can experience closure, namely, the returning of that direction to the starting point of his tracing. Until that has happened the traced contour may just as well enclose an area "outside" of the opening, i.e., the "ground", as the inside of the opening. In order to be perceptually certain of the enclosed area, however, the contour path traced must be retained in memory as well as the initial starting point, otherwise no adequate closure experience can occur. This requires the corresponding integration of successive tactual, kinesthetic experiences, as in the tracing of the figures, only in this case the contours are perceptually reversed. In the figures they surround the solid object, the touch and resistance being felt inward, in the openings, they "surround" the ground, the touch experience of the resistance being felt outward.

One of the factors of successful recognition then, is the readiness to shift from the contour experience of the object-figure to the reversed contour experience of the board-opening—and back again. This would here differentiate an adequate performance from an inadequate one. In normal Ss this shifting takes place very rapidly and often with little hesitation in performance. In the B-D S whenever there is identification of the figure form through verbal means, there occurs a gap or lag between the recognition of the form, and the fitting it into the board-opening, which is more often than not, recognized neither verbally nor behaviorally.

II The S in the case of cortical pathology seems to be unable to extract meaning from his tactual-kinesthetic percepts and to organize these into whole forms in a manner adequate to the task. This lack of integration may be due to interruption in the interacting brain functions; or it may be hypothesized that the situation is new and the mode of execution strange, in that this is not the accustomed way of performing. In such an unfamiliar situation a B-D S may react to the most salient and concrete aspects of the object in a piecemeal way, i.e., to the points, corners, curves, and angles of the figures as he attempts to fit them into the openings by searching for their counterpart in the board. Either the absence of integration or such an approach as a coping mechanism leads to a piecemeal mode of solution, i.e., a matching of partial aspects of the figure with partial aspects of the contour opening based on the experience of fitting. Cognitively, therefore, the B-D S does not here so much display a <u>complete</u> lack of planning as a very inadequate plan and piecemeal execution. This behavior of a piece-by-piece matching has been described by Goldstein and Scheerer, Scheerer, Werner and Strauss as typical of those tasks in which the B-I cannot accomplish normally, namely, by integrating cues into a perceptual or conceptual whole.

III It is obvious that the adequate recall of figures depends on two factors: first, the accuracy of the initial form impression allowing for some kind of identification; and, second, the availability of any traces based on that impression. We have already raised the question whether this identification has to involve certain integration and translation processes. The unaccustomed tactual-kinesthetic impressions are experienced in temporal succession because the figures are too large to be encompassed in one touch contact with their contour. Thus we have first a "haptic" form integration in the sense of Revesz*. This has to be translated into a visualized form even though its structure may be inconspicuous in awareness and only instrumental in the process of identification. (This would of course only hold for blindfolded and not blind persons.) An added difficulty in the translation process should be mentioned: The "haptic" form percepts are often qualitatively different from visually perceived forms. This point has been stressed by Revesz and Becker in their experimental studies which demonstrated for example that different types of "haptic" closure laws prevail from those in vision. Any recognition failure or difficulty with the figures could therefore result from defective integration on any of the mentioned stages (or levels).

a) All the above factors would also operate in the locations. Here, however, as was pointed out, recognition based on "reversed" contour experience is more difficult if shifting is impaired. It is therefore possible that a B-D S may recall figures better than their locations, which have not become structurally articulated on the board. From a cognitive point of view we also have to consider that

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* Revesz, Geza. Psychology of the Blind, 1949.

registering the form-fit as well as its position on the board implies the simultaneous reaction to two different aspects of the action, namely form and place. It is reasonable to predict that one would have to suffer at the expense of the other, particularly since the locale on the board is in no way intrinsically connected with the task of fitting the figure and board contour. Its location can remain entirely in the background of experience, particularly if the individual is preoccupied with the attainment of the proper fit at the time. This preoccupation with the individual figure-contour fit has in turn, a cognitive component in itself. Aside from the presumptive difficulty of simultaneous apperception of figure and its spatial locale, we have to postulate an inadequacy on a "higher level" of planning in the B-D. This expresses itself in the previously described lack of a set to learn. We found that in contrast to the normal, the B-D Ss rarely, if ever, utilized any accidental encounter with a form-board contour, which did not fit the given figure, for connecting it with another figure to be sought out or to be reidentified from previous contact. We may, therefore, conclude: The cognitive constriction of both the simultaneous function and of the readiness to utilize formboard information outside of the concrete search for the individual figure fit, play a role in the inferior memory for the form board locations of the figures. Whatever purely retentive impairments enter into this poor score, we cannot assess. But it is obvious that adequate trace formation, even of incidental material would have to suffer if the initial impression was not only of a background character, but of much less articulated clearness than in a normal S not handicapped by the stated cognitive strictures.

b) With regard to the number of figures recalled as well as faithfulness of the drawings, the B-D group's inferior performance suggests the following: The accuracy of the form identification seems to be restricted inasmuch as not all figures are equally missed in the recall. The analysis of the recall of simple versus complex figures, both in terms of frequency and order indicates that the B-D Ss recall proportionally more simple figures of their total recall than the normal Ss. Hence their initial recognition as a base for recall seems to have been differentially favoring the simple figures. In answer to the question whether the recall difference could be explained as a poor retention, one could point to these facts: First, that poor retention per se should affect all figures equally; second, that it should also affect figure recall and localization equally, which is not the case. Not only do the B-D Ss have a total figure recall of 34 per cent versus 64 per cent in the normals, their location recall is 29 per cent of their figure recall versus 51 per cent in the normals. Finally, both the normal and the Exp. Ss do not statistically differentiate on the preferred order in recalling simple figures, but show a common trend. They do differentiate, however, in the fact that the normal Ss, over and above this common tendency towards a preferred order for simple figures, recall more complex figures than the B-D group (50 versus 23 per cent). One may therefore conclude that there is a lawful tendency, shared by both groups, to prefer simpler figures in the recall order. This tendency, however, would not explain why the B-I group significantly omitted complex figures in its recall, also in rather straight correspondence to their increasing complexity. The assumption that poorer retention for complex figures is the only variable in this case would have to meet the argument that the average recall of three figures by the B-D Ss versus six in the normal does not even cover the five simple figures for the B-I group. In other words, there is an overall lower retention in this group, which reproduces fewer figures than the normals including the simpler. Therefore, the significant lower recall of complex figures by the B-I Ss speaks, not alone for a lesser trace availability of these figures, but also for an initially poorer identification of them.

Chapter IV

PERFORMANCE OF SCHIZOPHRENICS

The investigation was primarily designed for the comparison of the performance of brain-damaged subjects and normals on perceptual motor tests. The findings indicate that a difference does exist. It seemed advisable to administer the test battery also to schizophrenic patients in order to ascertain any differences between their performance and that of the other two groups. If the performance of the schizophrenics should be indistinguishable from that of the B-D, then the diagnostic value of the test battery for organics would be considerably lessened.

Twenty subjects were given the tests. Many more were selected but had to be rejected because of lack of cooperation, negativism, and refusal to continue, once difficulty was experienced.

The quantitative scores for all tests indicate that the schizophrenic group falls consistently between the normal and the brain damaged groups. Table 29 gives a comparison of the means of the three groups. The score ranges presented in Table 30 show the widest range to be in the B-D group and the next in the schizophrenic group. The results given in Table 31 indicate that the schizophrenic group does differ from the B-D group significantly at the .01 level on the quantitative scores.

If we analyze the behavior of the schizophrenics which was carefully recorded, the protocols show a number of characteristic differences between this and the two other groups. There is, first, Mean Quantitative Score on Each Test for Normal, Schizophrenic and B-D Ss

Test		Normal 35	Schizophrenic 20	Brain Damaged 35
S. Punchboard	Low number equals poor score	108.9	87.9	67.9
D. Punchboard		65.5	47.6	33.4
Digit Symbol		45	20.8	15
Ring	High number equals poor score	142.8	181.9	230.7
Plunger		21.6	42	62.2
Marble-Peg		79.3	117.9	186.2
Formboard		238.6	344.5	493.9

Table 29

Range of Scores on Each Test for Normal, Schizophrenic and B-D Ss

Test		Normal	Schizophrenic	Brain Damaged
S. Punchboard	Low number equals poor score	90-133	58-118	16-110
D. Punchboard		34-86	33-69	5-53
Digit Symbol		27-65	9-27	2-23
Ring	High number equals poor score	111-171	124-257	172-566
Plunger		8-36	20-80	26-238
Marble-Peg		54-105	73-207	96-480
Formboard		120-390	168-533	355-845

Table 30

Mean Scores, Standard Deviations and Critical Ratios between Schizo. and B-D Groups

Test	Schizophrenic	Sigma	Br.Dam.	Sigma	C.R.
S. Punchboard	87.9	11.71	67.9	21.6	4.4
D. Punchboard	47.6	12.15	33.4	14.05	3.9
Ring	181.9	25.00	230.7	80.5	3.3
Plunger	42	17.70	62.2	20.4	3.7
Digit Symbol	20.8	5.10	15	5.94	3.7
Marble-Peg	117.9	32.1	186.2	67.6	5
Formboard	344.5	105.5	493.9	103.6	4.8

Table 31

a much greater variability during the performance of the individual schizophrenic. Typically he fluctuates between a more normal and devious performance, lapsing into inappropriate execution of the task, and snapping back again into an adequate manipulation.

Some of the causes for this behavior may be found in the fact that the schizophrenics tend to perform unmindful of the instructions, the admonitions, or encouragements of the examiner; moreover, they tend to set up their own rules or interpretation of the task. The difference between the B-D S and the schizophrenic appears to be in the following factors: The B-D S has difficulties in adequate performance owing to cognitive restrictions and defective functional integration, so that he is retarded in task solution and shows characteristically related performance changes on the qualitative score; the schizophrenic S shows in the flashes of adequacy of his performance that he could execute the task adequately and at times does so, also at the rate of the normal S. In contrast to the B-D S, there is no indication of an inherent lack of ability to deal with the test problems, but it is apparently difficult for the schizophrenic S to maintain consistently a set toward the task goal for a length of time sufficient to complete the performance without deviating from it in terms of temporary violation of the instructions or other tangential preoccupations. Consequently the anticipatory reactions seem intact in the schizophrenic but he seems to have greater difficulty in sustaining the task or set. Thus he may work without errors for a period but the correctness of the performance abruptly falls off as he continues; or he may verbalize correctly what he is going to do and perform incorrectly. It is as though the loosely controlled thought processes have gone off on a tangent before he can either enter in or continue with the solution of the test.

The following samples of the schizophrenic S's behavior on each of the seven tests may be considered typical of the group as a whole: 1) Single Punchboard Test--the S begins the punching and may succeed in piercing each hole at a rapid rate, when his behavior abruptly changes, and then he begins to skip holes, go back and punch over already pierced holes; or he may pause after many successful punches and remain for many seconds with his stroke halted in mid-air before resuming. Frequently he counts the holes as they are punched.

2) Double Punchboard--Here again the schizophrenic S's behavior may begin with no error. He may continue through the first 15 or 20 holes without piercing the second sheet and then punch through the next 20 so deeply that the stylus strikes the base. The behavior usually halts as suddenly as it began and he finishes the preformance with no more punch-throughs.

3) Ring Test--The S usually starts the performance with great speed; however, in placing the rings along side of the base, he becomes involved in arranging them in a pattern and frequently loses sight of the initial task in his preoccupation with his designs; or he may attempt to perform as rapidly as possible by using both hands, taking two or three rings at a time and is seemingly unmindsul of admonitions from th examiner.

4) Marble-Peg Test--The schizophrenic S shows difficulty neither in crossing hands, nor in grasping the alternation

principle, but he consistently fails to follow the designated pathway. His performance may be rapid in erratic bursts, with pauses between, after which he may disregard instructions by attempting to place only pegs and by shifting the objects from one hand to the other. In a short time however, he usually begins simultaneous placement again.

5) Plunger Test--The S reacts badly to the blindfold and often asks for its removal. Reproduction of pressure level is erratic. He May reproduce correctly several times, only to press the plunger completely down at other times. He both over-and under-estimates with little consistency for pressure levels.

6(Digit Symbol--The S may be much concerned with getting the symbol correct and may erase often and make the symbol over. However, this behavior does not last long. After experiencing such difficulties, he may make unrecognizable symbols very rapidly in each box. When he does proceed along the row making the symbols correctly, he gets lost and may reproduce symbols in the sequence on the key, disregarding the number on the worksheet. He is able to snap back and make the symbols correctly until he has another lapse.

7(Formboard--The schizophrenic S may here proceed rapidly or he may be slowed bychecking and rechecking before fitting a figure. Many of the Ss talked to themselves throughout the performance and indicated that the figures had symbolic meanings to them. For example, upon exploring the diamond, one S said, "wealth, riches." Frequently the task is attacked with great speed and litt le time is spent on any one figure. There is a great deal of trial and error, though there are few attempts to force a piece into an incorrect opening. He may have 3 or 4 figures at one time, trying to find a place for them. The S seems to know when a piece fits, but his performance is slower than the normal because he fails to organize in a systematic way.

The most outstanding behavior characteristics thus seem to consist in erratic or periodic fluctuations of accepting, becoming involved in the task, and "losing interest" in it or becoming involved in incidental side issues or details. Since in the periods of actual task-oriented activity, no signs of defective integration in terms of cognitive anticipation, control, and motor skill are in evidence, the low scores, particularly on speed measures, are not attributable to the same causes as in the B-1. In this light the lower quantitative scores on speed have to be evaluated as not resulting from reduced motor ability or control but as resulting from the schizophrenic's diversional mode of approach to the task. Even where anticipation seems to differ from the normal during the mentioned lapse, the schizophrenic S deviates not in the sense of lacking anticipation as does the B-D S. His anticipation seems more impaired by the impatience to sustain the clearly manifested goal direction and to pursue his recognition of required sub-goals. This impression is supported by the fact that the complexity of the task seems to be no barrier to the schizophrenic if he can be induced to start, while it seems to overtax the B-D S's capacity. The former appears rather driven to attain the solution by soomer or later short-cutting the prescribed means-end rules which he temporarily complies with.

The qualitative test scoring as designed for determining abnormal difficulties and modes in performing of the B-D did not reflect many of the above-mentioned deviating characteristics in the schizophrenic behavior. The first result is that the considerable deviations in the schizophrenic's behavior from that of the normal as well as that of the B-D were not captured by the categories of our qualitative scoring. The simple reason for this result is that his deviations fell outside of the behavior categories as they were set up. The second result is that wherever our qualitative scores yielded numerical values for the schizophrenic test performance, these values alone apparently differentiate the schizophrenics more from the normal than from the B-D Ss. (See Table 32). It follows from these results that additional qualitative scoring categories would have to be introduced for assessing the non-scored deviating behavior of the schizophrenic in comparison to the B-D Ss and the normals. If this is done, we would expect score values of significant difference for the schizophrenics versus the two other groups.

Mean Qualitative Score on Each Test For Normal, Schizophrenic and B-D Groups

Test	Normal	Schizophrenic	Brain Damaged
Single Punchboard	.31	2.6	17.4
Double Punchboard	2.8	10.3	13.9
Digit Symbol	.9	8.6	12.1
Ring	2.9	10.9	15.6
Plunger	0	.5	1.4
Marble-Peg	2.3	10.5	10.4
Formboard	2.5	8.1	14.3

Table 32

Range of Qualitative Scores on Each Test for Normal, Schizophrenic and B-D Groups

Test	Normal	Schizophrenic	Brain Damaged
Single Punchboard	0-3	0-11	1-53
Double Punchboard	0-13	0-22	0-52
Digit Symbol	0-4	0-15	3-20
Ring	0-8	2-37	2-67
Plunger	0	0-4	0-5
Marble-Peg	0-9	6-19	4-30
Formboard	0-9	0-21	4-31

Table 33

Some Explanatory Hypotheses

The schizophrenic's subnormal achievements apparent on these tests would invite most readily an interpretation in terms of thought disorder which interferes with consistent and effective execution of the task. A great deal has been written about the prominence of the thought disorder in certain schizophrenic pictures, leading Vigotsky and Hanfmann to emphasize the patient's inability to adequately conceptualize. Such "impairment of abstract attitude" was pointed out by Goldstein and his co-workers, too, who also used sorting and performance tests as Hanfmann and Kasanin did later. The difference between the above authors as well as between them and Cameron and Rapaport does not seem to lie so much in the actual reported tests behaviors of the schizophrenics. The records all agree on manifested disorder in conceptualization and on a cognitive disturbance. The interpretations however vary. Whereas the Hanfmann-Kasanin group interprets their findings on schizophrenics as suggesting a cognitive impairment akin to that of organics, Goldstein leaves room for motivational variables which may interfere with the schizophrenic's inability to assume an abstract attitude. Rapaport and Cameron on the other hand, while admitting concretistic responses in these patients, also point to a tendency to overgeneralization and looseness in their "concepts." Regardless of these specific controversies, two issues seem important here: 1) The chief difference lies in the question whether these cognitive deficiencies must be considered permanent or temporarily and potentially reversible; 2) whether the thought disorder is primary or secondary to more basic attitudinal and motivational disturbances--a possibility also suggested in Goldstein's later discussions. The behavior of the schizophrenic Ss on our tests suggests an interpretation more closely in line with two of the above-mentioned alternatives, the first being a potentially reversible cognitive aberration and the second an attitudinal impairment. These patients "failures" on the perceptual motor level point more to a motivational disturbance than to a primary and consistent disintegration of cognitive and motor functions. One may speak here of an impairment in the ability to assume fillfully, a task-oriented and reality-determined attitude and to maintain it. Owing to this inability the schizophrenic, when accepting the test situation at all seems to react with a forced response to the task in the direction of least involvement and of attempting to resolve it on a low level of tension, so that the necessary sub-goal tensions as well as the main-goal tensions are neither built up to nor sustained on a normal level.

In this connection the findings in two experimental studies by Rickers-Ovsinkina * may be pertinent. The first concerned the reaction of schizophrenics to task interruption with the opportunity to resume and complete the tasks. Here a striking difference was found favoring the normals numerically in the resumption and completion at the first opportunity. Moreover, the schizophrenics also interrupted their activities repeatedly on their own accord.

In a second study ** comparing the responsiveness to different attractive objects in a free situation between normals and schizophrenics, the same author found the activities of the patients significantly more superficial and undirected than in the normals.

The theoretical conclusions hypothesized are as follows:

> "...the dynamic prerequisite for the execution of a directed activity is the presence of sufficiently firm and segregated tension systems. The hypothesis could be advanced that in a schizophrenic individual, even if some tension is available to sustain a response to environmental objects, the dynamic conditions prevailing in these regions are of such nature as to impede the formation of segregated and firm tension systems. The processes in the peripheral regions at least are mostly of a diffuse, poorly differentiated kind--hence the prevalence of undirected activities." * p. 176

> "Conditions, which in normals generally lead to the formation of firmly segregated tension systems, in schizophrenics result in systems which tend to be of a weak and poorly differentiated nature." ** p. 190

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* Studies on the personality structure of schizophrenic individuals: I. J. Gen. Psychol., 1937, 16, 179-196.

** Studies on the personality structure of schizophrenic individuals: II J. Gen. Psychol., 153-178.

"...the failure of schizophrenics to form and maintain firmly segregated tension systems with the peripheral personality layers might depend partly on an abnormal lack of communication of these regions with the more central ones which are not impaired and which under normal conditions should be able to provide energy to the peripheral spheres." ** p. 192

"...a task or an idea is not organized in a sufficiently articulated way to segregate itself clearly from other contemporaneous mental processes. It does not acquire the characteristics of a figure standing out against the surrounding ground. The walls of the corresponding tension system are weak and unable to maintain the system's integration over longer periods of time. The tension dissipates itself very easily even without any interference from outside." ** p. 193-4

It should be stressed that the above interpretations of fluidity in the boundaries and lack of firmness in the tension systems are meant to apply to those reactions which occur in the peripheral region of the schizophrenic personality and not necessarily to those in the more central and deeper regions. It may even be possible that the tendency to only build up weak tensions peripherally and discharge them diffusely and uncontrolledly is a "means" of preventing central involvement which centers in <u>other</u> inner experiences and preoccupations more important to the patient at the time. We are mentioning this because our behavioral observations support unmistakably the interpretation that our tests, being anyway of a rather neutral mechanical nature, did not make an emotional or interest appeal to the schizophrenics.

Chapter V

DISCUSSION

Consistency of Differences

In an overall comparison of our two groups of Ss on the seven test performances, we note the general consistency in the behavior patterns of each group throughout. There are, of course, some instances of overlapping between the groups on particular tests, if taken individually. But when the entire battery is considered, the marked statistical group differences on each test point toward a general and differentiating power of the instrument used in this study.

Though the tests prove to be quite discriminating between the normal and the B-D groups the variability within the B-D group especially is a matter of interest. The F-test indicates that a common variance for the two groups exists on the quantitative scores of only three tests--Single Punchboard, Double Punchboard and Digit Symbol. With the addition of the qualitative scores the common variance disappears on all scores except for those on the Double Punchboard. Moreover, the large standard deviation of the B-D group on six of the tests statistically reflects the fact that, though the trend of the group has a common direction, there is a considerable variability within the group. At the present time we do not know whether this is due to variations in type and extent of organic involvement, the duration of the injury, or impairment of cognitive functioning in the experimental group. Yet, whatever the cause may be it is apparent from the behavior of the B-I group that integration is affected in different degrees among the 35 Ss tested. For example, on certain of the tests employed, four B-D Ss were able to perform creditably, often approaching the normal group range. However, these same Ss were not able to maintain the level consistently through the remaining tests of the battery. Inspection of Table 34 reveals several such cases.

Intelligence Level and Test Performance

The question might well be raised as to whether the differences we have observed were not due to the slightly higher I.Q. range of the normal group. (See Table 2.). To resolve this question, a careful analysis was made of the performance of the Ss in both groups with the highest levels and those in the B-D group with the lowest I. Q. levels.

In the normal group, ten Ss had I.Q.'s above 115, while in the B-D group there were three with I. Q.'s above 115. If these intelligence levels contributed to the performance on the tests, the differences in our results which favor the normal Ss might be attributable to this ten to three ratio. However, inspection of the scores shows that only two of these ten normals score consistently above the mean for the group. Three contributed the lowest score of the normal group on the Punchboard, Double Punchboard and Marble-Peg tests. The remaining five had scores which clustered around the mean for the group.

Head Injury

S.P.	Ring	D.P.	Pl.	M-P	FB	D.S.
44	259	31	48	302	392	14
53	293	15	36	139	530	8
69	172	52	78	135	845	19
58	258	48	40	168	613	20
49	237	5	44	217	639	5
40	566	7	72	219	355	15
56	177	31	58	192	430	18
83	200	21	56	120	773	19
82	174	52	46	152	423	11
43	396	36	80	312	643	20
72	188	21	54	96	635	10
59	265.4	29	55.6	186.5	570.7	14.4 ——Mean

Cerebrovascular

S.P.	Ring	D.P.	Pl.	M-P	FB	D.S.
57	257	37	34	119	480	21
46	269	24	114	315	586	4
54	267	45	48	137	770	19
49	173	29	72	304	624	14
59	246	38	238	480	640	10
74	185	50	56	110	550	21
95	187	41	44	112	381	19
40	293	5	90	315	651	12
90	184	37	68	119	390	20
63	232	35	72	186	429	20
Mean——58.7	229.3	34.1	83.6	219.7	550.1	16

Normal Mean

108.9	142.8	65.5	21.6	79.3	238.6	45

Paresis

16	394	5	90	184	428	2
103	182	38	52	151	393	4
58	264	17	106	229	503	15
62	173	38	38	315	503	19
74	222	12	62	204	605	15
100	198	41	40	128	485	23
68.8	238.8	25.1	64.3	201.8	486.4	13——Mean

Multiple Sclerotic

64	175	42	38	169	437	13
75	193	23	50	116	613	15
68.5	189	32.5	44	142.5	525	14——Mean

Monoxide Poisoning

85	189	53	32	114	375	21
110	179	41	32	98	423	19
Mean——97.5	184	47	32	106	399	20

Brain Tumor

21	197	33	54	138	750	18
77	201	33	26	111	454	23
Mean——49	199	33	40	124.5	602	20.5

Post Enceph.

85	177	50	36	130	393	10
88	176	39	54	152	509	21
Mean—— 86.5	176.5	44.5	45	141	451	15.5

Table 34

In the B-D group, two Ss had I. Q.s below the normal range of 96, namely, 92 and 94. The S with the I. Q. of 92 had scores on all the tests, except the Digit Symbol, above the mean of his group. Three of the scores, those on the Punchboard, the Ring, and the Formboard Tests were high enough to overlap the normal group range on these tests. The second S with an I. Q. of 94, had very low scores on the Double Punchboard and Formboard; the scores on the other five tests were just slightly below the mean of the B-D group--within one sigma of the mean.

It appears from this test evidence that neither the relatively low I. Q.s nor the high I. Q.s greatly contribute to the achievement of these Ss on our tests and that the observed differences are attributable to other factors.

The Problem of Localization

It has been pointed out critically of a number of studies conducted using cortically damaged patients, that the so called "organic signs" found may sometimes also be observable in the "normal" population. (37) It is not their occurrence in the behavior of the B-D patient that is alone important here, but rather it is the fact that the "organic signs" occur with significantly greater consistent frequency and with equally measurable qualitative characteristics in the experimental versus the normal group.

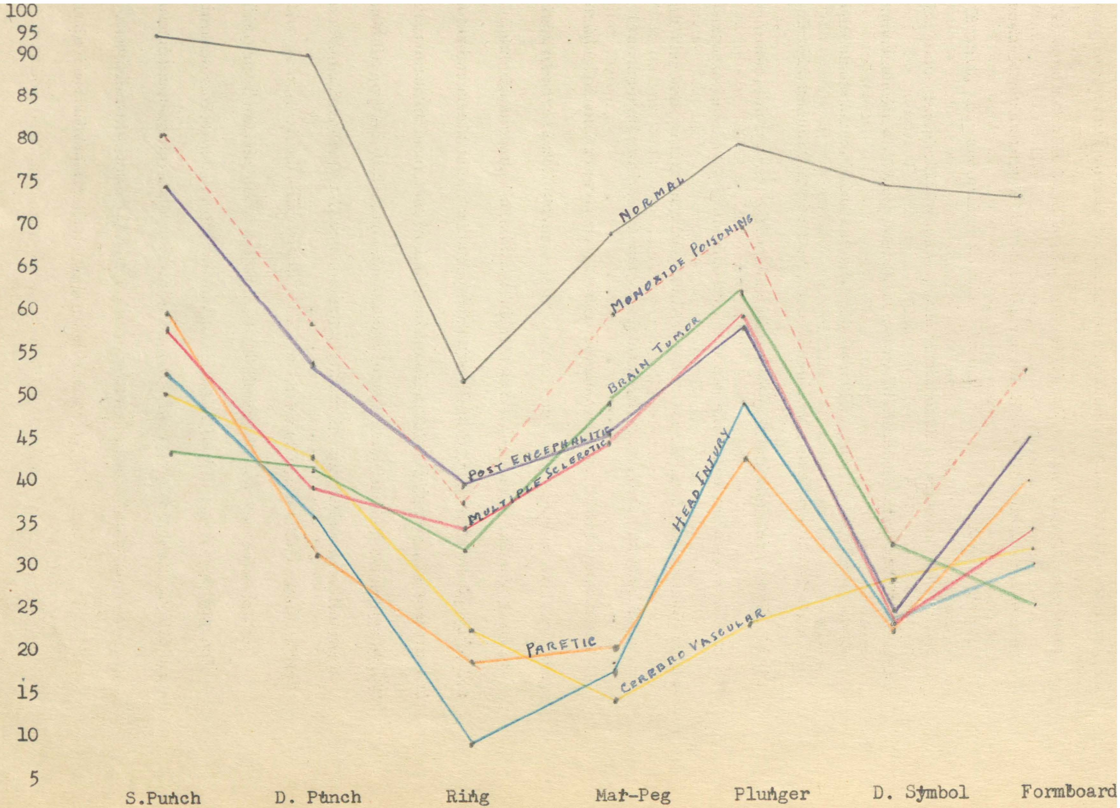
Another question which can be raised is whether the B-D group showed any differences in test results which would significantly relate to differences in locale or extent of brain injury. Before entering any discussion of the neurological theories involved, it may be apropos to present actual data on the scores of the different patients on the seven tests. Table 34, as well as the graph in Fig. 24, presents the distribution of test scores among the seven groups of B-D Ss.

Fig. 24 has been constructed in the following way: First, the scores on all tests for all Ss were converted into percentage scores; second, for those tests where a high score actually meant a low performance (e.g., time), that score was reconverted into a low percentage score by reversing it (e.g., 70 per cent becomes 30 per cent.) In this way we could plot curves for the scores for each group on all tests, arriving at test profiles for the battery.

The analysis of this score distribution shows that the Post-Encephalitic and Monoxide Poisoning cases rank relatively closest to the normal group. Though we do not consider this proportionally smaller deviation from the normal mean significant, it may well be that these results contribute to the variability in the B-D group. The number of two cases in each group, as well as the two Multiple Sclerotic and Brain-Tumor cases, is too small to really draw any conclusions from any difference in their performances from the rest of the B-D group. Considering the remaining 27 cases of Head Injury, Cerebrovascular accident and Paresis, the shape of the respective performance curves on all tests is strikingly similar as well as close in score range.

The possibility could also be considered that the two syndromes of Post-Encephalitic and Monoxide Poisoning had a less marked effect on the test performance in terms of the mean quantitative scores on all tests. The two Ss with monoxide poisoning might have been approaching recovery after an elapse of 16 to 18 months following the insult, and according to what is claimed in the literature on adult post encephalitic cases, there is usually a more pronounced retardation in shifting of motor sets, than an impairment in higher mental or motor skills per se. It is still surprising that these two Ss did relatively better than the others on the Marble-Peg and Ring tests, but approaching the other B-D Ss on the Formboard, Digit Symbol and the Double Punchboard. One could also raise questions about the two patients with brain tumors on their Plunger and Marble-Peg test scores, which placed them between the Post Encephalitic and Monoxide Poisoning groups. Again the low number should caution against generalizations.

More important than these attempts at differential diagnostic evaluation seems the following observations on the curves of Fig. 24: There seems to be a general directional conformity for all curves and all Ss in principles with two exceptions, one, in the Cerebrovascular cases the Plunger performance grows worse in comparison to the rest of the group, which "improves" somewhat; second, the two Brain Tumor Ss "improve" on the Digit Symbol test in contrast to all other patients. In spite of these two slight deflections, three general conclusions suggest themselves from the shape of the test profiles:
1) The inherent task difficulties of the various tests seem to reflect themselves in the shape similarity of the profiles for the


100
95
90
85
80
75
70
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55
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40
35
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20
15
10
5
NORMAL
MONOXIDE POISONING
BRAIN TUMOR
POST ENCEPHALITIC
MULTIPLE SCLEROTIC
HEAD INJURY
PARETIC
CEREBRO VASCULAR
S.Punch
D. Punch
Ring
Mar-Peg
Plunger
D. Symbol
Formboard

Fig. 24

normals and the patients; 2) for the patients, however, the graphic representation of response to performance task difficulties indicates always a more exaggerated score direction and range; 3) the graph does not seem to point to specific differential losses among any group of patients or individual patients. Neither do there appear to be any specifically spared performance fields which remain intact in terms of individual test successes versus failures on others. (The exceptions have already been mentioned.) It therefore seems more correct to say that the B-D Ss suffered from different types and differently localized brain pathology, but at the same time failed to show performance losses corresponding to circumscribed damage or a specific syndrome. There was rather, a performance change characteristic of the group as a whole, namely, a systematic lack of functional integration with a common qualitative direction. On the motor side, we identified this as lack of differentiation and reduced voluntary control; on the cognitive side, we identified it as a lack of anticipatory planning and difficulty in simultaneous finctioning; in addition, we found here, a lack of transfer in benefiting from experience with the tasks, whether this was in terms of learning from errors, from successes, or from incidentally made experiences with features of the task, while focusing on others (e.g., the formboard behavior). The latter findings may suggest further research on <u>incidental</u> learning or the acquisition of "learning sets" in the B-I, which has been less studied than has learning ability under laboratory instruction.

It is of course conceivable that questions could still be raised as to the differential effect of the site of possible circumscribed damage as a determiner of the respective performance level in the various patients. The final conclusion would have to be based on the evidence from autopsy. We do, however, believe that our findings do not support the position of adherents to the highly specific localization theory of brain functioning, such as Henschen and Nielsen. In considering such a localizationist thery, we might briefly examine some recent positions on this question.

Halstead(31) has described the inability of the B-I patient to shift from one thought or act to another with the same ease as the uninjured, to hold thoughts in mind for consecutive patterning, and to group things in a normal manner. He has attempted to relate this behavior to the frontal lobes. Our findings are in accordance with those of Halstead with the formboard, where normals recalled and located a greater percent of figures more accurately, and spent less time on the performance on the board than his Exp. Ss, who had sustained frontal lobectomies. They are not in accord, however, with Halstead's other findings that patients with non-frontal lobectomies and with head injuries perform only slightly below the normal controls on recall of figures and location, whereas only the frontal lobectomy patients performed significantly below normal. The difference in results here may be caused by the fact that Halstead allowed three complete formboard trials for all his Ss. From this point of view our procedure, using one Formboard trial, seems to be more sensitive than his. By securing more experience-opportunity for his Ss, Halstead may have achieved a masking of the difference between B-I and normal Ss on this test. In obtaining only a difference between normals and frontal-lobectomized patients, he could demonstrate the diagnostic value of his method for these patients and support his theory of greater impairment effect of frontal lobectomy versus other cerebral damage.

Though this possibility may be granted, the behavior deviations noted have also been frequently reported in patients who have suffered injuries in regions of the cortex remote from the frontal lobe. Many writers have advanced various theories to explain this apparent discrepancy. Lashley (48) holds that, "in addition to their specific function, all parts of the cortex exercise a facilitative effect upon the rest." Goldstein (25) explains the phenomenon as an "impairment of a function due to the damage of a not directly affected region by irritation emanating from a defect at another place." Recent studies of brain injury, both in adults and children, bring out very general changes in behavior which are found in the great majority of the cases and which bear only a slight relation to the site of the injury.

Furthermore, in considering any specific functional localization in the normal organism and the assumed functional change in circumscribed damage, due weight must be given to Jackson's (42) profound proposition that "to locate the damage which destroys speech and to locate speech are two different things." This statement should not be misinterpreted as a denial of any localizationor function, but rather as presaging the above-cited view of Lashley's and also lying at the basis of the thinking of other modern neurologists, such as Henry Head and Goldstein. The latter author has presented an elaboration of these views, which can be summed up in the proposition that certain areas of the brain contribute to the total function, particularly of the cortex more than others for a given function.

This view may be also applied to the relationship between the pyramidal tract and motor cortex, on the one hand, and the extra pyramidal and the remaining nervous system on the other hand, in voluntary movement. Pathology of both the pyramidal and the extra-pyramidal systems may contribute to the inadequacy seen in the performance of motor tasks. Lesions of the pyramidal tract result in reduced voluntary movement and the individual makes awkward more or less postural responses to situations that formerly called out quite specific skilled adjustments. Such disturbances are usually greatest in the fingers and distal extremities than in the proximal muscles. Thus we see our Ss with cortical involvement in attempting to execute a task involving the fingers using the whole arm and shoulder. (The flexion movements on the Marble-Peg Test)

The extra-pyramidal system while chiefly concerned with the postural aspects of behavior makes an important contribution to voluntary and skilled behavior, for the reason that behind every skilled movement is a requisite postural adjustment. It is therefore necessary for a complete synchronization of the pyramidal and extra-pyramidal systems for precise, skilled coordinated behavior.

The importance of this synchronization is pointed out by Walshe (68) in his attempt to show that the whole cortex is involved. He states:

"By no definition can we easily find a voluntary action that is discrete, for even the apparently very retarded movement employs a large field of musculature phasically."

"...to take a step is an affair, not of this or that limb solely, but of the total neuromuscular activity of the moment--not least of the head and neck." (68)

The activity involves the total organism and any incorrdination, no matter where it occurs, disrupts the functioning to some extent in the activity.

Particularly with regard to the problem of localization of voluntary action, the following statement by Nielsen is noteworthy:

"These various centers of performance of movements are in turn governed for the performance of acts. An arbitrary differentiation must be made between movements and acts, the latter consisting of a series of the former coordinated to the carrying out of a plan of action. There is no "center" for carrying out an act." (57) p. 251

Regardless of whether the views of Henschen and Nielsen or those of Goldstein are accepted, neither is incompatible with our hypothesis that it is an interruption of the integrative processes of the cortex which results in the difference in the observed behavior between the experimental and the control group in our study. Even the localizationist entertains the belief that the different areas of the brain are all connected with association fibers. Hence it would follow that there is interaction between the different areas. All areas participating are necessary for integration, which is defined here as the co-functioning of all areas, with that area in which the gradient of excitation is highest, functioning in a guiding role and all other areas functioning in a supporting role.

However, though we must not lose sight of the importance of neurological structures, all the behavior observed in B-D Ss is not entirely a result of damaged tissues. In part the behavior shows the struggle to meet demands; in part it reveals the S's attempt to avoid situations with which he cannot cope. In various ways he tries to find an environment or make an environment in which demands that are beyond his reduced resources will not occur. The orderliness and often meticulosity which have been observed on our tests, seem to be merely manifestations of the S's attempt to establish an environment to which he will always be equal.

The observed behavior seems to be the result of two major factors: First, those attributable directly to the lesion which are considered as primary--leading to the disorder or a disintegration of function in the cortex; second, those which are observable when the brain-damaged S tries to regain his mode of functioning and struggles with the inadequacy of his non-integrated cerebral structure. Always there appears a suggestion of disordered structure underlying the behavior, while the secondary psychological effect follows each aspect of behavior directly traceable to disintegration of brain tissue.

We believe that our test battery is sensitive enough to point up these differences in behavior from the total test scores which include the clinical indicators of the following tested qualities: organizing ability, perseverative tendencies, ability to plan future action, ability to shift, ability to correct behavior one knows is wrong, psychomotor flexibility. These qualities or the lack of these qualities are apparently clearly brought out in performing on the battery, as the tests were selected because they did permit a qualitative analysis of how the S executed his task and hence this may offer some explanation as to why such wide differences may sometimes appear between the groups. This same type of behavior presumably takes place on other tests but the nature of the task does not lend itself amenable to a qualitative analysis of the 'how' the S executes the task.

Chapter VI

CONCLUSIONS

I The battery of seven tests appear to discriminate adequately between the normal and brain-damaged groups.

II This difference appears to be much more clear-cut on these tests than on tests measuring intellectual changes.

III The battery presented makes no claim to finality. Whatever additions or modifications further research may bring to the diagnostic part of the work, the analysis and description of the behavioral phenomena is unlikely to undergo substantial changes; a workable basis inviting further exploration is therefore provided.

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Subjects Used in Control Study

SUBJECT		Age	S-A	S-P	P-C	P-R	C-D	F-B	Re	Loc	D-S	I.Q.
1.	S.B.	38	94	171	38	22	105	315	5	1	52	120
2.	V.C.	39	101	141	58	24	80	155	8	3	59	110
3.	M.M.	24	107	162	52	24	72	329	4	2	45	108
4.	P.D.	23	113	145	74	22	73	156	6	3	55	115
5.	M.S.	21	114	143	79	16	79	165	7	3	49	109
6.	T.J.	33	97	151	55	32	82	263	8	1	46	115
7.	B.O.	29	105	121	55	24	72	281	9	7	49	110
8.	S.E.	34	111	138	54	30	85	305	5	3	37	120
9.	K.M.	34	110	165	74	26	103	356	5	3	37	111
10.	B.D.	25	113	143	77	24	68	126	6	2	53	108
11.	P.O.	23	113	136	75	18	74	339	5	4	65	112
12.	G.M.	35	117	167	80	22	78	177	6	2	46	118
13.	D.G.	30	106	160	69	22	81	391	6	3	27	110
14.	H.M.	25	118	122	69	22	59	161	8	8	56	119
15.	M.H.	48	112	170	57	20	95	281	7	6	42	106
16.	A.R.	27	110	130	81	36	86	293	6	4	35	109
17.	K.A.	32	104	133	66	8	79	244	9	8	42	107
18.	K.W.	29	90	147	49	28	88	188	8	1	48	118
19.	A.K.	40	106	155	66	26	77	192	6	4	40	120
20.	M.J.	32	118	127	78	24	82	321	5	2	39	103
21.	S.W.	35	110	127	76	22	89	156	7	4	43	106
22.	G.F.	40	108	170	69	20	95	390	7	4	37	113
23.	B.G.	39	97	136	74	26	82	210	5	1	47	110
24.	K.C.	34	112	128	69	28	63	120	6	2	28	105
25.	V.R.	45	118	129	66	20	69	345	5	2	48	102
26.	A.E.	25	133	111	64	10	54	132	8	5	59	118
27.	Z.A.	26	121	120	67	10	82	236	8	4	53	120
28.	R.V.	34	114	126	85	16	90	211	8	6	57	119
29.	V.W.	33	110	134	86	14	67	185	5	2	45	125
30.	M.N.	41	113	146	57	12	69	166	6	3	45	106
31.	O.S.	58	97	153	54	20	105	287	7	0	35	98
32.	H.B.	30	98	147	34	26	60	245	6	5	40	109
33.	W.N.	25	112	152	59	20	69	129	7	2	56	112
34.	R.E.	24	99	141	57	24	83	300	7	3	34	101
35.	B.I.	57	110	152	71	18	83	202	7	0	28	96

Appendix A

Determining whether simpler designs are reproduced earlier.

(1) Number across top from 1 to 10, i.e., 1st design reproduced, second, third, etc.

(2) Number down the side from 1 to 35 (35 subjects).

(3) For person (1), if his first design is simple, write S in column 1, line 1. If second design is also simple write S in column 2, line 1.

(4) Continue until all reproduced designs are entered.

Order--	1	2	3	4	5	6	7	8	9	10
Person										
1	S	S	C	S	S	-	-	-	-	-
2	C	S	S	S	C	S	S	-	-	-
3	S	S	-	-	-	-	-	-	-	-
4	S	C	S	C	C	S	S	S	-	-
.										
.										
35		etc.								

(5) Compute mid-rank for blanks under order. For person 1, five designs are recalled; therefore, 5 are blank. Midpoint of 6, 7, 8, 9, 10 would be 8. Midpoint for person 2 would be 9; for person 3, 6.5; for person 4 it would be 9.5

(6) Sum the ranks of the Ss for person 1, i.e., $1 \neq 2 \neq 4 \neq 5 \neq 8 = 20$
Sum the ranks of the Cs for person 1, i.e., $3 \neq 8 \neq 8 \neq 8 \neq 8 = 35$

(7) Repeat for person 2 $\Sigma S - 2 \neq 3 \neq 4 \neq 6 \neq 7 = 22$
$\Sigma C - 1 \neq 5 \neq 9 \neq 9 \neq 9 = 33$

Etc.