AN ELECTROMYOGRAPHIC STUDY OF TENSION IN INTERRUPTED AND COMPLETED TASKS

by

Alfred Arthur Smith

Submitted to the Graduate Faculty

of

McGill University

in partial fulfilment of the requirements

for the degree of

Doctor of Philosophy

September

1950

TABLE OF CONTENTS

HISTORICAL.

I. GENERAL

It has been said that, had the physicist not discovered the electron, the chemist would have been forced to invent it. That is to say that, in trying to understand the chemical behaviour of atoms, some knowledge of the physical structure of those atoms is required; and if the relevant information is not forthcoming from other disciplines, it must be inferred -- "invented", if you will.

In similar fashion the physicist has had to "invent", and rather freely at times. All atomic nuclei, if composed solely of the more readily observable constituents, should blow up instantly and with incredible violence. But matter is surprisingly stable. To explain this stability, physicists now think of the nuclear constituents as being involved in an esoteric process known as "meson exchange", which serves to unite them. Needless to say, no physicist has observed this process directly.

Another instance from physics concerns certain peculiarities in the emission of electrons from radioactive nuclei; peculiarities which seemingly involve a local violation of some of the most basic laws of physics. To avoid this unpleasant situation, a rather embarrassing particle called the neutrino has been invented --- embarrassing because the neutrino apparently plays no other role in the physicist's picture of the world, nor does it seem at present even theoretically possible to detect in any direct fashion.

It would be easy to give additional examples. Examples, however -- to paraphrase Occam -- should not be multiplied unnecessarily; the ones cited suffice to emphasize the point that, even in such well-developed and scientifically respectable disciplines as physics and chemistry, scientific theorizing customarily goes well beyond the simple recording of relationships between directly observable quantities. In a sense, as Korzybski (12) has pointed out, science involves a search for structure. This search is in many cases carried on as much by inference as by observation. And the resulting structural picture frequently includes entities, forces and processes which are far from being open to direct scrutiny.

A similar situation obtains in psychology. To understand the behaviour of an organism, knowledge of the internal structure of that organism is required. And if -- as is all too frequently the case -- the requisite knowledge proves inadequate or non-existent, the psychologist quite properly attempts to fill the gaps in his theoretical picture by "inventing" appropriate processes.

Numerous examples of such theorizing are available. Hull's (9) system, with its postulated "intervening variables", is a case in point. Köhler (11), by the application of his principle of isomorphism, has inferred the existence of a "brain field" for which physiological evidence is at present lacking.

The example which is most directly related to the present investigation is due to Lewin (13). No attempt will be made at this point to give a detailed exposition of Lewin's theorizing. As a part of his system, however, Lewin postulated the existence in the organism of what he termed "quasi-needs" or "tension-systems". These tensions are associated with the carrying out of various tasks, and normally disappear when the task-activity is completed. If, however, the task is not finished, the quasi-need will not have been "satisfied" (to speak somewhat anthropomorphically); the organism will be left with an undischarged and relatively persistent tension-system; and this will, in general, lead to observable differences when appropriate comparisons are made between completed and uncompleted activities.

As will be seen, the comparisons which have been made to date have been largely concerned with psychological functions allied to "memory"; in particular, differences in recall have been stressed. The present study -- to anticipate somewhat -- involves both the observation of differences between completed and interrupted activities at a more physiological level, and the attempt to infer therefrom something about the nature of the postulated tension-systems.

II. THE ZEIGARNIK EXPERIMENT

Historically, the first experimental investigation of this question was Zeigarnik's (27) classic study of differential recall of completed and interrupted tasks. Since her study has served as the prototype of nearly all subsequent experiments in this field, it will be described in some detail.

Zeigarnik presented her subjects with a series of some twenty tasks. The tasks varied in nature and difficulty, and called for such activities (among others) as drawing a vase, doing a jig-saw puzzle, writing a favourite poem, and stringing beads. The subjects were permitted to finish only half of the tasks; in the unfinished ones, interruption was achieved by the introduction of a fresh task. All materials for each task were put out of sight as soon as work on it was ended, thus removing everything which might be of special aid in tests of recall. At the close of the experimental session, the subjects were asked to recount what they had been doing. Zeigarnik listed all the tasks which were recalled, and later classified them with respect to completeness.

One hundred and thirty-eight subjects, divided into four groups, were used. Each group was divided into equal sub-groups. Sub-groups received the same tasks, but those tasks interrupted for one sub-group were completed by the other. This procedure cancelled the danger that some tasks would be inherently more interesting and hence more memorable.

Zeigarnik reported her results in terms of the "recall ratio", RU/RC: where RU represents the number of uncompleted tasks which were recalled, and RC the similar value for the completed tasks. Obviously, ratios close to unity will occur when completed and interrupted tasks are recalled about equally well. Ratios greater than one imply better recall of unfinished activities, and conversely for smaller ratios.

For all groups an average of approximately one half of the tasks were recalled. Subjects showed both a strong resistance to interruption, and a decided tendency to resume work on an interrupted task. And, in terms of the recall ratio, RU/RC, about twice as many uncompleted as completed tasks were remembered.

This superiority in recall of the interrupted tasks appears in still another way. At the close of the experiment, Zeigarnik listed all the tasks in the order in which they were recalled. In these lists, both the first and the second tasks named were unfinished tasks much more frequently than they were finished ones.

In addition to the main effect, two other factors were disclosed. The first of these has to do with <u>when</u> the interruption occurred. Zeigarnik found that tasks which were cut off when nearly completed were remembered more often than those interrupted shortly after they had been begun.

The second factor concerns what might be termed the structure of the tasks. Certain tasks had very high RU/RC values. These high-ratio tasks were of a kind which required "final activity": that is, the part-activities in such a task (drawing a vase is particularly clear example) have an organized relation both to each other and to the goal. This is in contrast with tasks involving "continuous activity" (such as stringing beads) in which the part-activities merely follow one another in series; the end of such an activity does not depend on any relationship between parts, but on arbitrary factors such as the length of the string. Many of the low-ratio tasks were of this variety.

Granting the superior recall of the interrupted tasks, may it not have been due to factors other than the postulated "quasi-need"? One such alternative explanation might be that the interruption, in itself, disturbed the subject, and that it was this disturbance, rather than the fact that the task was unfinished, which produced the better recall. Zeigarnik investigated this point. Arguing that subsequent completion of an interrupted task should not make the interruption less disturbing, whereas it would of necessity discharge the assumed tension system, she compared experimentally the recall of tasks which were interrupted and not resumed with the recall of others which were interrupted and later completed. Here again, as in her main experiment, she found that the tasks which were never completed were recalled about twice as frequently as those which, although also interrupted, were later finished.

A second possibility, also tested by Zeigarnik, was that her subjects might have suspected that they would have to finish the tasks later, and therefore might have made special efforts to keep these tasks in mind. The experiment was therefore repeated with two new groups of subjects. The first group was told in advance that if a task were interrupted, it would be finished later. The second group was told that any interruption would be final. On comparison, the recall ratios for these two groups proved almost identical -- that for the second group being in fact slightly higher.

Adopting, then, the hypothesis that the better recall of interrupted tasks is due to an undischarged tension-system, the question arises as to how long such tensions will persist. (The test of recall was usually given right at the close of the experimental session). To answer this question, Zeigarnik repeated the experiment once more, but did not give the recall test until twenty-four hours after the experimental session. At this time, she found that the recall ratio had dropped to the low value of 1.14 --- a value so close to unity as to imply no difference between interrupted and completed tasks. Unreleased tensions, Zeigarnik, concluded, are weakened or dissipated with

with the passage of time.

III. OTHER LEWINIAN EXPERIMENTS

Zeigarnik based her conclusions mainly on the facts of differential recall, but noted that her subjects showed a tendency to resume work on interrupted tasks. This is, of course, in accordance with Lewin's conception of the tension-system as a quasi-need; and Ovsiankina (21) undertook the definite investigation of this point. She succeeded in demonstrating that, where an activity had been interrupted, and the subject was later given the opportunity of taking up the work once more, frequent resumption of the unfinished activity occurred. On the other hand, where the tension-system had presumably been discharged by attainment of the goal, such resumption (or, more strictly, repetition)failed to occur.

Lissner (14) studied the discharge of quasi-needs by "substitute" activity. The criterion of substitute value was non-resumption of interrupted tasks after different activities had been interpolated. Substitute value was found to increase both with the difficulty of the interpolated task, and with its similarity to the original activity.

Mahler (16) used a similar experimental technique to study the question of the substitute value of interpolated activities having different "degree of reality". (A "reality" gradient is most simply illustrated by considering the differences between thinking about an activity, talking about it, and actually doing it). It was found that, on the whole, activities of greater reality have greater substitute value.

Brown (4) studied the relative persistence of the tensions associated with tasks at different levels of reality. Using the Zeigarnik technique, he compared specifically the discharge of quasi-needs corresponding to "serious" and "non-serious" tasks. (Serious tasks were ones given as a quiz; non-serious were similar tasks, given as a means of filling in time). Brown's results indicated that the assumed tension-systems persisted longer in the case of the serious tasks.

Lewin's theories have been the basic point of departure for the experiments thus far described. It should, therefore, now prove useful to pause and consider a general theoretical point of view which is implicit in all this work. Lewin's own formulation is as clear as any. He states (13, p. 242) that:

"In accordance with our general conceptual and methodological assumptions nearly all of our investigations treat not only questions of <u>individual differences</u> but problems of general <u>lawfulness</u>. The center of gravity lies, as a rule, in the problem of the general laws".

This theoretical orientation will later be contrasted with the position taken by certain more recent investigators, whose main interest is clearly not in any question of general laws, but rather in the personalities of the individual subjects.

IV. THE QUESTION OF PSYCHOANALYTIC MECHANISMS

The results, up to this point, have been presented in terms of better recall of interrupted tasks. But any proposition has its converse: specifically, if the experimental subjects recalled more interrupted tasks, they also, of necessity, forgot more completed tasks. And such a reformulation suggests at least a surface similarity to those clinically described memory phenomena which have been attributed to the Freudian mechanism of "repression".

The connection is not, however, straightforward. For repression is customarily thought of as a process which operates to prevent or hinder the recall of ideas, events or actions whose recall might prove unpleasant; and it is hard to see how the recall of successfully completed activities could be held to be more disagreeable than the recall of similar tasks in which, however, the individual had objectively failed.

It was Zeigarnik who showed how the connection might be effected. Certain of the interrupted tasks had --- contrary to her general finding --- been recalled less well than the corresponding completed tasks. Inquiring into this phenomenon, Zeigarnik found that the interruptions in these cases had been experienced as failures. She attributed this effect to "isolation" of the tension-systems, and suggested that it was analogous to "repression".

Again, Adler (1) reports a study by Blumberg, in which all tasks were jig-saw puzzles, and all were interrupted.

All subjects, therefore, "objectively" failed on all tasks. The attempt was made to introduce "subjective" feelings of failure or success by the use of spurious norms: on half of the tasks, S was told after interruption that he was doing better than average, on the other half that his performance had been poor. It was found that those subjects who did not accept the experimenter's judgment of failure, and who felt that they could have done better, recalled more "failure"-puzzles than "success"-puzzles. Those who experienced "real" failure recalled more success-puzzles.

Nowlis (20) studied the effect of success and failure on resumption. Two tasks were used: the first being always interrupted, the second always completed. After the second task had been finished, S was afforded the opportunity of resuming work on the first (interrupted) task.

"Success", "Neutral" and "Failure" conditions were made to accompany interruption of the first task and completion of the second. Feelings of either failure or success were introduced by using false norms, and by appropriately disparaging (or praising) remarks on the part of the experimenter. For the neutral condition, no reference was made to what anyone else had done, nor did E make any evaluative comments.

Nowlis reports her results in terms of the percentage of subjects who not only resumed but actually completed the unfinished task. She found that:

"Success and Failure stimulation on an interrupted task .... definitely reduce resumption in comparison with a Neutral interruption, the effect of Failure being slightly more pronounced than that of Success......Success stimulation following the completion of a second task increases resumption of the original activity to a significantly greater degree than does Failure stimulation or a Neutral condition".

These experiments indicate the manner in which a concept of repression may be introduced. They suggest that where an unfinished task is, subjectively, simply that and nothing more, the usual "Zeigarnik" results will obtain. But where the subject is made to feel that lack of completion implies a personal failure, repression begins to operate. This is, of course, in line with the general theoretical nature of psychoanalytic concepts -- repression among them -- in stressing the role of the individual's own affective evaluations.

Brenman (3) reports an attempt at "systematic exploration of phenomena related to those phenomena upon which psychoanalytic theory has been built". The bulk of her report concerns a series of experiments on subjects in a hypnotic state: these are, by their very nature, neither conclusive nor of any great pertinence to the present discussion. Her relevant data arise from a control experiment carried on with unhypnotized subjects. Brenman used two groups of subjects. Each group was given twenty tasks; half of these were interrupted; and the Zeigarnik recall ratio was determined for each group. The variable of interest here is the manner of interruption: for one group

Brenman employed a "mild" interruption, and found a recall ratio of 1.60; the other group was interrupted in a "severe and threatening" way, and yielded a recall ratio of 1.36. This difference is in the expected direction, if it be supposed that some measure of repression would ensue from the threatening mode of interruption.

A double assumption is involved here: that, first, better recall of unfinished activities is the "normal" result, and that, secondly, repression will operate as an additional factor under conditions where failure to complete is threatening to the subject's self-esteem. Better recall of completed tasks is therefore taken as indicative of repression.

This duality appears most clearly in the distinction drawn by Rosenzweig (25) between need-persistive reactions which "serve to fulfill the frustrated need", and ego-defensive reactions which "tend to protect the integration of the personality if and when the latter is threatened". Need-persistive reactions are clearly identifiable with Lewin's quasi-needs; and it is the ego-defensive aspects of repression with which Rosenzweig is most nearly concerned.

As a study of repression in terms of this distinction, then, Rosenzweig investigated the recall of finished and unfinished tasks. To two groups of subjects he gave as tasks a series of jig-saw puzzles picturing common objects. Half of the tasks were interrupted. Recall was examined within one minute after work had ceased on the last puzzle.

The difference in the conditions for the two groups centered around the arousal of need-persistive reactions alone or of ego-defensive reactions in addition.

Subjects in the first, or "informal" group, were told that the purpose of the experiment was to obtain information about the puzzles themselves, with the view of using them as material in a later investigation. Work on any task, therefore, might be interrupted at any time; as soon, indeed, as the experimenter had the required data. Interruption, it was implied, did not reflect in any way upon the ability of the subject.

Subjects in the second, or "formal" group, were given the tasks as an intelligence test. Every effort was made to convey the impression that not the puzzles but the subjects themselves were being tested. Interruption, consequently, was to be interpreted as personal failure, and due to the individual's own shortcomings. Rosenzweig summarizes the results of the study:

"Those individuals who had performed under the informal conditions, where need-persistive responses were alone presumably entailed, recalled the unfinished tasks better than the finished.... Undischarged tension associated with the incomplete tasks was presumably the basis for this effect. The individuals in the 'intelligence test' group, who were presumably motivated in the direction of ego-defense as well as need-persistence, recalled finished tasks more frequently than unfinsihed......... Here ego-defensive repression may, according to our interpretation, have been instrumental in the forgetting....."

Lest the foregoing convey an impression of too great unanimity on the part of psychologists, it is only fair to note that considerable doubt has been cast on the fruitfulness of this (or any similar) experimental attack on the problem of psychoanalytic mechanisms. For example Rapaport (24), discussing Rosenzweig's evidence, asserts that "there is no reason to assume that his results constitute experimental proof of, or are more than an experimental simile to, the repression mechanism". And again, that "repression would appear as a specific case of affective influence on memory, and one which can be demonstrated by qualitative clinical analysis of the memory material rather than by statistical probability".

Similarly Glixman (7) objects that none of these experiments has "dealt with repression as the psychoanalysts talk of it". The present writer is no psychoanalyst. However, for certain theoretical reasons -- to be presented in a later section of this report -- he is inclined to agree with both Glixman and Rapaport, at least insofar as "repression" experiments using the interrupted-task technique are concerned.

V. IS PERSONALITY THE MAJOR DETERMINANT?

Einstein laid down the criterion that a general law of nature should be so formulated as to be independent of any particular observer. It was probably of laws in this sense -- statements of relationships which obtain independently of the idiosyncrasies of a particular subject --- that Lewin was thinking when he spoke of his investigations as treating "not only questions of individual differences but problems of general lawfulness". For Lewin, it was the structure of the situation as a whole which determined the results of experiments such as Zeigarnik's.

Rosenzweig's approach, while couched in different language, would appear to be essentially similar. Both need-persistence and ego-defense appear to be generalized responses; not dependent, in the final analysis, on any individual characteristics.

Two relatively quite recent experiments look on the matter from a different point of view. Here, and very broadly, the position seems to be that the response is determined almost in its entirety by the kind of person concerned; the situation is involved only to the extent of triggering off the appropriate and typical personal reaction. Thus Alper (2) adopts the premise that "selective recall is meaningfully related to the personality needs of the individual".

To demonstrate this premise, Alper set up the more explicit hypothesis that:

"In a given sample of subjects, unselected for personality factors, there will be no statistically significant differences between the incidental recall of completed and incompleted tasks if, experimentally, there is an equal number of completed and incompleted tasks to be recalled".

As subjects Alper employed ten college students for whom extensive personality data was later to be available. As task material, and on separate occasions, they were given two sets of twelve 20-word sentences.

These sentences had been broken into two-word phrases; the separate phrases were typed on cards; and the cards presented in disarranged form to the subjects. Their task was to re-assemble the phrases into meaningful sentences.

The sentences were of two kinds. In each set of twelve, six sentences were easily solvable within the set time limit of two minutes; each of these "could be arranged into four meaningful (alternative) arrangements".

The other six could not be solved within the assigned two minutes: two because of their much greater difficulty, the remainder because they did not in fact make sense, no matter how arranged.

Two experimental conditions were employed. In Session I (designed to be relatively non-stressful) the subjects were presented with the first set of sentences, and the instructions emphasized E's wish to determine the relative difficulty of the various tasks.

In Session II, the second set of sentences was used, and presented as a standardized test of intelligence for selecting candidates for Officers Training School. In view of the fact that the subjects were all draft-age males, and the tests were carried out during the war years, it was felt that the situation was one in which self-esteem would be threatened objectively in a manner "consistent with the self-esteem needs of that individual". To increase the stress still further, Alper used an accomplice who announced "successful" completion of the first eight sentences.

Ten minutes after the last task (during which time simple "tests" were carried out) the subjects were asked to write down any of the sentences they remembered. Alper does not seem to have demanded full and accurate recall; her instructions state:

"If you remember any part of the sentence, even though you don't remember the whole sentence, put it down".

The results are given in percentages. For completed tasks, the score was "the ratio of completed sentences recalled by a given S to the actual number of sentences which that S successfully assembled"; for incompleted, the ratio of "incompleted (unsolved) sentences recalled by a given S to the actual number of sentences which that S failed to assemble correctly".

Taking the average of these ratios, Alper finds no significant difference between completed and interrupted tasks in either session; and concludes that her hypothesis is "fully supported".

A number of objections can, and should be raised. In the first place, it is hard to see just what is to be understood by the term "unselected". No evidence is presented that the sample is <u>representative</u> (in the statistical sense) of any defined population. Admittedly, such evidence is difficult of attainment; but, lacking information on this point, the writer is inclined to feel that in terms of number alone Alper's sample of ten male college students is no more likely to be representative (of the human species, at any rate) than the larger and more varied groups used in previous studies.

Then, too, Alper has laid down in her hypothesis the apparently stringent condition that there should be "an equal number of completed and incompleted tasks to be recalled". Now, while no actual report is made of the number of sentences solved for either session, Alper does claim a significant <u>decrease</u> in number of solutions from Session I to Session II. The conclusion seems logically inescapable: whatever conditions may have obtained in the first session, in the second at least there could not have been "an equal number of completed and incompleted tasks".

These criticisms are, in the end, relatively minor. The basic flaw in the experiment lies in the type of task used. Alper describes the tasks as "disarranged two-word phrases which, when assembled in the proper order, make a meaningful sentence". This is, of course, the description before any work is done. At the end of the session, however, the six completed tasks -- since they are completed -- will now be six <u>meaningful</u> sentences. The unfinished tasks -- since they are unfinished -- will still be disarranged two-word phrases; possibly somewhat better ordered than at the start, but still poorly structured, relatively <u>meaningless</u>. Which, then -- disregarding other factors -- should be better remembered?

It has long been almost a psychological truism that meaningful material is better remembered than meaningless. McGeoch (15) for example, holds that there is "good ground for concluding that meaningful materials ... are usually much better retained than are nonsense materials". Truisms, however, are not necessarily true in all cases. The present writer therefore carried out an informal check of Alper's sentence material. The twelve sentences used in Session I were printed on filing cards, one sentence to a card. Each of the 6 "completed" (i.e., easily solvable) sentences was set down in the final, correct form as given by Alper; the 6 "uncompleted" sentences were disarranged. The cards were then stacked in the order used by Alper, and presented to the subject. S was asked to pick up each card in turn, read over the material on it three times, and thenproceed to the next card. When S had read the last sentence, he was given a sheet of paper and asked to write down what he remembered.

On the average, twice as many "completed" (meaningful) as "uncompleted" (meaningless) sentences were recalled.

This does not, however, tell the full story. It does not take account of how accurately and fully any particular sentence was reproduced. (Alper gives no indication of having taken such a factor into consideration). As an example, one S recalled six out of six "completed" sentences, and two out of six "uncompleted". His recall of the meaningful material was, however, practically word for word; whereas, in the case of the two relatively meaningless sentences, he was able to recall only a few words in each.

The implication is clear. Purely in terms of memorability, Alper's subjects should have recalled more completed than interrupted tasks; Alper found no experimental differences: therefore, some factor independent of personality characteristics must have operated.

A recent study by Postman and Solomon (23) is closely parallel in assumptions, in procedure, and in results.

Postman and Solomon make two basic assumptions: that "common motivational principles govern perceptual response and retention"; and that "it is not so much completion or incompletion per se then, that makes for differences in retention; rather it is the subject's motivated response to the completion or incompletion of his tasks which determines significant differences in retention".

In place of disarranged sentences, Postman and Solomon used jumbled seven-letter words; where Alper measured differences in reproduction, Postman and Solomon measured differences in recognition. Their results are essentially the same as Alper's: no difference between the recognition thresholds of completed and uncompleted task words.

It would be profitless to carry the discussion of this experiment any further. The same fundamental objection applies; nor does either study offer any real support to the thesis that personality factors are the major determinants of selective recall.

VI. MUSCULAR TENSION AND INTERRUPTED ACTIVITY

In the foregoing account, no attempt has been made to describe and analyze all experiments ever done with interrupted tasks. Rather, the endeavour has been to select certain representative studies, and to consider them in relation to the underlying theoretical assumptions of their authors.

One investigation remains to be described. Its interest for the present discussion lies not so much in the results obtained as in the methodology.

G.L. Freeman (6) developed a technique for measuring "the changes in muscle tension which occurred during the solution and interruption of various tasks". Basically, this involved the measurement (mechanically and optically) of changes in deformation of the patellar tendon: such tendon deformation was correlated with the tensional state of the quadriceps muscle.

Twenty tasks were employed, each requiring on the average five minutes to complete. Half of these were "interrupted" one minute after work had begun. The interruptions were of two kinds: Accidental ("a large piece of cloth fell on S's head", "small screws ... were rained down upon the subject", etc.); and Deliberate ("subject was asked if he had felt himself sitting on a screw-driver", etc.).

Comparison was made between the average level of tension during the second minute of work on the completed tasks and during the periods of "interruption" on the others; tension during interruption was found to be higher.

Unfortunately, it appears that Freeman was not in fact investigating the effects of <u>interruption</u>, as defined by other experimenters; rather, his study was one of <u>distraction</u>. This, at any rate, seems the only inference to be drawn from such statements as: "Our subjects continued their tasks notwithstanding interruption". This being so, it is unlikely that the Freeman results are of any value in elucidating the phenomena of differential recall.

Nonetheless, certain very general considerations indicate that differences in muscular tension might well be expected, even under conditions much more closely comparable to those of the more usual studies.

There is, in the first place, the very broad generalization (to which lip-service at least is paid in many a psychological quarter) that "the organism acts as a whole". If this statement be accepted naively, it would seem that there should be some differences in muscular tension correlated with the known differences in memory-function. These hypothetical differences might, of course, be too slight or too well hidden by other factors to be detectable by any techniques now available: but they should be worth looking for.

Again, and from a more specialized point of view: if the central nervous system acts as a field (in the sense proposed by Köhler and others), then, by definition, any part-process in one region of that field must influence, however slightly, all other part-processes. And once more a search for motor correlates is indicated.

Such a search -- using more sensitive measures of muscular tension -- is now to be described.

EXPERIMENTAL

I. PURPOSE

In broad, and in terms of experimental method, the present study was designed to show that the technique of continuous electromyographic recording could be applied with advantage to a situation where usually more orthodox psychological approaches have prevailed.

In particular, it was hoped that the electromyographic data thus obtained would throw light on the neurological mechanisms responsible for differential recall in the interrupted-task situation.

II. TASK MATERIAL

In setting up the experiment, first consideration was given to choice of task. First, it seemed that motor tasks were called for, since the experiment was concerned with muscular tension. Then, since any present instrument for the measurement of muscular tension is of necessity quite sensitive to abrupt and large-scale movements, the choice of task was thereby limited to ones which could be carried out smoothly and with uniform motion. Finally, the experience of previous investigators indicated that, for best results, the tasks should be well structured (in the Gestalt sense).

The final decision fell upon four tasks which entailed the drawing of simple geometrical forms. Figure 1 illustrates the patterns used. The figures were drawn separately with

India-ink on letter-size sheets of white paper, and presented to the subjects as mirror-tracing tests. That is, S was asked to draw around the outline of the presented figure, which was visible to him only in indirect vision. The mirror-apparatus was a modified form of the "Katoptograph", described by Wechsler and Hartogs (26), and used in a different context by Malmo, Shagass and Davis (18).

The circumferences of the figures were: 26 cm. for the two smaller figures (always used as completed tasks); and 31 cm. for the larger figures (always interrupted). S was always interrupted at a point 5 cm. from the goal (and therefore 26 cm. from the start). This procedure, it was hoped, would equalize the work done on all tasks, whether completed or interrupted.

As indicated by the small arrows in Figure 1, drawing was carried out in a clockwise direction for one set of figures, and in the opposite direction for the other pair. This procedure -- since the results for completed and interrupted were to be averaged separately, had the effect of compensating for differences in the position of the hand at the end of drawing. Effectively, the interruption-point of the large "triangle", while different from the goal-point of the small "triangle", coincided with the goal of the small circle; and similarly for the opposite pairing.

The tasks were presented in a different and random order to each S. Thus S no. 4 completed the first task (a circle); was interrupted on the next two (circle, followed by "triangle"); and was allowed to finish the fourth (a "triangle"). S No. 5 was interrupted on the first task (a circle); completed the next two ("triangle" followed by circle); and was interrupted on the last (a "triangle").

III. RECORDING APPARATUS

Muscular tension was measured in terms of electromyographic potentials between bi-polar electrodes, amplified and recorded on an Offner Type D ink-writing electroencephalograph.

The following lead placements were used:

1) Neck -- a pair of chlorided silver electrodes of EEG type, affixed to the back of the neck by collodion. One was placed on the mid-line, over the fifth cervical vertebra; the other at a point 1.5inches above and 1 inch to the right. The potentials recorded here originated in part from trapezius.

2) Forehead -- the electrodes here were 1.5 cm. cubes of cellulose sponge, soaked in thin electrode jelly, with the end of the lead wire passed through once and doubled back. Attachment was effected by means of short lengths of surgical tape, to the dry surface of which small gauze pouches were cemented with collodion. The tape adhered to the skin surface, and the electrode was inserted in the pouch, to make contact with the skin through a 1/2 cm. hole in the tape. One electrode was attached at mid-line, the other 1.5 inches to the right. The potentials originated from frontalis.

3) Chin -- sponge electrodes, fastened by surgical tape above and below the point of the chin. The upper electrode presumably picked up from depressor labii inferioris, the lower from genioglossus.

4) Right and Left Arm -- sponge electrodes, secured by

pierced rubber straps, to which rubber pouches had been sewn. The upper electrode was approximately mid-way between elbow and wrist, over the belly of extensor digitorum communis (located more precisely by having S tap vigorously with the forefinger); the lower electrode was placed 1.5 inches distally.

5) Right Leg -- sponge electrodes, affixed by surgical tape; the upper electrode at a point 1.5 inches forward of the center of the line from the head of the tibia to the lateral malleolus; the second electrode was 1.5 inches below. The potentials recorded here arose from tibialis anterior.

Muscle potentials from these areas were recorded continuously throughout the experimental session. In addition, measures of the average potential during 10-second periods, taken every 20 seconds throughout, were obtained by the use of electronic integrating circuits, designed and built by Dr. J.F. Davis (5). Since only four such integrators were in use, data of this type are available only for Forehead, Neck, and Right and Left Arms.

IV. SUBJECTS

Nineteen subjects in all were tested. Fifteen of these went through the experiment as outlined in the following section; four, used as a "control" group, were allowed to complete all tasks.

Of the main group, 8 were college students (5 female, 3 male); and 7 (all male) were service personnel from a nearby air force station. The 4 "control" S's were likewise RCAF personnel.

The college group ranged in age from 18 to 21 years.

All were at the time taking their first course in psychology. None were familiar with any of the previous work -- experimental or theoretical -- on interrupted tasks.

The air force group ranged in age from 21 to 32 years. In terms of formal schooling, all members of this group had completed at least grade 8.

V. PROCEDURE.

Prior to attachment of the electrodes, S was told:

"I wish to find out something about the activity of your muscles while you are carrying out a few simple tasks. These tasks will require nothing more than drawing around the outlines of simple geometrical figures -- circles and the like -- while looking in a mirror. I will tell you more about the tasks a little later. Right now, I have to attach a number of wires to different parts of your body. These wires are only for recording the activity of your muscles; you will feel nothing but contact from them at any time".

The electrodes were then attached, and the subject taken from the lead-placement room to the test-room proper. Here he was seated in a wooden arm chair, and given a general and informal outline of the manner in which the experiment was to be conducted.

As has been said, there were four tasks in all. S was not, however, told in advance how many to expect; in fact, materials were at hand for at least five tasks, and in a position where S could see them if he looked.

For each task, the following periods can be distinguished:

1) <u>Pre-Period</u> -- during this period S sat back in the chair and relaxed as much as possible.

2) <u>Instructions</u> -- E inserted one of the task-figures in the Katoptograph, moved the apparatus (which was mounted on a small wheeled table) in front of S and in a convenient position, and gave S both a pencil and the appropriate instructions.

3) <u>Expectation Period</u> -- S sat quietly, not moving, holding his pencil on the start-point.

4) <u>Task Period</u> -- S carried out the task (or as much of it as E permitted).

5) <u>Post Period</u> -- S kept his pencil on the point last reached (goal-point or interruption-point) and remained motionless.

6) The apparatus was moved away, and S sat back and relaxed once more, starting the pre-period of the next task.

Pre, Expectation, and Post periods were generally one minute in length. Task time varied from 10 seconds to over a minute, with an average of around 30 seconds. The pre-period for the first task, however, was 3 minutes in length, as was the final period of relaxation (the pre-period, in a sense, for a non-existent fifth task). Instructions took about 15 seconds.

These instructions were:

"The next task will be to draw a circle" (or "triangle"). E then inserted the appropriate figure, moved the apparatus up and gave S a pencil. After checking to ascertain that S could see the figure clearly in the mirror, E said:

"I want you to place your pencil on the start point, here. Now, wait until I say Go; and when I say Go, start drawing around the circle, in the direction of the small arrow, until you get back to the start point again. When you stop drawing, do not change your position, and keep your pencil on the paper until I take it from you".

S was then questioned to be sure he understood; one minute later, E said "Go!"

E had at his side a signal button, pressure on which deflected a marking pen on the EEG. This was used to signal the beginning of the various periods and -- of most importance -- the beginning and end of activity. Thus, E signalled when he said "Go" at the start of each task, and again as soon as he saw that S had stopped drawing -- whether because of interruption or because the goal had been reached.

The method of interruption was designed to be as little disturbing as possible. E could, from his position at one side and slightly to the rear, observe S throughout the course of his drawing. When, therefore, S had reached the point in the task where interruption was to occur, E said quietly:

"Stop. Keep your pencil on the paper".

(The interruption point was not, of course, marked; E judged its location and stopped S accordingly).

To ensure conditions as closely similar as possible for both completed and interrupted tasks, E used exactly the same words (and, as far as he could determine, the same tone of voice) when S reached the goal of the completed tasks.

In summary, the course of events for each task was:

1) Pre-period -- S sitting back;
2) Instructions -- apparatus arranged;
3) Expectation -- S awaiting signal to start;
4) Task;
5) Post period -- comparable to E-period; and
6) Pre-period for next task.

VI. TREATMENT OF DATA.

The primary data consist of 1) the muscle potential record (see Figure 2), in which the height of any individual spike represents the instantaneous value of the potential between the relevant electrodes, and 2) a set of numbers, or integrator readings, which are proportional to the average spike height during defined ten-second intervals.

Now, since spike heights and integrator readings alike depend both on the tension in the muscle from which the recording is being made and on the gain of the amplifying circuits, it is clear that the primary data as such are not comparable from subject to subject, nor from time to time during a single test -- unless it has happened that no gain changes were made. Such data, then, must be converted to values which are generally comparable. The method of conversion employed here expresses muscular tension as micro-volts of potential difference between the bi-polar leads. Its rationale is as follows:

The tension in the muscle produces a certain unknown and fluctuating potential difference between the electrodes. This P.D., amplified at a known gain, produces -- at some defined moment -- a deflection of the recording pen, or spike, of height H, and also, when accumulated electronically for ten seconds, an integrator reading I. A known source of voltage is now substituted for the unknown P.D. If now, when the known voltage is at a value V-1, the pens are again deflected an amount H, we may define the unknown instantaneous P.D. to be V-1 volts (or rather, microvolts, since the potentials are of this order). Similarly, if a known voltage V-2 accumulates over a ten-second period to yield I units on the integrator, then the average value of the unknown P.D. during this period can be defined as V-2 microvolts.

In the present system, the standard or calibration signal was a 45-cycle sinusoidal voltage, generated by a Hewlett-Packard audio-oscillator, and controlled by a microvolter. This signal, at various appropriate levels, was impressed on the recording and integrating circuits at the end of each experimental session.

Two main classes of measurements were thus made feasible. If, for example, an estimate of the average tension level during one of the major periods (Pre, Expectation, Post, etc.) was required, the integrator data were used; three integrator values being available for each such one-minute interval. The integrated value of the calibration signal, obtained at the close of the session, was used to select one of a set of previously constructed calibration curves. For any one integrator, these consisted of an experimentally determined family of curves, relating integrator reading to microvolts of input. Once the appropriate curve had been determined, the experimental integrator readings were converted to microvolts and averaged.

For short-term phenomena, a different procedure was instituted. This involved the direct measurement, on the primary record, of the highest spike in each 1/5th second segment of certain designated two-second periods. All such measurements were made to the nearest 1/2 millimeter. Accuracy of this order was ensured by the use of good quality K.&E. scales, divided to 0.5 mm., and by carrying out the measurements under a large illuminated magnifier.

The ten measured spikes in each period were then averaged, and the average converted to a microvolt value by comparison with the similarly measured height of the recorded calibration signal.

This procedure, though fruitful, unfortunately proved somewhat laborious: nearly 10,000 individual measurements being required in the end.

VII. RESULTS.

The integrator data yielded measures of the average tension during each of the major periods: Pre, Expectation, Task and Post. Comparisons, whether of direct measures or of measures of change (e.g., Task to Post-periods) revealed <u>no significant differences</u> between completed and interrupted tasks for the experimental group.

The two-second averages derived from measurements of individual muscle spikes turned out to be rather more fruitful. They constituted, in the first instance, an attempt to answer the question, How much does tension decrease immediately S stops drawing?

Two periods were therefore selected for comparison: the last two seconds of drawing, and the two seconds immediately following. For convenience, these periods will be designated henceforth as T.and P. Decrease in tension after drawing is given by the difference T-P, averaged separately for each S and for completed and interrupted tasks.

Table I presents the group averages, in microvolts, for each area (except Leg; for which, because of the high incidence of muscle twitches and other random and inadequately explained shifts in tension, no trustworthy data could be obtained).

Muscular tension, then, is seen to decrease more after completion than after interruption. The differences in the amount of decrease have been shown to be highly significant (1% level of confidence) for Chin, and fairly significant (5% level) for Neck.

The difference for the Active Arm, while large, cannot be directly evaluated, although the significant F-value implies that it is valid. It is possible, however, to set up the null-hypothesis in a slightly different form, and thus obtain an estimate of statistical reliability.

Let the occurrence of a larger decrease after completion be called a "plus", and the opposite occurrence --

greater decrease after interruption -- a "minus". Now the null-hypothesis -- that there is no real difference between completion and interruption -- becomes the equivalent hypothesis that "pluses" and minuses" are equally probable: the a priori probability of either being 1/2. Consequently, for a sample of 15, the chance probability of obtaining any given number of pluses and minuses can be determined by precisely the same technique as is used to determine the chances of obtaining that number of heads when tossing coins: by selecting the appropriate term from the expansion of $(\frac{1}{2} + \frac{1}{2})^{15}$.

Examination of the individual data from the present experiment showed that 13 S's gave a larger decrease after completion; by the binomial expansion, the probability of this result is just over 0.003.

Before it can be concluded that the observed differences are to be attributed to interruption, alternative explanations must be examined. Pachauri (22), for example, has shown a correlation of 0.67 between the average time allowed for performance (whether completed or interrupted) and frequency of recall. For the present data, mean performance times for completed and interrupted tasks respectively are 33.5 and 34.0 seconds. The half-second difference is not significant; and any differentiating factor related to task-time can most probably be eliminated.

Examination of the actual tracings reveals fair differences from task to task in the quality of the performance.

To examine this factor, a rough "Irregularity" score was devised: all 60 drawings were sorted into 3 piles according to whether they were judged to be fairly smooth, somewhat irregular, or quite irregular. These three categories were given arbitrary weights of 1, 2 and 3. In terms of the rough score thus obtained, completed and interrupted tasks do not appear to be significantly different in quality of performance.

Finally, it might reasonably be suggested that the potentials do not decline so much after interruption because the interruption is unexpected and hence in a measure "startling" to S. (This is, of course, an hypothesis similar to the one which Zeigarnik sought to exclude by examining the recall of tasks which were interrupted and later completed). Data, however, are available from an experiment by Malmo, Shagass and Davis (17) which effectively rule out this explanation. The effects on muscular tension of sudden and intense auditory stimulation were recorded (in the same laboratory and using the same instruments and measuring techniques as in the present study). When the course of muscle tension in the right arm, before and during stimulation, is examined, the "startle" effect is seen to persist for only a fraction of a second: accordingly, when the <u>average</u> tension during a two-second period after the onset of stimulation is compared with the pre-stimulus level, the increase amounts to less than two microvolts. Hence, since the similarly measured two-second averages in the present experiment show much greater differences (with what reasonably would seem to be a less "startling" stimulation), it can be concluded that something more than a "startle" effect was in operation.

The values reported in Table I are for decreases in muscular tension -- i.e., differences between the last two seconds of task activity and the first two seconds of the post-period. It is instructive to examine the actual values from which these decreases were calculated. Table II shows these values for the active arm; in addition, the average tension during the <u>first</u> two seconds of drawing has been included.

The entries for the beginning of the task, and for the post period, do not add materially to the picture thus far presented. An obvious problem arises, however, in connection with the quite noticeable differences between completed and interrupted tasks during the last two seconds of activity.

Two clues are available which, taken together, suggest a testable hypothesis. In the first place, both completed and interrupted tasks start at the same level of tension and increase at the end: the main difference being that tension in the interrupted tasks does not increase as much. The second suggestive factor is that, <u>from the point of view of the subject trying to reach the goal</u>, not as much is accomplished in the interrupted tasks. The hypothesis is, then, that muscular tension in these tasks is related to the perceived distance from the goal; consequently, since at the point of interruption S has only traced 84% (26/31) of the total figure, measurement of the tension in the completed tasks at a comparable point should yield comparable results.

Unfortunately, in a recording system such as was used, measurements along the final record represent units of time rather than units of distance; and the required point cannot be directly and accurately located. Its location can be estimated, however, with reasonable precision by assuming that S drew at a constant rate throughout. Thus, if 100 seconds were taken to complete a tracing, it was assumed that 84% of the task had been done when 84 seconds had elapsed.

By this means, "84% points" were located for all completed tasks; and the average tension in the two seconds just preceding was determined. As it turned out, the average tension at the "84% point" of the completed tasks was 172.4 microvolts -- a value practically identical with 173.1 microvolt average for the end of drawing in the interrupted tasks.

The final picture is presented in Table III, and in Figure 3. The agreement is surprisingly good -- so good, in fact, that the distance between corresponding points for completed and interrupted tasks had to be exaggerated considerably in drawing, to prevent coincidence without making the figure unreasonably large.

One point remains. Four control subjects were given exactly the same test procedure -- except that they were allowed to finish all the tasks. When the various comparisons are made for this group, no differences between completed and "interrupted" tasks appear. In this connection, "interrupted" refers of course to the tasks that would have been so treated in the main experiment.

THEORETICAL

In the present study, a two-fold thesis was adopted. In the first place, it was suggested that a particular experimental technique -- continuous electromyographic recording -- could be used with advantage in experiments of this nature: on this level, the experimental data constitute sufficient evidence.

Secondly, and on the theoretical level, it was implied that such electromyographic data would throw light on the neural processes underlying the phenomenon of differential recall. It now remains to demonstrate this proposition.

In any such attempt much depends on where the theorizer starts, and what kind of language he employs. In the present instance, it has proved illuminating to begin with the completed tasks, and, following Humphrey(10), to describe them in terms of a four-dimensional, space-time organization.

For convenience, the motor responses involved in drawing a circle will first be considered. From the point of view here adopted, these responses constitute, not a discrete series, but a total response, organized both in space and time. Or, more precisely -- since the "time" at which any particular part-response occurs is not independent of the "place" at which it occurs the organization is in space-time. This distinction is but a recognition that Minkowski's (19) oft-quoted dictum that "space by itself and time by itself are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality" applies as well to the world of psychological events as to the world of physical events.

Grating, then, that activity on a given task may be spoken of as a response organized in space-time, whence arises this organization? The best psychological and physiological evidence to date implies that overt activity, muscular responses and the like, do not organize themselves. Central nervous system activity appears to be necessary. This being the case, the implication is that, corresponding to the organized Response, there is a central process similarly organized in space-time. (Logically, there is of course no "real" difference between central process and overt response: the separation is admittedly arbitrary, but useful for purposes of analysis).

Obviously this does not answer the question of organization. It merely refers it to a different level. For the moment, however, the question of how the central process is organized will be deferred.

If, now, there is any physical connection between central process and final response, that connection must be (as far as is now known) by means of nervous impulses with a <u>finite velocity of transmission</u>. Consequently, the organization of the central process must in this sense be "prior" to the organization of the overt response: the central process "anticipates" the response.

Lest this emphasis on the speed of neural transmission seem trivially self-evident, it may be pointed out -- as Korzybski (12) has done -- that one of the fundamental differences between Newtonian and non-Newtonian (relativity) theory lies precisely in Einstein's explicit recognition of the finite velocity of any signalling process.

Apart from this logical argument, the present experiment yields more direct evidence of "prior organization". In tracing the figure which has been called a "triangle", the first movement required is in exactly the opposite direction from that which appears to be correct to the subject looking in the mirror. And yet no subject moved off in the wrong direction -- a result which would surely seem astonishing were there no previously organized process to "anticipate" the correct move.

The amount by which the central process anticipates or "leads" the response -- to borrow a term from the vocabulary of the electrical engineer - obviously depends on the particular ideas held about such a process. The magnitude of the "lead" will be at least as great as the time of transmission between motor cortex and the muscles involved; and it may well be longer. Hebb, for example, has criticized current theories on the grounds of their failure to make "any serious attempt to elaborate ideas of a central mechanism to account for the delay, between stimulation and response, that seems so characteristic of thought" (8, xvii); and has formulated a theory to permit of delays of some considerable length.

Up to this point the analysis has been more than a little artificial. The subjects whose behavior was being discussed might well have been both blind and deaf, for all the notice that has been taken of what they see and hear. And yet they do quite obviously both see and hear: they start drawing when they hear the signal, their tracing approximates quite reasonably the presented figure, and they successfully reach and stop at the designated goal. Their response, then,-- and hence, presumably the central process -- is at least partially under sensory control.

On the other hand, both the behavior and the later reports of many of the subjects indicated that their response was to a considerable degree independent of what they saw. One S -- who had made a particularly accurate set of tracings -- remarked that he had "figured out ahead of time how to do the task, and sort of shut his eyes and did it". In this connection it should be remembered that the procedure involved a one-minute expectation period before each task, which would allow ample time for such "figuring out".

This argument suggests, too, that the activity here is not just a matter of motor organization alone, but that an element of verbal or conceptual activity -- of thinking -- is present. The suggestion is made more plausible when the "patterning" of the muscle tension shifts is examined. It has been seen (Table I) that the effect under investigation -- tensional differences between completed and interrupted tasks --

is not a matter of any generalized somatic tension; rather, it appears to be confined to specific muscles groups.

The leads in two of the areas concerned -- Active Arm and Neck -- tap muscles which, anatomically and functionally, would be directly involved in carrying out the tasks; the results here present no special difficulty. The only other area showing any significant effect is Chin. The potentials here originate in muscles which are associated, not directly with the task, but with speech. (This conclusion is based not only on anatomical considerations, but on the results from a previous and as yet incomplete study, in which potentials from this area were shown to be associated with talking). Now, it is probably fair to assert that -- at least in the human adult in our present culture -- "thinking" is by and large a matter of symbol-manipulation -- of verbal activity. Consequently, specific activity in the speech muscles would seem to imply the existence of something that might appropriately be labelled a "thought process"; an implication which accords neatly with the retrospective remarks of the subjects.

It is now appropriate to consider the theoretical effect of interruption. In view of the picture that has been built up, of an organized response and a similarly organized central "thought" process which leads the response and which is at the same time relatively free from sensory control, what conditions are likely to obtain at the end of activity, in both completed and interrupted tasks?

When, in the completed tasks the goal (in terms of overt response) has been reached, the organized central process, by hypothesis, will already have run its course; and cessation of activity should be accompanied by a relatively rapid and complete relaxation of all associated muscular tensions. On the other hand, when such an organized activity is interrupted during its course, the central process -- by reason both of its relative autonomy, and of the fact that it "leads" the response -- may tend to continue for some time. And this carry-over, can be expected to show up in a less rapid decrease of any tensions associated with the doing of the task. This is, of course, the pattern of events here disclosed.

So far, the question of organization has been dodged. The problem is essentially that old and knotty one of "set", of "determining tendency", of directive and anticipatory processes in general.

In a sense, organization is present perceptually from the start. But this organization is in the first instance essentially static: a pattern of lines in space; whereas the question is one of the organization of processes in space-time.

Recently Hebb (8) has elaborated a conceptual tool for handling similar problems, certain features of which meet the requirements of the present discussion. In brief, Hebb suggest (8, xix) that: "Any frequently repeated, particular stimulation will lead to the slow development of a 'cell-assembly', a diffuse structure comprising cells in the cortex and diencephalon.... capable of acting briefly as a closed system, delivering facilitation to other such systems and usually having a specific motor facilitation. A series of such events constitutes a 'phase sequence' -- the thought process..... The central facilitation from one of these activities on the next is the prototype of 'attention'. The theory proposes that in this central facilitation, and its varied relationship to sensory processes, lies the answer to ..... the problem of the direction of thought".

Approaching the question from this point of view, what picture -- in neuropsychological terms -- can be drawn of the situation when an adult human subject is confronted with the tasks here employed?

Since these tasks involved fundamentally only simple movements of a pencil over a sheet of paper, and since the subjects were both adult and literate, it would seem reasonable to assume that S's problem was not <u>how</u> to execute any particular movement, but rather <u>which</u> of a number of familiar movements to carry out. In terms of the postulated neural structures, S brought to each task an extensive set of previously developed cell-assemblies, which somehow became selectively organized into a more comprehensive spatio-temporal pattern, or phase sequence.

Such further organization could occur in part during the one minute expectation period: the instructions, together with the pattern of sensory impulses resulting from S's inspection of the task material, might presumably serve to facilitate selectively certain of the cell-assemblies, and to establish or improve the connections between assemblies. Such a process would then be the neural correlate of what one S described as "figuring out ahead of time what to do". And thus, when the question is raised: whence arises the postulated neural organization? one answer is that it is in part brought to the situation by S, and in part derived from the organized nature of the task.

Following this line of argument, the signal to start can be thought of as "triggering" this organized process, or phase sequence. And the phase sequence, by virtue of its specific motor facilitation, serves to guide the overt activity.

Activity having begun, sensory "feed-back" (both visual and proprioceptive) should exercise a further selection among and facilitation of available neural structures. It is possible that such an increasing degree of organization of the phase sequence is reflected in the gradient of muscle tension shown in Figure 1.

In this connection it is fruitful to think of the phase sequence as operating on two levels. On one, it involves recurrent serial activity in cell-assemblies associated with the particular movements being executed.

On a different level, it involves a higher-order structure corresponding to the performance of the task as a whole. Now, as the task proceeds, as S sees himself drawing nearer the goal, activity on these two levels will converge; i.e., it will to an increasing degree involve activity in the same neural structures. And this convergence will promote both increasing motor facilitation on to the final common path (and hence higher muscle tension) and also establish the connections between the various component structures more and more firmly.

Whether this sort of organizing process goes on uniformly during the task activity, or whether S's perception that the goal has been reached will be a more potent organizing factor than any of the previous stages, is a question which cannot be answered without -- at the least -- finer and more numerous measurements than are at present available. The fact that muscle tension seems related more to perceived distance from the goal than to the actual time or effort expended, might perhaps make the latter alternative somewhat more attractive.

Such a series of assembly-actions, organized in part by previous learning and in part by the immediately existing pattern of sensory stimulation, will obviously fulfill many of the requirements of the central neural process postulated heretofore. At any point of the task (short of the goal) there will be "expectancy" of the next movement: in terms of the theory here adopted, the activity in the corresponding cell-assembly will have components of facilitation on to the next such structure in the sequence. Each cell-assembly is capable of self-maintained activity, as is the phase sequence as a whole. Consequently -- if it be assumed that sudden interruption does not too seriously disrupt the sequence -- the central activity will carry on for a short time, maintaining the associated muscular tensions at a relatively high level.

Hebb (8, p. 143) has estimated the duration of such self-maintained action at about half a second for a single cell assembly, and a few seconds for a sequence of recurring assembly actions. In the present experiment, tensional differences are in evidence when comparisons are made for the brief two seconds after cessation of overt movement, but are not present when the comparison is made for the full one minute post period. Thus the duration of higher tension after interruption -- which has been attributed to self-maintained activity,-is probably of the same order of magnitude as assumed by Hebb on other grounds.

This correspondence, while gratifying, is also a source of theoretical difficulty. For one of the aims of the present study was to throw light on the neurological mechanisms responsible for differential recall as studied by Zeigarnik and others. And obviously, a central process which, both on theoretical and experimental grounds, ceases activity long before the time at which recall tests are customarily administered can hardly be a sufficient answer.

One suggestion -- admittedly tentative -- may be offered. It has been assumed that the central conceptual process, or phase sequence, becomes more well established as the task proceeds. This would imply that phase sequences corresponding to completed tasks are somewhat better organized than those corresponding to interrupted tasks. Also, the sudden interruption might well act to produce some loss in organization of the phase sequence, thus further increasing the difference (centrally) between completed and interrupted tasks.

Now, Hebb has suggested that a well-organized phase sequence is not likely to be repeated in detail; it will tend to "short-circuit", to run its course rapidly; in consequence, behavior, by and large, will be "dominated by the thought process that is not fully organized" (8, pp. 227-230)

If this idea is applied to the type of situation now being discussed, the implication is that, when recall is asked for later, the phase sequences corresponding to completed tasks have a greater probability of "short-circuiting": of running through too rapidly and in too abbreviated a form to control effectively that form of behavior usually labelled "recall".

There are obvious limits to this relationship. Too great a loss in organization can hardly be expected to improve recall: otherwise one would be forced to the absurdity of predicting that a task with which S had no opportunity of familiarizing himself would be recalled more readily than one on which considerable time and effort had been expended.

The suggestion, then, is that subsequent recall of an activity is favored by increasing organization of the associated phase sequence, up to the point at which that phase sequence becomes sufficiently well established as to render short-circuiting likely. Beyond this point, the more highly organized process will become progressively less likely to effect recall.

Figure 4 represents graphically the form of the assumed relationship. The points C and I represent the organization of the phase sequence achieved in completed and interrupted tasks respectively. If this portion of the reasoning is approximately accurate, then any loss in organization of either completed or interrupted tasks (or both) should make recall more nearly similar, or even better for completed than for interrupted.

In the present experiment, the phase sequence was assumed to derive its organization in part from events prior to the task activity proper (previous learning, instructions, and inspection of the task material), and in part from perceptual and kinesthetic concomitants of the task activity itself.

Considering this second factor,if the subject is stopped before he has done much on the task, the phase sequence will not be so well established, and recall of interrupted and completed tasks will become more nearly equal. This, in fact, is what Zeigarnik found: tasks which were cut off when nearly completed were remembered more often than those interrupted shortly after they had been begun.

Again, it has been said that interruption may have some disrupting effect on the phase sequence. It seems not unreasonable to infer that the results of Brenman's experiment--in which a "severe and threatening" interruption yielded less difference in recall than did a "mild" one -- can be explained on the assumption that severe interruption will prove more disorganizing.

A similar approach fits such "repression" experiments as Rosenzweig's into the general scheme. Here, in the "formal" or "intelligence test" group, any interruption which is felt by the subject as a personal failure may well be sufficiently disturbing to produce a reversal of the usual recall ratio. Undoubtedly there is more to such "repression" experiments than this simple picture would suggest. For example: how will the fact that S is doing what he believes to be an "intelligence" test affect the development of the relevant phase sequences? No clear-cut answer can be given; a possible solution might be that, in those cases where S's "attention" is in a sense divided (i.e., he is equally interested both in the activity in progress and in the more general goal of getting a good score), two different and conflicting phase sequences become active. Under such conditions, the central processes related to any task, completed or interrupted, could not develop so fully; and this general loss in organization would tend (see Figure 4) to better recall of the completed tasks.

This, it may be noted paranthetically, does not indeed sound much like "repression", as conceived by psycho-analysts: and hence the present writer's tendency to agree with Rapaport that the Rosenzweig data do not constitute experimental evidence for the clinical concept of repression.

Finally, the theory suggests that, given two sets of tasks, one highly, the other only partly organized, the situation may well arise in which neither type has, on the average, any advantage in recall. This is presumably the case in the Alper study. Her task material was practically unorganized at the beginning. In the uncompleted tasks, almost all the organization of the phase sequence must be attributed to the subjects' set; in the completed tasks, this factor is operating, but in addition, and overshadowing it, would be the meaningful structure of the final sentence This picture helps account for the fact that while Alper's subjects recalled completed and uncompleted sentences equally well, the small study done by the present writer, using the same sentence material, showed much better recall of "completed" tasks. In that study, it may be remembered, the S's had no particular task to do: their instructions were simply to read over the presented material. The degree of organization would therefore be almost solely a function of relative meaningfulness, and would be effectively zero for the jumbled phrases.

Consequently, where no task has been given, recall of meaningful material will predominate. On the other hand, where task activity is involved, the consequent increase in organization tends to equalize recall.

In summary, the theory here adopted is that:

1) Task activity may be considered as a response, organized in space-time;

2) Corresponding to this response there is a similarly organized central conceptual process, which "leads" the response, and which is capable of self-maintained activity for brief periods;

3) This central process is thought of as a phase sequence -- a series of recurrent actions in previously developed neural structures -- which becomes progressively better organized as the task proceeds;

4) Maintenance of muscular tension after interruption is taken as evidence of self-maintained activity in the phase sequence;

5) Recall of an activity is attributed to re-activation of the corresponding phase sequence: probability of recall is assumed to increase with increasing organization of the

phase sequence, up to the point at which "short-circuiting" can occur and allow the phase sequence to run its course in too abbreviated a form;

6) Such short-circuiting of the better organized process corresponding to completed tasks is invoked to explain the better recall of unfinished activities in such experiments as that of Zeigarnik;

7) The reversals of this relationship -- as found in "repression" experiments -- depend on the operation of factors which decrease the organization of the phase sequences associated either with interrupted or completed tasks, or both.

In its present form this theory can serve as a rough example of the type of "structural picture" to which reference was made in the introductory section. A logical recapitulation of the manner in which the picture was derived may prove of some interest.

First, a set of relatively disconnected relationships between particular experimental situations and particular observed results (recall differences and the like) was described. Following this, a new experiment, with new data (on tensional levels) was presented. And finally, there is available a considerable (if incomplete) body of information on neural structure and function.

Now, from the point of view of the present writer, the role of scientific theorizing is to unify such sets of observed relationships into a broader and more consistent set (a "structural picture"); postulating unobserved relations where necessary, but keeping such unobservables to a minimum.

In the present case, unification is achieved first by assuming that certain defined spatio-temporal relations can hold between neural elements: hence the cell-assembly, phase-sequence, etc. Such a structure is, of course, at present as inaccessible to direct scrutiny as the physicist's neutrino.

In the second stage, certain partially defined relations between experimental situation and phase sequence on the one hand, and between phase sequence and observable responses on the other, were assumed. The resultant structural picture might then be represented as:

```
Experimental------   Phase    ------ Recall
 Situation           Sequence        Differences, etc.
                        |
                        |
                        |
                        |
                        |
                        |
                   Tensional
                  Differences
```

This simple picture admittedly requires further development and clarification; development which should proceed, both experimentally and theoretically, on two levels. On the one, the question of whether, and to what extent those relationships which have here been subsumed under the general term "phase sequence" can and do hold between known cellular structures, is a question clearly falling within the province of the neurophysiologist. To the psychologist, on the other hand, falls the task of determining, more precisely and in greater detail, the nature of the relationships between observed data and postulated neural processes.

BIBLIOGRAPHY.

1. ADLER, D.L. The experimental production of repression. Proc. Eighth Annual Meeting of Topological Psychologists, 1940, 27-36.

2. ALPER, T.G. Memory for completed and incompleted tasks as a function of personality: an analysis of group data. J. abnorm. soc. Psychol., 1946, 41, 403-420.

3. BRENMAN, M. The use of hypnotic techniques in a study of tension systems. In BRENMAN, M. & GILL, M.M., Hypnotherapy. New York: International Univ. Press, 1947.

4. BROWN, J.F. On the dynamic properties of the levels of reality and unreality. Psychol. Forsch., 1933, 18, 2-26. Cf. LEWIN, K. (13).

5. DAVIS, J.F. Integrator-counter for muscle potentials. Unpublished M. Eng. thesis, McGill Univ., 1949.

6. FREEMAN, G.L. Change in tonus during completed and interrupted mental work. J. gen. Psychol., 1930, 4, 309-334.

7. GLIXMAN, A.F. Recall of completed and incompleted activities under varying degrees of stress. J. exper. Psychol., 1949, 39, 281-295.

8. HEBB, D.O. Organization of behavior. New York: Wiley, 1949. (Cf. pp. xvii, xix, 143, 227-230).

9. HULL, C.L. Principles of Behavior. New York: Appleton-Century, 1943.

10. HUMPHREY, G. The nature of learning. London: Kegan Paul, 1933.

11. KOHLER, W. Gestalt Psychology. New York: Liveright, 1947.

12. KORZYBSKI, A. Science and sanity. (2nd Ed.) Lancaster, Pa.: Science Press, 1941.

13. LEWIN, K. A dynamic theory of personality. (trans. by Adams, D.K. & Zener, K.E.) New York: McGraw-Hill, 1935.

14. LISSNER, K. The discharge of needs by substitute activity. Psychol. Forsch., 1933, 18, 218-250. Cf. LEWIN, K. (13)

15. McGEOCH, J.A. The psychology of human learning. New York: Longmans Green, 1942.

16. MAHLER, V. Substitute activities of different degrees of reality. Psychol. Forsch., 1933, 18, 27-89. Cf. LEWIN, K. (13)

17. MALMO, R.B., SHAGASS, C. & DAVIS, J.F. A method for the investigation of somatic response mechanisms in psychoneurosis. Science (in press).

18. MALMO, R.B., SHAGASS, C. & DAVIS, J.F. Electromyographic studies of muscular tension in psychiatric patients under stress. (to be published).

19. MINKOWSKI, H. Space and time. In LORENTZ, H.A., EINSTEIN, A. & MINKOWSKI, H. _The principle of relativity_. London: Methuen, 1923.

20. NOWLIS, H.H. The influence of success and failure on the resumption of an interrupted task. _J. exper. Psychol._, 1941, _28_, 304-325.

21. OVSIANKINA, M. The resumption of interrupted activities. _Psychol. Forsch_., 1928, _11_, 302-379. Cf. LEWIN, K. (13).

22. PACHAURI, A.R. A study of gestalt problems in completed and interrupted tasks. _Brit. J. Psychol_., 1935, _25_, 447-457.

23. POSTMAN, L. & SOLOMON, R.L. Perceptual sensitivity to completed and incompleted tasks. _J. Personal_., 1950, _18_, 347-357.

24. RAPAPORT, D. _Emotions and memory._ Baltimore: Williams and Wilkins, 1942.

25. ROSENZWEIG, S. An experimental study of "repression", with special reference to Need-persistive and Ego-defensive reactions to frustration. _J. exper. Psychol_., 1943, _32_, 64-74.

26. WECHSLER, D. & HARTOGS, H. The clinical measurement of anxiety. *Psychiat. Quart.*, 1945, *19*, 618-635.

27. ZEIGARNIK, B. Das Behalten erledigter und unerledigter Handlungen. *Psychol. Forsch.*, 1927, *9*, 1-85.