JYVÄSKYLÄ STUDIES IN EDUCATION, PSYCHOLOGY AND SOCIAL RESEARCH 12

Studies in brain pathology and human performance

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ON THE RELATIONSHIP BETWEEN SEVERITY OF BRAIN INJURY AND THE LEVEL AND STRUCTURE OF INTELLECTUAL PERFORMANCE

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Preface

The present monograph reports a part of a more comprehensive project concerned with the ability structure of brain injured patients. The study was carried out at the Institute of Occupational Health (Head: Professor Leo Noro) and financed by grants Nos. M-3595 and MH-6054 awarded by the National Institutes of Health, Public Health Service, U.S.A. This monograph amounts to a final report on the work done under grant No. M-3595. The next volume will deal separately with the problem of localization of brain injuries and the interrelation between location of injury and performance.

It goes without saying that no kind of comprehensive, fundamental research is possible without an adequate institution, equipment and trained research staff. The present writer is particularly glad to acknowledge the generous and favourable attitude assumed by the Institute of Occupational Health even toward the investigation of such problems involved in the project — which is still to be continued — as cannot be immediately assessed from the standpoint of their practical utility.

During the early planning phase the present writer had an opportunity to discuss the problems of the study with Professor Niilo Mäki. The exchange of opinions on the starting points and objects of the diagnostics of brain injuries proved extremely useful from the point of view of the present investigation. I am also grateful to him for the critical remarks he advanced concerning the methodology of testing.

At the Institute of Occupational Health many of my colleagues have given me valuable help in the course of the study. The numerous discussions during the planning stage of the study with Dr. Jyrki Juurmaa, Dr. Toivo Pihkanen and Mr. Aarne Sipponen on the theoretical problems involved were highly valuable. The practical execution of the study would have been far more difficult without the alert assistance given to me by several of my colleagues. In this context I wish to make particular mention of Mrs. Rauni Myllyniemi, who carried out a major part of the testing during the first phase of the study, and Mrs. Seija Kivistö and Mrs. Kaarina Airikkala, who participated in a

great many ways in the testings and the treatment of the results during the second phase of the investigation. Mr. Kyösti Suonio gave a valuable contribution to the remolding of the material into a shape which faciliated its statistical treatment.

The choice of the neurological variables for the criterion analysis was performed by Dr. Toivo Pihkanen. His contribution to the study has been invaluable, not least because it was thanks to his active interest that the investigation of the series of patients could be carried out in a flexible and time-saving way. Another neurologist who participated in the necessary re-rating was Dr. Pekka Tienari; the discussions with him also gave me useful impulses.

Dr. Touko Markkanen has assisted the present writer in many ways in the statistical analyses of the research results. Particularly his own active search for new methods and their further elaboration has turned to the benefit of the present project too. The contribution of the Electronics Department of the Finnish Cable Company in the statistical treatment, and its flexibility in the introduction of new programmes, in particular, should also be aknowledged in this context.

Cooperation with the Rehabilitation Center of the Brain Injured in Suitia was also valuable for the study. My thanks are due to Mr. Matti Ristiluoma, and Miss Ella Andersén, in particular, for the assistance they advanced for the execution of the study.

The text of this monographs was translated and checked by Mr. Jaakko Railo and Mrs. Seija Kivistö. It is my very agreeable duty to aknowledge the flexibility they also showed toward the changes and corrections which I had to introduce into my manuscript in the course of the study.

The manuscript was read by Professor Tapio Nummenmaa and Professor R. Olavi Viitamäki.

I wish to express my sincerest thanks to all those who have aided me in the execution of the project and in the preparation of this monograph for publication.

Last but not least I wish to express my very best thanks to my wife, who has supported me in a great many different ways during the different phases of this study.

A. The Problems

1. Introduction

The present monograph consist of three parts, the first of which is a description of the problems, the second an account of the empirical investigation, and the third a discussion of the results. The first part describes the practical and theoretical background of the study present an outline of the problems, and gives a review of previous studies. The empirical study consists of two parts, the latter of which may partly be regarded as a cross-validation study of the former, even though it also is intended to supplement the first part. In the empirical part an account is given of the data and of the treatment of the results. The results are discussed in brief. The discussion concentrates on three main themes. The first relates to the analysis the clinical (medical) criterion and to the possibilities of developing the criterion; the second is concerned with single tests as indicators of brain injury and the comparison of the results of the present study with those previously obtained; finally, the conclusions to be drawn on the basis of the results of the factor-analytical study are discussed.

From the standpoint of test psychology, the problems of brain injury research are characterized by practical needs. The basic aim has most frequently been to develop a diagnostic method capable for differentation between patients with different symptoms. The attempts have mainly been directed toward forming a test battery which would discriminate between organics and mental defectives, on one hand, and also between organics and psychiatric cases, on the other. In planning the therapy and preparing a rehabilitation program, for example, it may be essential whether some behavioral disturbance of the patient should be considered functional or organic. On the other hand, differentation between psychoneurotics and organics may also be necessary in practice. The aims have mainly been pursued in two ways, the first of which could be generally characterized as detector (or indicator) approach, and the second as »profile of patternanalytic approach». (Probably the best known representative of the first group are single tests as Bender, Benton, Graham and Kendall, Kahn, Kohs, and perhaps Porteus; of the other group, test series or methods of Babcock, Hunt, and wechsler. Besides we may mention the TAT, Rorschah, and also other projective techniques, which in a way form a group of their own among these methods.) Psychometrically, from the standpoint of factoranalytic structure, there is no essential difference between these two approaches or the methods they make use of. Most of the tests used in the area are performance tests, whether they are used as single indicators or as subtests in a factor test battery. In practice the difference between them would seem to be the fact that several single tests of that kind are relative free from the effects of intelligence or they can be developed into such. Within the latter approach, instead, attempts are directed specifically toward the measurement of particular sub-dimensions of intelligence and the drawing of conclusions on the basis of differences between these subtraits or dimensions. The concepts »hold» and »don't hold» are central in the terminology of this approach. (The test »holds» if it seems to be unaffected by brain injury.) As to practical diagnostic work, it can be asserted that at best these types complement but do not exclude each other. Perhaps it must also be stated that on the basis of many results these single indicators can by no means be considered so free from the effects of intelligence as they have been assumed to be. On the other hand, tests measuring intelligence may also prove sensitive to factors other than intelligence, which is apt to increase their unreliability and inappropriateness for their original purpose. For these particular reasons information about the structure (i.e. structural validity) of the test batteries may be regarded as the most essential (Cronbach and Meehl, 1955). This holds true, above all, to the extent we wish to examine the validity problem of this area as a theoretical problem.

Structural analysis of interindividual differences is also important with regard to the validity of practical diagnostic work. It may reveal to us some structural inconsistencies which otherwise are difficult to discover and which may give rise to confusing discrepancies in our results. As an example illustrating the problem we may present the Memory-for-Desing (MFD) Test developed by Graham and Kendall (1946), a typical single indicator test. It is generally assumed that a poor result on this test is due to poor memory. Think, now, that we strive toward developing this method in practice. Assuming, for instance, that by making the test more difficult we are making the performance on it even more dependent on memory. Conscgvontly if we make the test more difficult, we expect that the brain-injured, who generally perform inferiorly on this test, give an even more inferior performance compared with a control group. However, this may not happen; the result may point to an opposite direction (in terms of standardized values, of course.) — As a basis of this expectancy we may here refer to some preliminary experiments with this test made at the Institute of Occupational Health. In a correlative analysis we observed first that correlation between visual tests and MFD-test were on an average slightly (but not significantly) higher in the brain-injury group than in the control group. The results of a factor analysis revealed, however, a more distinct difference between the groups in that the variance of the MFD-test was apparently more closely related to visual factor in the brain-injury group than in the control group. An attempt was therefore made to eliminate the possible effect of visual factor by matching the two groups in terms of that factor with the result that the difference in mean performance between the brain-injury and control groups became immaterial. — The most appropriate interpretation of the result seems paradoxical: the greater contribution of spatial ability to the variance of MFD-test in the brain-injury group would seem to result from the fact that the test actually is, on an average, somewhat more a test of memory for a brain injured subject (Because the ability to recall visual images is declined on the average.), while to the members of the control group the visual component of the test is so simple that in the process of memorizing there hardly exist any differences as regards perceiving or transposing gestalts.

In practical diagnostic work this paradoxical situation may manifest itself in the fact that the test generally discriminates between brain-injury and control groups. It does so partly because some brain-injured patients perform inferiorly on it due to their poor visual ability, and some because of their poor memory. In other words, because the test in question is one on which satisfactory performance is dependent on at least two factors, statistical differences between deviant and control groups can occur more easily. But undoubtedly the discrepancies among the results of different investigators is partly due to the same reason. Now, of course, it may be pointed out that with regard to practical diagnostic work it would not matter very much whether the unsuccessful performance of the brain-injury group is due to one or two or any factors, if only the statistical difference between the means of the groups would repeatedly occur from one study to another. This may be true, say, in that simple case we had to test a patient of whom we knew before to what diagnostic category he belongs. But if we are asked to determine to what diagnostic category the patient most probably belongs which is, as a matter of facts, the more common problem we are faced with, we plainly ought to know what we are measuring. In my opinion, a long practical (clinical) experience may prevent us from making wrong decisions due to causes of this kind, but it seems to me, further, that in this area psychometric investigation can compensate practical experience to a considerable extent.

Faulty conclusions as to test structure, like the kind mentioned above, are naturally even more fatal when conclusions are to be drawn on the basis of simultaneous comparison of several test results. Particularly this kind of comparison has from the very beginning been central in the problem area of the test-psychological brain-injury research. The use of the concepts of »hold» and »don't hold» is naturally based partly on the assumption that we know the meaning of the concepts, that we know what holds and what does not hold. Considering how much these concepts have already been used and how many different indices can be calculated in their connection, it is surprising to observe, how little attention has been paid to the information we have on the structure (in terms of individual differences) of the comparable subdimensios of these subtests. With a few exeptions (of these, Cohen, 1952 must be mentioned) this essential matter has largely been overlooked. To illustrate the matter with an example, we could think, of some index based on a comparison between a memory-reproduction test and, say, a test of visual ability. Then our differential diagnostics are in a way based on the fact that either there exists a difference between these contributing factors or there does not. As far as any differences are discovered between contributing factors of this kind within one individual under normal conditions, they are assumed to result from the different degrees to which these factors manifest themselves in this person. From this point of view I would consider most essential to obtain information about the underlying factors upon which performance on these subtests depends. Someone may again point out how some subtest pattern analyses of this kind can be justified as diagnostic methods and be valid in spite of the fact that we hardly know anything about the underlying factors the tests are based on. The accuracy of the method, however, is always only probable; Thus if we do not know about various sources of error or factors which may contribute to the differences or similarities present — in this case, for instance, sex could be one — we cannot get a very valid result in the individual case. — Sex differences particularly may emerge dominantly on some spatial tests of that kind. (For example, because women's performances are slightly, though significantly, poorer than those of men, their scatter on spatial-ability tests may prove smaller because some other factor whose contribution to the test variance is considerable has much more significant effect.) Then, on the other hand, the individual degree of difficulty of the test may also lead to faulty conclusions — particularly because we know nothing about the premorbid or pretraumatic level. — According to may personal opinion, the profile method or patternanalytic method or whatever it may be called, may prove to be one of the most profitable tool in the future. Its advantage lies, above all, in the fact that an individual's performance is compared with his own performance; it is as if he were his own control. For that reason I consider of great importance such fundamental work which, on one hand, enables us to discover various factors possibly leading to differences of test structure with different groups of individuals; and, on the other hand, to carry out variations and modifications of tests so that still greater parts of variances of tests in different groups may be explained by referring to the same factors in those groups. If there is reason to assume that performance on a certain tests depends on different factors in different clinical groups, it is questionable whether this kind of comparison, or any kind of profile method where those tests are contributing factors, is valid from a scientific standpoint. As a matter of fact, the problem in question therefore is the same central one, *modus operandi,* to which already Goldstein in this time paid much attention from a general point of view.

In the field of factor-analytic research, especially as far as the study of vocational fitness was concerned, the emphasis previously placed on the significance of the factorial purity, or unidimensionality has been sharply criticized among others by Super, who has endeavored to demonstrate that the validities obtained with unidimensional tests are lower than those arrived at by employing multidimensional tests (Super, 1960). Therefore, there is reason to emphasize in this connection that the foregoing requirement that the variances of the tests within different groups should be accountable through reference to identical factors is not the same as the requirement of unidimensionality. What is desired is that the factorial structure of the tests, even where more than two dimensions are involved, should be approximately similar in different groups. In point of fact, without such structural analysis it is impossible for us to know whether the subtests which may now differ from one other to some extent ought to differ even more (compared with other subtest-differences appearing in our profiles); and, on the other hand, whether the tests which do not differ from one another in our profiles now, behave in this way simply because they are measures of same factors and not, as we assume, of different factors. Further, it is quite obvious that this kind of knowledge of the structure tends to increase the probability of hits in individual clinical cases. This kind of analysis of factorial structures forms, within the field of clinical psychometrics, part of the laying of foundations that is only at its initial stage at present. The purpose of the present study is to contribute toward the exploration of one of the central problems in that field, i.e., the extent to which factor-analytical tests obtain loadings on identical factors in different groups, namely in brain injury and control groups. A more detailed account of the set of problems at hand is given in the following section.

2. The Problems of the Study.

As stated in the introduction, the problems of the study may be divided into two groups:

— Problems related to the identity of the factorial structure of the test battery;
— Problems related to the medical criterion of brain injury.

The basic assumption is that the variance of the tests is not dependent on the identical factors in different groups. And, on the other hand, it is assumed here that the traits characterizing brain injury, such as severity, duration, etc., can be considered separately and independently from one another. Consequently, the study is correlative in nature, a study in which certain test variables are compared with an outside criterion, brain injury. Nevertheless, main attention will not be focused on the validity problems (the ability of the tests to predict the criterion), but, instead, on the inter-individual differences occuring within the groups in regard to both criterion and test behavior.

The main group of problems is formed by the questions concerning the identity of the factors. The problem may be formulated as follows: *To what extent can the interindividual differences within the brain injury group,* on one hand, *and within the control group,* on the other, *be accounted for in terms of identical factors?* Or, in other words, *to what extent do the brain injured perform the tasks of the test situation by means of the same factors as the individuals in the control group?* This set of problems also involves the question of the number of factors in these groups, i.e., the degree of differentiation, and, on the other hand, the question of the extent to which the factors themselves are identifiable.

To investigate these problems, use is made of a test battery consisting of so-called factor tests, whose factorial structure in normal groups is known and whose reliability has also proved sufficient. The study is chiefly concerned with the following dimensions: verbal comprehension, verbal fluency, numerical ability or mathematical reasoning, visual ability, aiming psychomotor speed, and perceptual speed. The battery includes, in addition, a number of special tests mainly related to perceptual speed (maze, color naming), as well as other single tests which in previous studies have proved to be indicators of brain injury (MFD and SAET).

Investigation of this set of problems presupposes that detailed attention be also accorded to the realiability and relevance of the criterion *dimension on the basis of the neurological measurements available.* Here, *instead of an effort* being made *to take into account all the circumstances possibly bearing on the clinical condition, the study is restricted to a single dimension in respect to which interindividual differences within the brain injury group are assumed to occur. This* dimension *is the degree of severity of brain injury,* and *it will,* in a sense, *represent brain-injurdness in the present study.* Accordingly, *it is assumed that all the other factors are distributed randomly among the subjects — an assumption to be checked in later studies.* (Vol. II.)

The study is of an orientating nature; Attempt will be made to apply different methods of analysis to the criterion dimension and to the test dimensions. Severity was chosen as the first criterion dimension of brain injury because of its general significance, and also because the available neurological variables were generally dichotomous, indicating merely the presence of the symptom. It was assumed that a sufficiently reliable and relevant dimension could be formed out of these subvariables simply by adding the raw scores together. Among possible traits characterizing brain injury there are scarcely any other — with the exception of duration and, perhaps, the age at onset of injury — which can be quantified as simply as severity. It goes without saying that the assumption of accumulation, on one hand, and the assumption of the random distribution of the other factors related to this abnormal condition, on the other hand, simplify the situation.

But, according to the opinion of the present writer, to be able for example to describe the possible qualitative differences between different brain injury groups we are in need of a relevant reference system on which our description can be based. What we need first, then, is to map out a restricted number of reference axis, dimensions (neurological, socio-medical or whatsoever), which can be accounted for in order to explain the existing variance within the experimental and control groups. It should be taken into account, however, that despite the fact that we start with the development of a severity dimension (for the reasons mentioned above) under the assumption of a random distribution of other possibly relevant dimensions, we are, as a matter of facts full aware of the complexity of the problem. The reasons for, that this part of our study will be published separately, are technical. Analysis of other dimensions of brain injury has been continued by trials of developing a location and duration dimension. The results obtained are, however, being published in the second volume of this report (see Airikkala, 1964).

3. Previous Studies Related to the Problems.

An increasing amount of research concerning brain injuries has been done in recent years not only because of the theoretically interesting nature of the topic but also because of an increasing practical need for adequate methods of investigation. Besides the two world wars, traffic accidents in particular, and also the more recent methods of psychiatric treatment, brain surgery, and so on, have contributed to the interest felt toward this field. On the other hand, the heterogeneity of these extensive sectors has resulted, as it was already mentioned, in a considerable lack of uniformity in the field. Practical needs have also tended to determine the theoretical starting points and objects. For example, the psychological study of the brain injured is largely colored by the fact that after the first World War, investigators suddenly had to examine daily a large number of persons with focal injuries. It is possible that the greater probability of patients with focal injuries to survive has considerably influenced the theory formation of the area. It must be noted, in any case, that the literature within the field is so extensive that any survey easily becomes superficial. Being aware of this. the writer intends to limit the following observations to a relatively narrow sector, and deal only with three aspects. On one hand, an attempt will be made to consider the problems pertaining to the psychological study of the brain injured as a general criterion problem, and, on the other hand, attention will be called to studies where methods similar to those used here as single indicators of brain injury have been employed; moreover, a brief sketch will be presented to describe some (recent) factor- and pattern- analytical studies and comparative analyses of the ability structure of the brain injured and its changes.

a. Criterion of Brain Injury.

An increasing amount of attention is being paid to various classifications characterizing brain injury. No very extensive systematic analysis of different traits has been carried out yet, even though many investigators, e.g. Reitan, Morrow and Mark (Reitan, 1962; Morrow and Mark, 1955), have given consideration to many factors which should be taken into account in forming these criterion dimensions and in outlining grounds for selection procedures (extent, location, level (cortical vs. subcortical), dominant vs. nondominant hemisphere, etc. Moreover, type of condition — injury vs. disease, duration, etiopathogenesis, etc.) The difficulty of mastering and controlling such a number of simultaneously operative factors has induced many investigators to prefer experimental design in which homogenity of experimental group forms an essential characteristic. In this design two principles are important. First, that regarding the critical characteristic a distinct (maximal) difference should exist between experimental and control groups, and second, that differences within the groups as regards the other traits possibly connected whith the deviancy (trauma or lesion) are minimal. Application of this type of design has lead investigators to prefer lesions and surgically operated cases which permit a relatively exact determination of — at least — the material severity of the deviancy. Thus, such an »experimental» injury as lobotomy has also been subject to a great deal of interest. A good example of these investigations is provided by Halstead's exceedingly well defined and clear-cut study (Halstead, 1947). Wolff, for example, recommends (according to Reitan, 1962) the following kinds of criteria: (a) accurate appraisal of the anatomic defect, (b) knowledge that other sites in the brain are not missing or, if they are, appraisal of them that matches in accuracy that of the initial lesion, (c) knowledge of possible vascular and related disorders that might be confounding with respect to interpretation of the effects of the initial lesion, (d) knowledge of mass remowed, within the limits of accuracy of acceptable avainable techniques, (e) the hemisphere not involved must be free not only of structural damage but also of dysfunction, including seizure disorder, (f) one function cannot be singled out for study unless the investigator has knowledge of the intactness of all other functions (such as sensory and motor functions, speech and language, adequacy of interpersonal relations, etc.) which may be related to the function in question, (g) the measurements and findings must be assessed with relation to each subject's background so as to assess the unique personality configuration that forms their context, and (h) knowledge must be available of the individual patient's environment following brain damage, including the full range and requirements of the adjustmental demands placed upon the patient.

In describing these criteria suggested by Wolff, Reitan points out that in practice it is extremely difficult to meet them all simultaneously, although this need by no means signify that we should give up investigation. »Scientific knowledge accrues through a series of approximations, and the balancing and corrective influences that operate in the scientific community.» Reitan further points out that no one has fully succeeded in applying Wolff's criteria, although Chapman and Wolff (Chapman & Wolff, 1959) have endeavored to do so. He further points out that such a set of independent variables may be difficult to identify validly. On the other hand, in practice the number of ambiguous and diffuse cases is undoubtedly greatest within the group of patients which the psychologist is, for example, expected to differentiate into organics and nonorganics. At least at Finnish clinics this is often the main need. Therefore it would be desireable that information on the validity of tests in distinguishing or indicating some possibly general characteristic, i.e. subdimension of brain injury would be available. Here an opposite experimental design may prove profitable. The diffuse group is taken as such, and attempts are made to construct on the basis of variance within the deviant group unambigous dimensions of injury one at a time. As stated already, is it necessary to assume then that the other contributing factors are distributed at random; but, on the other hand, by comparing the dimensions obtained in this way with one another and with certain outside criteria it gradually becomes possible to gain knowledge about their content and relevance (validity). An excellent starting point for such an approach is furnished by the analytical technique applied by Rao — the so-called discriminance analysis (Rao, 1952).

These two approaches do not appear to be mutually exclusive. What kind of advantage may then be expected from the use of the latter? The advantage probably lies in the opportunity of rendering the dimensions unambiguous and reliable, upon which they can be compared with one another in a relatively constant, unchanged form. This is important primarily because it may be possible that the relevant dimensions underlying or characterizing brain damage do not all correlate linearly in the same way in different groups representing damage of different types, different durations, and different degrees of severity; as Reitan (op.cit.), for example, points out, depending on the psychological constellation, the effect of an organic lesion may be different in different cases, even when the degree of severity is the same. Consequently, these two techniques to obtain criteria for validation of psychological tests, for example at best complement each other.

It would be ideal, of course, if the groups under investigation could always be generally described in terms of a restricted number of actually relevant dimensions, which could be used as a reference axis regarding the existing interindividual differences within the deviant group. By the aid of Rao's method, the dimensions can, according to the present writers' opinion, be described in detail in terms of the relative weights of the component variables (anamnestic and neurological items) included in the series (for particulars, see the discriminance analysis performed in connection with the empirical study, p. 37).

Because no very systematic analysis of the various factors characterizing brain damage has been carried out for the time being, there is little guidance as to the kinds of neurological components that could be included in such a criterion dimension. There undoubtedly occurs a great deal of heterogeneity in practice too; it may be difficult to attain agreement on the basic variables that should be employed. It is true that some neurological methods have been paid more attention than others because of their greater objectivity, but the results of EEG studies, for example, have by no means been entirely free from contradictions.

b. Psychological Tests as Indicators of Brain Injury.

After much diversity in the beginning, certain types of tests are now clearly becoming dominant and favored in this field. The preferred types of tests may be divided roughly into four groups — eye-hand-coordination tests, various memory tests, perceptual tests, and conceptual tests. A wholly separate group is formed by various tests variables which have not originally been developed for the purpose, but have been discovered, through some incidental observation, to possess some degree of validity in regard to brain injuries, and have thereafter been employed as such. A typical example of the foregoing variables is provided by the one based on an observation by Shapiro in 1951, a variable consisting of the rotations observed on Koh's Cube Test or on other similar tests (Shapiro, 1951, 1952, 1953). Typical examples of the four principal test categories, respectively, are Bender's Visual Motor Gestalt Test (BGT), Graham and Kendall's Memory-for-Desings Test (MFD), the Spiral Aftereffect Test (SAET), and, perhaps, Kahn's Symbol Arrangement Test (SAT).

There exists relatively great amount of literature on all the tests mentioned. The reader may be referred to Corman and Blumberg's study (1963), for example, where results obtained with the MFD, SAET, TMT, and BGT, among others, are reported. The results yielded by many of these tests are partly contradictory. Information about the criteria is given in very few studies. In most cases, a neurologist's or psychiatrist's subjective assessment or diagnostic classification into organics and nonorganics has served as a criterion. Quite a typical course of events is that a test is published after the obtainment of positive, possibly chance, results upon which other investigators attempt to apply the test some time later, with negative results only too often. Garret, Price and Deabler (1957) may be mentioned as an example. They obtained positive results with the SAET (and with the MFD test as well). Some time later, Gilberstadt, Schein and Rosen (1958) reached negative conclusions, and they regard the diagnostic usefulness of the test as very limited. Page already came to a similar conclusion (Page et al., 1957) in 1957. In contrast, a positive opinion of the SEAT is presented in the foregoing article of Korman & Blumberg (1963), although the authors state that the best test among those discussed is the MFD. As to the usefulness of the Bender Gestalt Test, Goldberg (1959) regards it as rather doubtful. Griffith and Taylor (1960, 1961), who experimented with this test later, stated that the rotations have been »shown to depend at least partly upon stimulus properties». Furthermore, Hannah (1958), has demonstrated the dependence of the errors upon the position of the stimulus. Mehlman and Vatovec (1956) advanced the view that the validity of the BGT in the differential diagnosis of organic cases is relatively poor. — In contrast, Aaronson (1958), for example, has demonstrated that the SAET results are dependent on intelligence; but he states, on the other hand, that this test is perhaps most sensitive to temporal-lobe left-hemisphere involvement. Aaronson was also the first to call attention to a distinction which may appear particularly with the brain- injured; the phenomenal perception of the aftereffect of movement as such may be missing (absent) in some cases, whereas others may only be unable to give an expression for (report) their impression. Goldberg and Smith (1958) have found the spiral score to correlate with age to the extent of -.39, and they warn investigators against an indiscriminate use of the test. A number of modifications of these tests have been published, and their scoring systems developed in various ways. Armstrong (1952), for example, has elaborated Graham and Kendall's MFD test (also the present writer has somewhat modified the original MFD test for his purposes; for details, see the empirical part of the study). As far as elaborations of the SAET are concerned, Scott, Bragg and Smarr (1963) and Sindberg (1961) should be mentioned first. Hannah (1958) and Mehlman and Vatovec, in turn have published studies with a somewhat modified forms of Bender Gestalt test. A test developed by Yacorzynski (1950) may be mentioned as an example of concept-formation tests; the idea underlying this variant is fairly applicable, and the test has yielded positive results also afterwards (see Altrocchi and Rosenberg, 1958). Further cross-validation studies are necessary, however, to confirm the results of these studies.

Further, the Symbol Gestalt test published by Stein (1961) and later investigated by Parsons, Maslow and Steward (1963) is worth mentioning here. These investigators found the test applicable, although the proportion of false positives was high as 31 %. They suggested therefore that the test be standardized anew.

Among the tests not belonging to the groups mentioned above, reference should be made to the Trail Making Test, with which Reitan, among others, has obtained positive validity results. Furthermore, a Tactual Form-Perception (stereognosis) test (see Benton and Schultz, 1949) and the Five-Task-test, FTT (see Buhler and Mandeville, 1956) have been used as means of differentiation. The MMG (metamegetho-graph) test, an interesting modification of the SAET developed by Scott, Bragg and Smarr, should also be mentioned. In this test, an attempt has been made to eliminate the influence of the patient's verbal level (1963). Cross-validation studies with negative results have, however, been reported (Sloan and Bensberg, 1951).

Consequently, the field is characterized by a considerable diversity of methods and inconsistency of results. The greatest deficiency is the absence of criterion data in reporting the results. Too often no information is given about the actual criterion of brain injury. Further, it should be mentioned that even though some single indicator tests are based upon a theory of some kind most of the results obtained depend on comparatively incidental observations; effors to make similar observations with other group have often ended negatively.

c. Pattern-or Profile-Analytical Methods.

A constantly expanding sector of its own field of brain injury research is formed by profile- and pattern-analytical methods. A multitude of techniques have already been develop. It appears that the objectives and starting points of different investigators may differ greatly from one another. In his survey, Jastak (1949) divides the investigators into two groups in terms of their points of departure. In one group, the starting point is the assumption that mental disorders are reflected *indirectly* in the differrences between subtraits of the ability structure. The assumption underlying the work of the other group is implicitly more narrow, in the sense that *intraindividual differences* in the test results *as such* are assumed to be symptomatic »without the medium of intellect». However, the difference between the two approaches is not, perhaps, so great as Jastak is inclined to think. Jastak, who counts himself among the supporters of the latter approach, prefers it since it »assumes less and explains more». The first part of his assertion is undoubtedly correct but in regard to the latter part, it may be pointed out that the approach may lead to excessively general and, consequently, irrelevant »explanations». In my opinion, however, the difference between the two approaches is merely apparent, from a theoretical point of view, so it does not merit a more detailed discussion in this connection. As I see it, all the investigators have basically had a common starting point; they strive toward a more valid, extensive mode of description based upon unambiguous subtotalities whose reliability as interindividually differentiating dimensions can be established. Only by means of systematic validity investigation is it possible to find out satisfactorily to what extent an approach involves consciously or unconsciously introduced assumptions that are not tenable.

In my view, the pattern-analytic approach provides a very useful methodological starting point for systematizing psychological diagnostics which can bring it on a more objective and reliable basis. I would even be inclined to maintain that at this stage a direct, systematic mapping-out of characterological dimensions is possible only by applying some method that relates in one way or another to the measurement of intraindividual variance (i.e., a pattern-analytic method). If certain intraindividual differences on performence level between subdimensions which can be reliably measured interindividually are chosen as the objects of measurement, we can arrive at sufficiently general traits that not only possess descriptive value (clinically) but also inter-individual relevance which renders possible their quantitative analysis. — The method seems to have been welcomed with enthusiasm and put to quite an extensive use by clinical psychologists. This may chiefly be due to the fact that it provides, or at least appears to provide, a more precise basis than a mere »holistic» impression for diagnosis, without implying the application of narrowly psychometric principles. However, Jastak emphasizes — quite correctly — the significance of working out theoretical questions in regard to the development of multidimensional diagnostic methods of this kind. If such questions are not solved adequately, there is a possibility that the contradictory nature of the empirical results and a negative attitude toward the hypotheses underlying them gradually leads to a diffuse rejection of the entire method in a way which is psychologically analogous to the diffuse manner in which the method now seems to be accepted despite the recurrent negative results it yields.

Actually Wells (1927) was the first who applied this method in practice, followed among others, by Babcock (1930). Perhaps the best known pattern-analytic methods developed so far are the following: the Mental Deterioration Index (MDI), sometimes referred to as the

Deterioration Quotient, which is based on Wechsler & Bellevue's test. From this index there has been developed the so-called Senescent Decline Formula or SDF (Cople, 1948), which is also based on the same test. The index derived from the Babcock-Levy test is called the Efficiency Index (EI). A further example is provided by the Hewson Ratios. Many of these indices are based upon the differences between two or more subtests, typically on the difference between a verbal and performance test scores like those of the Wechsler-Bellevue scale; there are also techniques in which the highest and the mean performances are compared with each other, and so forth.

Further, a number of studies with the purpose of improving these techniques may be referred to at this point; an example is provided by Birren's (1952) investigation. Especially detailed is Cronbach's analysis (1950, see Jastak, op.cit., 1953). DuMas (1952) and Allen (1948) should be mentioned in this connection; Allen has elaborated Wechsler's method, though his results are not particularly convincing. Also Haggard (1958) deserves mention at this point because of his specific efforts to develop the mathematical basis of this type of approach.

The results yielded by this method have not, however, been as positive as many investigators favoring this approach have perhaps hoped. For example, it is noteworthy that Botwinick and Birren (1951) could find scarcely any correlations between the different indices, or the correlations present were low. They state, in fact, that much attention should be paid to the reliability of the subtests concerned and perhaps also to the excessive difficulty of the tests. On the other hand, the usefulness of this kind of approach on low levels of intelligence has been criticized by Peixotto (1950), among others; Juckem and Wold (1948), have reached a similar conclusion as to intellectually superior individuals, and they regard the Hunt-Minnesota Test as comparatively useless with persons of high intellectual level (intellectually gifted persons). Magaret and Wright (1943), among others, have come to quite negative conclusions concerning the feasibility of pattern-analytic methods of this kind in general. Furthermore, Wheeler and Wilkins (1951) state that indices of the kind under consideration very often diagnose many normal persons as brain injured. On the other hand, Hunt (1949) has discovered that these indices vary in quite a considerable degree as a function of age. And, further, Gibby (1949) was able to demonstrate that with many individuals scatter patterns between the first and second form of the Wechsler test differ greatly from one other. Quite negative conclusions have also been reached by Corsini and Fasset (1952), who have expressed a desire that the serious clinical use of Wechsler's Mental Deterioration Index should be discontinued. Their attitude toward the method itself is positive, however, and they state that there may exist other, more useful indices, the Verbal-Performance Ratio (WPR), for example.

All in all, one cannot help getting the impression that in developing indices of deterioration and impairment use has been made of fortunate incidents; the methods have been developed in the direction of better discrimination between the brain injured and non-brain-injured in the particular sample under consideration. As a consequency, the investigators have only too often arrived at results which cross-validation study has not been able to confirm. This kind of procedure may well contribute toward a gradual weakening of favorable opinions on the usefulness of the method. A negative result of an entirely conclusive kind, however, is the one reported by Cohen (1952). On the basis of a factor analysis he made he was able to demonstrate that the subtests of the Wechsler or WAIS can be explained in terms of different factors in different clinical groups in other words, persons belonging to different clinical groups solve these IQ subtasks by the »aid» of somewhat different abilities. — Finally, an article of Gerstein (1949) should be mentioned in this connection; he considers, among other things, the possibility that Vocabulary, which is generally regarded as a »hold» variable, is only seemingly stable — but it is possible that the manner of definition itself has changed, although such changes cannot be registered very accurately. In coming across results like these we need not think, however, that diagnostic methods of the kind now under considération should be given up. On the contrary, we must consider the possibilities offered by this kind of analysis for developing these various subtests so as to make them better measures of the same factors in different clinical groups, and thus have them fulfill their purpose in that complex series. One of the advantages of psychological tests is their sensitivity, which may make them downright irreplaceable in some situations as sufficiently early indicators of certain alterations in the brain. The certain lack of reliability acompanying this sensitivity can, as I see it, be compensated at least in part by striving toward more complex methods of this kind in which the component factors, however, are sufficiently unambiguous and reliable. In this way we may arrive at methods which are »complex enough to be adequate and simple enough to be manageable» (to cite Gronbach, 1950). We shall return to a brief consideration of these problems in the Discussion section of this monograph.

B. Empirical Study

For practical reasons, the empirical study was divided into two parts, to be referred to as Part I and Part II in the following. Part II was carried out after Part I, and partly its purpose is to be a certain kind of cross-validation study for checking some of the results obtained in Part I. At the same time, however, it is meant as a further elaboration of the ideas underlying Part I; for example, some additional test variables were included for checking certain hypotheses. Hence, the results are finally considered as an intergral whole in the Discussion chapter. As to the methods and subjects, for example, no difference of principle exists between the two parts; on the other hand, there are some practical differences. For example, the results of Part II were treated exclusively by employing an electronic computer, a fact which contributed in some degree to the choice of the variables. However, this factor has not had any essential influence on the design of the experiment. Moreover, on the basis of the results of Part I, the scoring systems of some tests were altered, and some new tests (or tests formerly administered only to part of the subjects) were added to the test battery. In this sense Part II serves in a way to supplement certain ideas put forward in Part I. The specific problems dealt with in Part II have partly been modified from the problems presented in the foregoing on the basis of the results arrived at in Part I.

1. Methods

a. Tests and Variables.

Psychological Tests.

This is a tests-psychological study which can be characterized from a methodological point of view primarily as a correlative and factor-analytical study. Criterion variables are analyzed by the discriminance-analytical method in order to obtain a severity scale of brain injury. Further, a comparison of the mean performances of two groups of brain injured subjects and a control group are made to test the significance of the differences observed in the test results. In the following, a brief account is given of the tests used.

In the selection of tests, attention was paid to their hypothetical factor structure, on one hand, and to their capacity to discriminate between the brain-injured and the controls, on the other.

1. Completion of Squares. On the left side of test sheet there is one white figure upon a black background and on the right four smaller figures. The S is required to reason which one of the four figures must be combined with the larger figure on the left to make the latter a complete square. 40 items. Time limit, 5 min. Variable: number of correct items.

2. Pieces. On the test paper there are drawn figures of differing shapes, each of which originally consists of two different kinds of »pieces». From a total of five »pieces» available for choice, the S has to indicate the two of which the figure is composed. Time limit, 6 min. 25 items. Variable: total number of pieces chosen correctly.

3. Word Group. On the paper there are 48 rows, each consisting of a group of five words. The S is requested to indicate in each row the word which does not belong to the same group as the four other words. The grouping has to be done on the basis of the meaning of the words. Time limit, 8 min. 48 items. Variable: number of correct items.

4. Synonyms. The subject has to select from among five words the one with the same meaning as the given stimulus word. Time limit, 5 min. 50 items. Variable: number of correct items.

5. Opposites. The subject has to select from five words the one which is just the opposite of the given stimulus word. Time limit, 5 min. 50 items. Variable: number of correct items.

6. Arithmetic Problems. The test consists of alternate rows of addition and subtraction problems with 10 items in each row. The figures to be added contain two or three digits, and those to be subtracted, two digits. Time limit, 5 min. 100 items. Variable: number of correct items.

7. Completion of Arithmetic Problems. The items are simple problems involving addition, subtraction, multiplication, or division. In each problem, one or more digits have been omitted. On the basis of the other digits involved, the S has to fill in the empty spaces correctly. Time limit, 6 min. Variable: number of digits filled in correctly.

8. Information. A test of general knowledge and orientation, presented in multiple-choice form, with three alternatives in each item. 60 items. No time limit. Variable: number of correct answers.

9. Memory-for-Design Test. This is a modification of the Graham-Kendall Memory-for-Desings Test. (Graham & Kendall, 1946.) The modification is based on a pilot study in which it was found that some of the brain-injured Ss tested made a number of errors of a peculiar type. They might have recalled the figure otherwise correctly but one part of it (or sometimes the whole figure) contrariwise, reverse in respect to the original. Therefore, some of the figures in the original test were replaced in order to obtain sufficient variance in this trait. It was hypothesized that if a figure seems to look more »concrete» in a reversed form, the brain-injured Ss should reverse it more often than the control Ss. The exposure time of each test figure was 5 seconds. 15 items. Variables: Number of reversals (two points for a whole figure, one point for a detail), and number of errors (including extra details not appearing in the stimulus, and forgotten details. In Part II a different scoring system was adopted. A division of the original items or test figures into specific parts served as the basis for scoring. Reversals, errors, and omissions were scored per each part, not per whole test figure, so the number of »items» actually rose to 32. Variables: number of reversals, number of errors, and number of omissions.

10. Silhouette. The task of the S is to draw below the horizontal line a figure that is symmetric with the given silhouette contour line. No time limit. Variable: number of reversals (i.e., one point for each turning point of the contour line at which the S draws a line paralled with rather than opposite to, the direction of the line in the model pattern).

11. Symmetric Drawing. Analogous to the above test, but vertical. The model pattern resembles the half of an oak leaf. No time limit. Variable: number of reversals (counted like in Silhouette).

12. Mazes 1 and 2. Two paper-and-pencil labyrinths. The most notable difference between the versions is in their degree of difficulty. Maze 1 is comparatively simple, while Maze 2 is more complicated. Variables: Performance time in 10 seconds.

13. Color Naming (Stroops Test). The test consists of three parts. 1. The S is required to read above as quickly as possible 12 rows with

7 names of colors on each, all typed on a white cardboard background. 2. The S is asked to call off as quickly as possible the names of the colored dots painted in rows on a white background; the main colors, besides black and brown, have been made use of. 3. The S is asked to name as fast as possible the colors in which the same color names as in Part I have been printed — not to read the names themselves. The task is found difficult since Ss are inclined to read the text instead of naming the colors of text. Variables: 1. Time taken to read black text; 2. Performance time in naming the color of dots; 3. Blue-green confusion in color naming; 4. Time taken to read colored text; 5. Number of errors in reading colored text; 6. Difference between the time taken to read colored text and the time taken to read black text.

14. Spiral Aftereffect Test. The apparatus was essentially similar to that described by Price and Deabler (Price & Deabler, 1955). The disc was driven by a noiseless DC motor at the speed of 90 r.p.m. The test situation and the instructions used were similar to those described by Price and Deabler. The spiral was first driven to the right for 30 seconds after which the S had to report his perception. The same was repeated to the left. The aftereffect perception of the S was scored as follows: The S was requested to indicate the moment at which the perception of the aftereffect stopped (or the movement came to a standstill). If the aftereffect lasted less than four seconds, a score of 0 was given; 1 point was scored for 5—9 seconds, and 2 points for 10 seconds or longer. In the second part (In Part II) of the study, the duration of the stimulus was 20 seconds and 0 was scored for 0—4 seconds, 1 points for 5—10 seconds, and 2 points for 11 seconds or more.

15. Dot Aiming. The S has to put dots in the squares of a checked paper, placing one dot in each square. The S proceeds row by row, from left to right as fast as possible. Time limit, 50 seconds (in the second part, 30 seconds). Variable: total number of dots placed.

16. Triangles. In the test paper there are printed small triangles, connected with a line. The S has to proceed quickly along the line in the specified direction and place a dot in each triangle. Time limit, 50 seconds (in the seconds part, 60 seconds). Variable: Total number of triangles marked (dotted).

17. Finger Tapping. The apparatus employed is a cylinder, 25 mm. in diameter and 100 mm. in height. On the top there is a button which,

the S, while holding the cylinder in his hand, has to press with his thumb at the highest possible rate. Tapping speed is recorded for 10 seconds, twice for the right and twice for the left hand. Variable: total number of tapping.

18. Hand Tapping. The same apparatus is used as in the finger-tapping test. The S holds the cylinder on the table, and the tapping is performed twice with the left and twice the right palm of the hand, each time for 10 seconds. Variable: total number of tappings.

In the course of the study, the test battery was augmented with tests measuring verbal and numerical memory. Because these tests were administered only to part of the subjects, the results will be published later. Likewise, an apparatus for measuring the perception of phenomenal color afterimages has been devised. A color projector for producing monochromatic color has been constructed. It was assumed that in the perception of the color afterimage, wich is at least partly a central process, there would be differences between brain-injured and control subjects. The results of this experiment have been published elsewhere.

As the reader may have noticed the battery is composed of commonly used tests. Further, almost every hypothetical factor is represented by two parallel tests and the tests of unknown factor-structure are usually composed of (at least) two parts. We have, therefore, considered permissible to be content with the correlations between those parallel variables as approximations of reliabilities of the tests. The mean correlation of the (parallel) ability tests is about 0,63 in the control group and about 0,60 and 0,70 in the first and second brain injury groups respectively. No considerable differences seem to exist either between the respective correlations in different groups. Among the correlations there is only one unsatisfactorily low (between variables pertaining to bilateral asymmetry of hands), but in general the reliabilities of the tests can be estimated to be satisfactorily high.

Neurological Findings and Observations.

From the routine case records kept at hospital on each of the patients studied, there were chosen twenty traits based on amnestic data or neurological findings assumed to be relevant from the standpoint of the dergree of seriousness of brain injury. (The selection was made in cooperation with the neurologist of the Hesperia Hospital, Dr. Pihkanen). The following traits were regarded as essential:

Anamnestic Data	Neurological Findings
1. Sensory disturbances	10. Mood changes
2. Perceptual disturbances	11. Aphasic disturbances
3. Mood changes	12. Perceptual disturbances
4. Loss of consciousness	13. Haptic disturbances
5. Aphasic disturbances	14. Pareses (paralyses)
6. Pareses (paralyses)	15. Coordination disturbances
7. Balance disturbances	16. Reflex disturbances
8. Vegetative disturbances	17. Vegetative disturbances
9. Primary unconsciousness	18. EEG
	19. X-ray examination of cranium
	20. PEG

The anamnestic data has been obtained, according to the hospital system, partly from patients, partly from relatives, and partly from earlier case histories. There also occurs some variance in this respect between hospitals. It may be assumed, however, that this lack of systematization in method and the resulting error are distributed at random among the variables. The scoring of the traits were done on a two-point scale (1 or 0) depending on whether the symptom was present or not.

b) Procedures

Administration

All the tests were given individually. As special attention was to paid to the achievement of positive motivation, testing was proceeded by an interview, upon which attention was given to the problems of the patient, and the value of testing emphasized as an aid in solving these problems. It took about three hours to carry out the testing and interviewing. With some patients, the test performance was used as a basis for vocational guidance. With others, again, the test result was a contributing factor in assessing capacity for work (pension). These differences possibly affecting motivation may also be assumed to be distributed evenly between the brain-injury and control groups.

Statistical Treatment of Data.

In the following a brief description is given of the procedures, statistical computations and analyses adopted in the course of the study. As mentioned already, the first and second parts of the study differ somewhat in respect to the statistical and other computational procedures. It therefore seems appropriate to give an account of each separate step of the study. *The results of the computational procedures are given in the same order in the following chapter.*

Part I.

1. Criterion of Brain injury.

— Discriminance analysis — applied here for the purpose of obtaining realiable unidimensional criterion (a severity scale) of brain injury — calls for a basic selection of groups to be differentiated from each other. Therefore the neurologist participating in the study subjectively estimated the degree of severity of the brain injury of each subject on the basis of the traits listed above.

The ratings were made when 100 patients had been tested (see, »subjects», p. 35). This sample consisted of both brain injured and non brain injured subjects in randomly distributed proportions. For each patient, information on the presence or absence of a symptom in each trait was available. In carrying out the estimation, the neurologist was aware of neither the test results nor the diagnosis of the patient. The rating was done on a four-point scale ranging from 0 to 3, according to the estimated degree of seriousness of the injury.

— On the basis of the resulting classification, a discriminance analysis was made to discover the extent to which the twenty traits presented are capable of distinguishing the extreme groups from each other. Groups 0 and 2+3 (N=32+35) were included in the analysis (for the distributing of rating see p. 37). The analysis was made by the method developed by Rao (op.cit., p. 246—250). On the basis of the analysis a discriminant loading (coefficient) was computed for each subtrait. This indicates the relative share a trait has in distinguishing the groups (here differing as to the degree of seriousness of injury) from one another.

— To test the reliability of the rating an other neurologist later rerated of the severity of the possible brain-injury of each patient in the same sample of 100 subjects. The re-estimation was made on the basis of the same information (see above) and in the same manner as the original rating. This time, however, the neurologist was first presented two extreme cases (one with severe injury, the other with none) in order to make the situation more relevant to him. The second neurologist had had earlier contacts with only few of the cases.

— On the basis of the discriminant coefficients obtained a severity index was computed for each subject participating in the study through multiplying by the respective loading each of his subscores on the twenty anamnestic and clinical findings. (As only two alternatives could be used (symptom present — symptom not present), the individual index was obtained simply by adding together the values of the respective loadings.)

2. Validity Correlation between Criterion and Test Variables.

Following the formation of the criterion dimension, a preliminary correlation analysis (N=100) was made to examine the validity of some of the test variables. This analysis was mainly concerned with the test variables that were assumed to be indicators of brain injury. The correlations contribute towards completing the picture of the relevance of the criterion used, and on the other hand, conclusions concerning the diagnostic efficiency of the indicators may be drawn from them.

For the computation of the intercorrelations, the raw scores on the tests and the criterion were transformed into normalized standard scores. The correlations are Bravais-Pearson »product-moment» correlations calculated.

according to the formula

$$r = \frac{\Sigma xy \cdot \frac{\Sigma x \cdot \Sigma y}{N}}{\sqrt{(\Sigma x^2 - \frac{(\Sigma x)^2}{N}) \cdot (\Sigma y^2 - \frac{(\Sigma y)^2}{N})}}$$

A multiple correlation (R) of all the test variables hypothesized to be sensitive to brain injury was computed by Murray's graphical estimation method (Murray, 1956).

The results of an orientative factor analysis based on the correlations mentioned were published elsewhere (Weckroth, 1961).

3. Comparison of the Mean Performance of the Brain injury and Control Group.

— From a total of 260 subjects tested (see »subjects» p. 35), and experimental and a control group were formed on the basis of the discriminant loadings mentioned above (see also, Results, p. 37). The inadequacy of the clinical records, and the attempt to match the groups in terms of such factors as age, sex, educational and occupational status, etc. narrowed the number of subjects in the groups down to 70+70. The distribution of the severity indexes obtained was also somewhat skewed so that the majority of subjects had a mild injury or none at all.
— The means of the test results were computed from the primary scores without any transformation. The statistical significance of the means was evaluated by Students t-test (McNamara, 1950). In reaction-time, error, difference, and reversal variables a higher score implies inferior performance, and on ability tests superior performance.

4. Comparison of the Ability Structures of the Brain Injury and Control Groups.

The following procedure was applied in order to compare the factor structures of the two groups:
— The intercorrelations of the test variables were computed separately for each group (N=70, in both groups). Pravais-Pearson's product-moment coefficients were calculated using normalized standard values. The difference variables (Nos. 12, 17 and 18) were formed on the basis of the same values.
— The centroid matrix of the factor analysis was computed by Thurstone's centroid method (Thurstone, 1953). The highest correlation of each variable was used as an estimate of its communality. In determining the number of factors, the size of both the residuals and the factor loadings was taken into account. Nevertheless, as the number of factors is of essential consequency in the comparison of the factor structures of the groups, it was considered inappropriate to rely upon the relatively subjective criteria mentioned above. In determining the number of the factors, the cosine rotation method (extended cosine solution) developed by Markkanen (Markkanen, 1960) was applied.

— To rotate the centroid factors obtained, two different procedures were used, a) the extent cosine solution method, and b) the varimax method (see Harman, 1960). The former was employed for the determination of the number of factors, i.e., the degree of differentation of the factor structure of the group, on one hand, and for purposes of transformation analysis, on the other. With oblique solutions, however, the interpretation of the rotated factors may sometimes present difficulties. This is why an orthogonal rotation by means of the varimax method was also performed.

— To compare the factor structures of the two groups, a transformation analysis was carried out in accordance with the method developed by Ahmavaara (see, Ahmavaara, 1957, and Ahmavaara and Markkanen, 1958). Through this procedure, the similarities and/or differences between the ability structures of the groups are described by expressing the factors structure of the brain injured in terms of the rotated factor matrix of the control group. In the comparison, attention is called on one hand to the number of factors or the degree of differentation of the ability structure and, on the other hand, to the extent to which the variance of the test variables can be explained in terms of identical factors in both groups.

— Only the most essential variables were subjected to analysis. Some variables were excluded from the series owing to the fact that they were, test-technically, more or less dependent on each other (e.g., some variables of the Color Naming test). On the other hand, some tests and variables, such as Blue-green Confusion and the Spiral Aftereffcet Test, were excluded because their communalities with other tests appeared to be very low, at least in the control group, due to the minimal variance; but also because the main objective was a comparison of the component factors of intelligence.

Part II.

5. Continuation of the Analysis of the Factor Structures of the Brain Injury and Control Group.

— In the cosine solution method the decision as to the sufficient number of factors to explain the factor spare depends partly on the orthogonality vs. obliqueness of the axes. Therefore in the continuation special attention was paid to this issue. On the basis of principal axis matrix computed for (with) seven factors a number of matrices were computed varying the number of factors (between 5 and 6), the determinant of the cosinus matrix (selecting the two most orthogonal solutions), and the level of communality required for a test to be selected to a factor test (accepting 0,40 and 0,50 respectively). By this variations attention is presumably paid both to the reliability and common variance of the test variables and to the degree of differentation of the factor structures in question. It was hoped that continuation of the analysis would give further information about the hypothetical factors which could account for the differences found in the first part of the study between the factor structures of the groups.

6. *A Discriminance Analysis of Anamnestic and Neurological Findings with a Group of Severely Injured.*

— A cross-validation study of the discriminance analysis performed during the first part was made on the basis of same measurements and subtraits. Also the ratings were made by the same neurologist. The traits were re-analyzed because in the original study the PEG, for example, was not made to all subjects (depending on its extreme characteristics as a clinical instrument). The patients not subjected to this test in the original study because of clinical contraindications were recorded as PEG-negative.

— It was also reasonable to hypothesize that in a group of brain injured the results of the analysis could differ from the original results, which were obtained with a group consisting both of brain injured and of other clinical cases with no apparent signs of brain-injury.

— A group of 62 patiens (see »Subjects», p. 36), with systematically collected clinical record (concerning the twenty traits) were selected for the second analysis. The group may be assumed — a priori — to consist of more severely injured subjects because PEG in particular is a selective factor in this respect.

7. *Factor Analysis of a Group of Severely Injured*

— For the sake of comparison the means and standard deviations were computed for the test variables. The selection of the test variables to be included in the second stage was done on the basis of the results obtained in the first part of the study.

This time the correlations were computed by using the raw scores as such. (All computational procedures were carried out on electronic computers.) Consequently some signs of the correlation and factor loadings are apparently inconsistent with the respective figures of the first part (where e.g. small number of errors or reversals were given positive score.)

The factor anlysis was performed by the principal axes method. Rotations were made by varimax method. For the sake of comparison selection were tried with both five and six factors. On the basis of the results, however, a trial with four factors seemed also necessary. This rotation was made graphically.

2. Subjects.

A total of 300 individuals were tested in the course of the study. The material was gathered (in the time of six years, 1959—1964) in collaboration with the Finnish Red Cross Hospital, The Hesperia Hospital, and the Medical Department of the Institute of Occupational Health.

The collection of material was carried out according to following lines:

— The patients were tested before the determination of final clinical diagnosis.

— When over one hundred patients (of whom about 40—50 % were suspected to have — at least mild — brain injury) — had been tested a neurologist of the team performed the estimation of the severity of brain injury of each subject (see p. 30). At this stage about twenty patients were disregarded because of the insufficiency of either neurological or psychological record. In general patients, who were not able to perform a major part of the tests, were disregarded.

— The experiment group and the control group were formed when 260 patients had been tested. To the brain injury group were included the 70 subjects having the highest individual scores on the severity index (computed on the basis of discrimination analysis, see p. 37). From the rest of the subjects an equal number of subjetcs were selected to the control group. It was intended to form the control group as equal as possible with the brain injury group with regard to such variables as age, occupational status, duration of illness and sex. Of these traits age was the most prominent because in the rest of the sample the mean age was significantly lower than in the brain injury group. Twelve female patients were included in the brain injury group and fourteen in the control group (because of the relatively small number of female subjects they were not treated separately in statistical calculations).

With regard to the etiopathogenesis the groups consisted of following subgroups:

	Frequency	
	Brain	Control
Traumatic	29	16
Vascular	20	2
Epileptic	8	1
Toxicological	5	8
Neurotic	—	10
Orthopedic deviancy	—	3
TBC	—	7
Arteriosclerotic	—	2
Luetic	3	—
Schizophrenic	—	5
Multiple	5	16

When in addition 40 brain injured subjects were tested on additional sample was formed of the subjects belonging to the highest severity category. Sixtytwo subjects were included in this sample (of these one third were included in the former brain injury group.)

3. Results.

The results of the empirical study are set forth in the same chronological order as the successive steps of the study were described in the foregoing chapter, »Statistical Treatment of Data» (pp. 30—35). In principle, the empirical study consists of seven sequences, of which the first four from the first part, and the last three the second part of the study.

PART I

1. Criterion of Brain Injury. A Discriminance Analysis of Anamnestic and Neurological Findings.

The frequency distributions of the rating of severity made separately and independently by the two neurologists are presented below:

Severity	Frequency Neurologist A	Frequency Neurologist B
0 no brain injury	32	37
1 mild injury	33	31
2 medium degree of injury	22	23
3 severe injury	13	9
Total number of cases	100	

The second rater seems to have been somewhat »less severe» in his ratings, but no significant differences can be found between the mean ratings. The correlation between the ratings was + 0.946, which indicates almost perfect agreement between the raters. (This result was preliminarily published elsewhere, see Weckroth and Pihkanen, 1963.) This agreement indicates at least that the choice of the subtraits may be considered adequate.

The results of the discriminance analysis are presented in Table I.

Table I

Discriminance Loadings of Anamnestic and Clinical Findings

Anamnestic Data		Clinical Findings	
motor disturbances (pareses, paralyses)	0.2297	pneumoencephalography	0.8511
		coordination disturbances (incl. fine motor dysfunction)	0.4847
vegetative disturbances	0.2186	vegetative disturbances	0.4562
loss of consciousness	0.1724	reflex disturbances	0.4303
primary unconsciousness	0.1127	perceptual disturbances	0.3841
aphasic disturbances	— 0.0044	electroencephalography	0.3584
sensory disturbances	— 0.0865	pareses (paralyses)	0.1713
balance disturbances	— 0.1341	aphasic disturbances	0.1504
mood changes	— 0.1400	haptic disturbances	0.1072
perceptual disturbances	— 0.1468	X-ray examination	0.0876
		mood changes	0.0398

The neurological findings proved to have more discriminatory significance in general than the anamnestic data, among which there were even negative loadings. This is obviously due to the fact that the control group is largely composed of psychiatric patients, among whom perceptual disturbances, mood changes, and balance disturbances may be quite frequent. Of the traits involved in the severity scale constructed, the following are of the greatest significance: PEG, disturbances of coordination, reflex disturbances, vegetative and perceptual disturbances, and EEG. In addition, paretic signs and symptoms, attacks of unconsciousness, and neurologically established aphasic disturbances are of consequency. On the basis of the relative magnitude of the loadings it is possible to form a picture of how the severity scale to be employed as the criterion in the following is constituted. (A more detailed report of the discriminance analysis and psychiatric rating of the severity of brain injury is presented and discussed in a separate paper, Weckroth et al., 1962.)

It goes without saying that the difference between the index means of different groups formed on the basis of the discriminant loadings are highly significant (P=0.001 between extreme groups).

2. Validity Correlations between Criterion and Test Variables.

As mentioned before following the formation of the criterion dimension an orientative study was made to examine the validity of some tests included in the battery under the assumption that they are »indicators» of brain injury.

The intercorrelations and validity correlations of the test variables are shown in Table II.

As shown in the table, all the validity correlations are positive and, with the exception of one, significant at the five per cent level. Attention may be called to the unexpectedly high validity of the simple reaction time of reading colored text (=naming the color of print), and to the low validity of the SAET.

The intercorrelations are, perhaps, somewhat higher than expected. On the other hand, some of the variables assumed to measure the same underlying factor correlate in a rather modest degree with each other (see f.ex.reversal variables). Again, it is noteworthy that the reversals of the Symmetric Drawing and Silhouette tests correlate quite satisfactorily with the SAET.

Table II

Intercorrelations and Validities of »Indicators» of Brain-Injury
N=100

		1	2	3	4	5	6	7	8	9
1. Colored text, time	1									
2. Memory for Design, errors	2	27								
3. Memory for Design, reversals	3	33	47							
4. Blue-green confusion	4	33	27	22						
5. Symmetric Drawing, reversals	5	22	19	46	29					
6. Silhouette, reversals	6	35	22	34	23	55				
7. Color Dots, errors	7	46	26	14	38	14	07			
8. Colored Text, errors	8	41	21	15	32	36	21	56		
9. Spiral After Effect	9	17	25	15	04	41	35	21	17	
Criterion	10	42	37	37	28	27	27	23	23	19

The multiple correlation of all the test variables with the criterion attains the value of R=+ 0.740. It can be concluded that the test variables together have some (status) validity to differentiate more severe brain injured from less severely injured.

3. Comparison of the Mean Performance of Brain Injury and Control Group.

The means and standard deviations of the test results, as well as the differences between the means, are presented in Table III.

The figures reveal that experimental and control groups were not equated perfectly on age; however, the difference between the means of the groups is not significant. Furthermore, *the brain injury group is inferior to the control group in all the traits without exception.* Even though the differences are not significant in respect to all the traits, *the tendency is general.* The differences between the groups are highly significant with regard to the following test variables: Colored text, reading time; Difference in time between reading black and colored texts; Word Groups; Dot Aiming; Triangles; »Pieces»; Color dots, reading time; Opposites Memory-for-Designs, reversals; and Silhouette, reversals. On the other hand, the smallest differences between the

Table III

Mean Performance of Brain Injured and Controls
Significance of Differences between Means

Group	Brain injured N = 70 Mean	Brain injured N = 70 SD	Control N = 70 Mean	Control N = 70 SD	Differ-ence	t	p
1. Age	41.96	13.35	39.10	10.68	2.860	1.3774	—
2. Color text, reading time, black text	77.46	73.03	58.16	24.85	19.30	2.0788	5.0
3. Color dots, time	13.13	12.68	8.645	3.604	4.484	2.8246	1.0
4. Colored text time	21.80	14.91	14.79	6.336	7.010	3.5956	0.1
5. Diff; black text-colored text	13.34	9.391	8.988	15.49	4.355	3.4165	0.1
6. Completion of Squares	19.06	6.583	21.36	7.656	2.300	1.8932	—
7. Word Groups	23.43	11.54	30.00	10.91	6.570	3.4372	0.1
8. Arithmetic Problems	30.79	11.67	35.05	13.55	4.260	1.9789	5.0
9. Dot Aiming	50.13	16.85	59.89	15.22	9.760	3.5702	0.1
10. Information	44.93	9.843	46.72	8.979	1.790	1.1161	—
11. Maze 1	93.47	66.30	68.00	50.54	25.47	2.5381	2.0
12. Maze 2	245.6	194.3	189.5	149.7	56.10	1.8998	—
13. Triangles	71.74	21.85	88.36	25.38	16.62	4.1229	0.1
14. Finger Tapping	77.80	14.50	83.87	17.76	6.070	2.2000	5.0
15. Hand Tapping	108.0	19.21	110.6	23.24	2.600	.71630	—
16. Pieces	15.00	10.55	21.91	12.43	6.910	3.5198	0.1
17. Synonyms	18.11	11.25	20.32	9.815	2.210	1.2298	—
18. Opposites	21.46	11.53	26.47	9.445	5.010	2.7925	1.0
19. Completion of Arithmetic Problems	10.76	7.949	13.19	9.574	2.430	1.6225	—
20. Symmetric Drawing, reversals	3.414	4.711	2.343	12.88	1.071	1.4284	—
21. Silhouette, reversals	6.586	5.652	4.057	5.235	2.529	2.7281	1.0
22. Memory-for-Design, reversals	64.05	3.073	42.38	3.090	21.67	3.1087	0.2

groups were obtained in regard to the following variables: Information; Completion of Squares; Maze 2; Completion of Arithmetic Problems; and Symmetric Drawing reversals.

It is noteworthy that it is not necessarily the more difficult one of a pair of parallel tests that differentiates better between the groups (eg., Completion of Arithmetic Problems, Synonyms, Maze 2). This peculiar trend is presented and discussed in a separate paper (Pihkanen & Weckroth, 1962).

For the majority of the test variables, the standard deviations are approximately equal. In the case of three of the color-naming variables, however, the variance ratio is significant, and the same is true of reversals in the Symmetric Drawing. No general tendency in respect to the variances is discernible.

4. Comparison of the Ability Structure of Brain Injury and Control Group.

The correlation matrices of the two groups are presented in Tables IV and V.

The centroid matrix of the control group is shown in Table 1 (Appendix 1) and that of the brain injury group in Table 2 (Appendix 2). The centroid matrices are presented in their final, reduced form. In both groups, seven centroid factors were originally extracted in spite of the fact that in the brain injury group the loadings of the last two factors were generally low. The multiple correlations of the test vectors, on the basis of which the reduction of the number of factors took place, are listed below:

Table

Multiple Correlations between the Test Vectors

Control Group

Test variable[1]	17	8	20	10	16	6	12
Multiple R							
(7 factors)	73	65	58	72	80	83	94
(6 factors)	49	60	55	52	51	68	—

Brain Injury Group

Test variable	18	9	8	20	15	12	3
Multiple R							
(7 factors)	68	65	74	82	81	85	88
(6 factors)	68	60	56	81	78	80	—
(5 factors)	46	55	55	—	66	54	—

As stated above, the multiple correlation of a vector shows its correlation with all the other vectors. In determinig the number of factors

[1] See Table IV.

Table IV

Correlation Matrix
Control Group (N=70)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Completion of Squares	1																						
2. Word Groups	2	43																					
3. Synonyms	3	56	67																				
4. Opposites	4	54	67	67																			
5. Arithmetic Problems	5	33	59	60	69																		
6. Completion of Arithmetic Problems	6	42	56	54	67	70																	
7. Pieces	7	50	44	44	54	47	56																
8. Information	8	45	58	55	52	38	34	22															
9. Maze 1	9	54	38	40	34	29	32	35	22														
10. Maze 2	10	45	24	19	15	19	25	22	23	63													
11. Color Text, time	11	32	45	40	44	59	33	27	32	32	26												
12. Diff.; black text- colored text	12	32	32	31	26	33	29	33	19	24	27	33											
13. Dot Aiming	13	33	18	32	23	37	12	12	04	25	28	49	35										
14. Triangles	14	30	13	20	03	10	02	19	03	29	41	30	35	57									
15. Finger Tapping	15	20	09	18	09	19	07	15	00	32	34	49	31	51	50								
16. Hand Tapping	16	22	14	23	16	23	03	10	03	24	25	52	28	51	50	70							
17. Finger Tapping, diff. right-left	17	09	-04	-18	01	-17	-17	-05	02	12	-17	-21	-21	-17	-14	-32	-10						
18. Hand Tapping, diff. right-left	18	-06	-19	-15	-23	-25	-12	-06	-04	01	-06	-26	-06	-06	-02	-02	-23	25					
19. Symmetric Drawing, reversals	19	35	22	29	35	21	19	38	18	30	27	19	02	24	00	02	08	-18	-14				
20. Silhouette, reversals	20	33	15	35	39	13	29	31	08	25	12	-04	24	05	-05	-03	08	-13	-10	58			
21. Memory for Design, reversals	21	47	48	56	49	56	40	37	36	40	34	32	28	41	18	20	14	-17	-17	48	29		
22. Age	22	24	04	03	10	-05	01	13	-31	24	24	20	09	33	10	25	22	-16	-23	10	23	13	

Decimal points omitted

Table V

Correlation Matrix
Brain Injury Group (N=70)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Completion of Squares	1																						
2. Word Groups	2	45																					
3. Synonyms	3	37	65																				
4. Opposites	4	37	77	74																			
5. Arithmetic Problems	5	55	60	55	51																		
6. Completion of Arithmetic Problems	6	40	58	55	55	63																	
7. Pieces	7	41	51	57	51	51	55																
8. Information	8	28	63	46	58	41	30	41															
9. Maze 1	9	27	20	18	21	35	23	29	10														
10. Maze 2	10	40	18	16	18	33	27	31	05	43													
11. Color Text, time	11	39	70	52	50	62	42	31	43	27	17												
12. Diff.; black text-colored text	12	31	33	42	39	47	41	25	18	19	18	33											
13. Dot Aiming	13	39	60	44	53	63	56	42	44	53	37	54	42										
14. Triangles	14	23	47	32	28	47	37	17	37	31	31	45	47	71									
15. Finger Tapping	15	16	31	29	49	22	28	29	30	16	12	28	19	42	33								
16. Hand Tapping	16	23	42	35	41	34	31	35	33	28	19	50	20	47	49	72							
17. Finger Tapping, diff. right.left	17	07	13	06	-01	15	05	08	33	12	-06	19	12	09	23	-17	06						
18. Hand Tapping, diff. right-left	18	-14	-08	-09	-10	12	-04	05	-00	-04	-16	-02	01	-04	-02	-04	-19	36					
19. Symmetric Drawing, reversals	19	39	42	06	26	27	26	29	27	23	30	32	08	36	17	16	18	05	-19				
20. Silhouette, reversals	20	42	28	20	28	27	35	21	-05	15	32	14	32	24	06	02	-02	00	-10	42			
21. Memory for Design, reversals	21	40	48	44	40	47	40	41	28	47	47	35	18	50	34	42	36	-02	-11	41	24		
22. Age	22	25	27	26	22	19	46	24	00	27	24	34	39	38	32	14	19	-05	-29	37	36	18	

Decimal points omitted

on the basis of the multiple correlations, attention should be paid not only to the relative size of the multiple correlation of the test vectors representing each factor, but also to the effect that the exclusion of a certain particular vector has on the multiple correlations of the others. As shown by the figures above, in the control group the dropping of the vector representing the seventh factor (test variable no. 12) has a reducing effect on the multiple correlations of the other vectors. The remaining six factors can be regarded as relatively independent of each other. In the brain injury group, on the other hand, the multiple correlations are relatively high even after the exclusion of one factor, indicating that the factors are linearly dependent on each other. Therefore, it also seemed appropriate to drop the test vector with the highest multiple correlation at this stage (variable no. 20).

The rotated factor matrices of the control group are shown in Tables VI and VII. Table VI indicates the results obtained with the »extended cosine solution», and Table VII the results of the varimax rotation. The corresponding matrices of the brain injury group are shown in Tables VIII and IX. For the sake of comparison, the same rotations were also carried out in the control group with five factors (Tables 3 and 4, Appendix 2).

The interpretation of the results of the factor analysis may be summarized as follows:

Control Group.

The interpretation of the factors obtained by the orthogonal (varimax) rotation (Table VII) is comparatively unambiguous.

Factor I is obviously a factor of general intelligence, in which all the tests of verbal, spatial, and numerical ability have relatively high loadings. Factor II may be interpreted as a general psychomotor speed factor. Both the aiming tests and the tapping-speed tests are presented in it. Factor III primarily saturates the reversal variables, and Factor IV the variables measuring the bilateral asymmetry of the hands. Factor V may be termed a visual factor. Factor VI is presented almost exclusively in the Information test, and it might be characterized as a general amount-of-knowledge factor; the negative loading of age in this factor seems natural.

The interpretation based on the orthogonal solution can also be applied with slight modifications to the results of the cosine rotation.

Control Group

Table VI

Rotated Matrix
Extended Cosine Solution

	I	II	III	IV	V	VI	Test
1	33	18	25	45	19	21	1. Completion of Squares
2	-08	45	-15	13	01	49	2. Word Groups
3	-11	57	24	-06	19	25	3. Synonyms
4	19	24	16	-12	24	67	4. Opposites
5	-11	30	-08	-18	28	63	5. Arithmetic Problems
6	00	00	00	00	00	83	6. Completion of Arithmetic Problems
7	16	-10	15	16	09	64	7. Pieces
8	00	79	00	00	00	00	8. Information
9	40	00	13	64	18	19	9. Maze 1
10	00	00	00	78	00	00	10. Maze 2
11	-04	15	-26	07	56	38	11. Color Text, time
12	-18	09	-06	16	23	23	12. Diff.; black text-colored text
13	01	15	05	14	68	-07	13. Dot Aiming
14	-09	06	-13	36	44	-09	14. Triangles
15	-07	-13	-09	17	70	08	15. Finger Tapping
16	00	00	00	00	83	00	16. Hand Tapping
17	62	00	00	00	00	00	17. Finger Tapping, diff. right-left
18	38	01	05	01	03	-17	18. Hand Tapping, diff. right-left
19	02	17	82	08	04	-23	19. Symmetric Drawing, reversals
20	00	00	74	00	00	00	20. Silhouette, reversals
21	-09	42	30	20	10	05	21. Memory for Design, reversals
22	01	-56	05	44	08	23	22. Age

Table VII

Rotated Matrix
Varimax Solution

	I	II	III	IV	V	VI
1	45	22	33	20	49	06
2	73	07	04	-15	21	27
3	66	18	29	-11	17	36
4	85	08	29	02	-01	04
5	79	22	10	-22	-08	11
6	79	-05	10	-08	14	-07
7	60	05	19	09	29	-12
8	47	02	08	02	15	58
9	32	26	26	22	56	-07
10	11	28	16	-10	67	-04
11	49	58	01	-22	-02	-03
12	29	34	-02	-14	28	07
13	03	58	22	-30	31	06
14	-01	61	-08	-05	39	07
15	06	76	-04	-08	18	-13
16	09	81	06	-06	01	-07
17	-02	-19	-03	53	-07	01
18	-18	-06	-11	46	10	12
19	17	01	82	-13	08	-04
20	21	-05	63	-03	14	-08
21	44	18	42	-19	24	19
22	00	19	21	-21	20	-55

Decimal points omitted

Neither the verbal nor the spatial or numerical abilities form any so that in the latter case the share of the verbal ability appears considerably greater.

Brain Injury Group.

Neither the verbal nor the spatia or numerical abilities form any separate factors in the group of brain injured. Here, too, Factor I must

Brain Injury Group

Table VIII — *Rotated Matrix, Extended Cosine Solution*; Table IX — *Rotated Matrix, Varimax Solution*

	VIII I	VIII II	VIII III	VIII IV	VIII V	Test		IX I	IX II	IX III	IX IV	IX V
1	-35	35	41	-41	30	1. Completion of Squares	1	38	48	00	06	32
2	-26	00	83	-14	35	2. Word Groups	2	81	25	20	14	17
3	-11	-13	37	17	48	3. Synonyms	3	70	04	19	-03	34
4	-10	-19	47	33	41	4. Opposites	4	82	05	22	-11	25
5	08	39	44	-24	39	5. Arithmetic Problems	5	49	37	21	39	35
6	-16	12	26	-04	54	6. Completion of Arithmetic Problems	6	48	25	18	01	48
7	-18	21	39	-01	18	7. Pieces	7	57	34	06	-06	19
8	00	00	82	00	00	8. Information	8	70	13	23	25	-17
9	00	67	00	00	00	9. Maze 1	9	00	52	35	05	16
10	-22	70	02	-19	-01	10. Maze 2	10	00	63	15	-07	21
11	-22	10	59	-18	40	11. Color Text, time	11	51	20	37	23	23
12	00	00	00	00	69	12. Diff.; black text-colored text	12	21	04	26	13	58
13	04	50	26	13	29	13. Dot Aiming	13	33	43	59	17	30
14	07	36	17	12	34	14. Triangles	14	14	22	70	27	27
15	00	00	00	81	00	15. Finger Tapping	15	38	01	58	-35	-02
16	-24	13	25	46	05	16. Hand Tapping	16	38	13	70	-19	-01
17	21	08	43	-39	10	17. Finger Tapping, diff. right-left	17	12	05	02	55	-02
18	64	00	00	00	00	18. Hand Tapping, diff. right-left	18	-04	-18	-04	52	-05
19	-50	38	52	-44	05	19. Symmetric Drawing, reversals	19	27	58	-02	-07	10
20	-31	16	07	-36	49	20. Silhouette, reversals	20	15	34	-18	-08	52
21	-09	60	28	13	-13	21. Memory for Design, reversals	21	36	57	29	-10	01
22	-47	08	-01	-20	61	22. Age	22	09	26	13	-20	58

Decimal points and positive signs omitted.

be interpreted (according to the results of the orthogonal rotation) as a factor of general intelligence. Factor II combines two factors which were separate in the control group (namely reversal factor and visual factor). Both the reversal variables and the visual ability tests have loadings in this factor. Factor III can be characterized as a general psychomotor speed factor. Factor IV can be termed a factor of bilateral asymmetry. Factor V may perhaps be described tentatively as a flexibility factor, for the tests requiring prompt and flexible adaptation, or the transposition of activity or a gestalt, have loadings in it. — Attention may be called to the fact that in the brain injury group, there are quite considerable differences between the orthogonal solution and the cosine solution. Especially with respect to the latter, a certain kind of structural inconsistency may be established. Even the intercorrelating tests of the same factor area may be represented in the same factor by rather different loadings (e.g. verbal tests 2 and 3, reversal variables 19 and 20, speed tests 15 and 16) and, on the other hand, tests normally loaded on different factors may be represented on one and the same factor (e.g. variables 9, 10, 13, and 21). In addition, special attention must be paid to the fact that aiming and tapping speed variables appear on different factors.

A rough and superficial comparison of five-factor matrices of brain injury and control groups (see Tables VIII and IX, and Tables 3 and 4, Appendix 2) reveals that Varimax solution gives more consistent results than Cosine solution. In the brain injury group the picture formed of the ability structure is seemingly dependent on the rotation method used. On the basis of this it is not, however, alloved to draw any conclusions as to the usefulness of the cosine solution. Attention must be paid to the fact that in the control group the results are not so dependent on the rotation method. — Of the five factors of brain injury group only three can be adequately identified (factors I, III, and IV, Table IX; and factors I, II, and IV, Table 3, Appendix 2) if we ignore the minor differences appearing in the quantitative relations between the respective loadings. The second factor of brain injury group seems to break down into two of each other relatively independent factors of which the one may be termed a visual factor, the other to reversal factor (III and IV, Table 3, Appendix 2) whereas the fifth factor seems to be a characteristic for the brain injury group only. This last factor appears quite distinctly also in the cosine matrix (factor V, Table VIII) allthough loaded in addition by some ability variables. As established before some illogical consistencies appear when the cosine method is used. The comparison of the five-factor matrices reveals, however, a rather interesting factorial differentiation which seems meaningful. The general psychomotor speed factor which is represented both in verbomotor (variables 11 and 12) and in aiming and tapping speed tests appears in the control group in all the analyses (independently of the number of extracted factors or the rotation method) splits in the brain injury group in an unusual way. Variables

13 and 14 are clearly connected with the visual factor, variable 11 with the reasoning factor while the simple psychomotor speed variables form a factor of their own.[1] Later on (page 61) we shall return to this theoretically interesting form of factorial differentiation. However, it must be remembered that this comparison was based on the assumption of an equal number of factors in the groups. As known for the present the problems of the number of factors and their qualitative identity are methodologically entangled with each other, so far as we do not have any exact criterion as to the determination of the number of factors. Also the method applied in this study (developed by Ahmavaara and Markkanen) to the determination of number and identity of factors must be considered as preliminary outline of problems.

On the basis of the above mentioned results it might have been expected that general psychomotor speed factor at least would not have been among the vectors on the basis of which the common factor space of the groups may be described (see the table, p. 62). Quite apparently the multiple correlations do not bring any information as too the structural quality of the factors common to both groups. It is also possible that the unusual differentiation of simple speed factor »caused» by brain injury is reflected in this result which is probably due to the fact that by this method an attempt is made to describe the factor space by reference to vectors as independent of one another as possible. It is, however, impossible to explain the position of the visual factor on the basis of this assumption. As ascertained before, there were rather remarkable differences in the structure of this very factor upon comparison between the brain injury and control groups. This matter can not, however, be dealt with here in more detail.

Number of factors. In transformation analysis the number of factors in the ability structures of the groups are also compared with one another by means of multiple correlations. In a sense, the multiple correlations then indicate the number of mutually independent factors that are common to the two groups or, in other words, can be identified with one another. The number of factors in the more differentiated group is used as the starting point. In the table below, the multiple correlations between the vectors for the control group have been presented in the factor space of the brain injury group (cf., Table IV).

[1] In this respect, however, the picture given by the varimax solution is more identical with that of the control group.

Table

Test Vectors

	17	8	20	10	16	6
Multiple Rs (6 factors)	973	961	985	952	974	942
(5 factors)	877	916	—	637	804	810
(4 factors)	439	—	—	634	596	580

Thus the highest multiple correlation in the first row is that of vector 20 representing the »reversal factor», and upon dropping this factor the highest multiple correlation (on the second row) is that of vector 8 representing the »information factor». The factors remaining after the exclusion of these two are, judging by the multiple correlations, relatively independent of one another. According to the interpretation presented in the foregoing, the factors common to both groups are I, Bilateral Asymmetry, II Visual Ability (Factor IV in Table VI), III, General Speed Factor (Factor V in Table VI), and IV, General Intelligence (Factors I, II, IV, and V, respectively in Table VIII).

The result as to the number of factors is primarily (but not wholly) consistent with the interpretation presented in the foregoing on the basis of the orthogonal rotations. Is should be stated that in the brain injury group, by far the greatest part of the variance of the Information test can be accounted for in terms of general intelligence and, in particular, verbal ability; in the control group, on the other hand, the variance of the general amount of knowledge is relatively independent of these factors. This result is of considerable consequence in regard to the construction of deterioration indexes. As found in comparing the *mean performances,* the Information test was one of the few exceptions in which the difference between the means of the groups was not significant — a result which is on the whole in agreement with the results of the studies of deterioration of performance. In contrast, the greater part of the variance of the reversal variables in the brain injury group seems to be explicable in terms of the spatial factor. It is difficult to discover, however, to what extent the significant difference is due to this fact.[1]

[1] A detailed analysis of the figural reversals, the reversion traits, and their interrelations is being published separately.

Abnormal Transformation of Variables. The transformation matrix computed for the examination of the abnormal transformation in the variables is presented in Table 5 (Appendix 3). According to the sum of the squares of the differences, the largest amount of abnormal transformation occurs in test variables 5, 12, 15, 18, (and in variable 22, age).

Abnormal Transformation of Factors. Table 6 (Appendix 4) shows the amount of abnormal transformation in the factors of the brain injury group in terms of the space of the control group. (The sums of squares at the bottom indicate the amount of abnormal transformation in different factors and those on the right in different variables.)

Of the variables on which there appears abnormal transformation, perhaps most interest is aroused by variable 12, which was established before to measure the flexibility dimension in the brain injury group. It seems natural that abnormal transformation is observed on it, i.e., it is logical to assume that a variable which turns out to be a factor test only in the other group, differs with respect to its factorial quality in these groups. On the other hand, it is very difficult to find consistency among the other variables. Taking into account that the choice of test vectors may be susceptible to chance, we may, perhaps, attempt to generalize this result to some degree if we restrict ourselves to deal only with test variables. The fact common to these variables is that the parallel tests hypothetically representing the same factor area appear as factor tests in the analysis of the control group but not in that of the brain injury group (except numerical tests). The variables 12, 15, and 18 appear as factor tests in the analysis of the brain injury group. From this point of view, the result may perhaps therefore be regarded as fairly consistent with the information reflected by the rotation results and multiple correlations presented earlier. It must be stated, however, that the result gives very little additional information as to the formation of further hypotheses concerning the »mechanisms» which in connection with brain injury could cause changes similar to those established. The same concerns the abnormal transformation of factors (Table 6, Appendix 4). It appears that the common variance of the variable composition used here is from necessity smaller in the number of factors in the brain injury group than in the control group, partly because of their lower degree of differentiation. It is no wonder then, that there seems to appear quite a general symptom of »abnormal transformation» when the structure of the brain injury group is described in terms of the structure of the control group.

PART II

5. Continuation of Analysis of Factor Structures of Brain-Injury and Control Group.

The results of the number of trials with various solutions are presented in Tables 9—20 (Appendices 7—18).

With respect to the structural characteristics of the two groups, the observed traits and trends may be summarized as follows:

When five factors are extracted and rotated, the interpretation of the factors in the control group is clear and unambiguous: The first is a general reasoning factor having highest loadings on variables 2, 4, 5, 6, and 7. Test of verbal, numerical, and visual ability are included. The second factor is quite obviously a factor of verbal ability (both comprehension and fluency); the highest loadings are on variables 2, 3, 4, and 8. The following factor is one of visual (or spatial) ability with loadings on all the visual tests, 1, 7, 9, and 10. It is noteworthy that »bilateral asymmetry» is also represented in this connection. The next one is a psycho-motor-speed factor which has its highest positive loadings on variables 11, 13, 14, 15, 16, and negative loadings on the bilateral-asymmetry variables, 17, and 18. It may be noted that also simple reading speed is represented in this factor. The fifth factor is a reversal factor pertaining to the ability to transpose visual gestalts.

All the factors mentioned are easily identifiable in the matrices consisting of six factors when the value of 0.40 is required as the communality minimum. The matrices consist of the five factors mentioned and a factor of bilateral asymmetry. Still higher demands on communality values seems to split the factor structure of the control group so that only verbal, motor, and reversal factors are clearly identified whereas the visual (or spatial) factor seems to split in to two parts, the other component being easily characterized as a speed- of- perception factor. The consistency of the reversal and verbo-motor-speed factors is remarkable also because it is just in these factors that the most prominent differences exist between the groups with regard to the results of the analyses in general. In the following table, the most typical factor pattern of the brain-injury and control groups is summarized. (It is the five-factor case. The loadings have been taken from one of the respective matrices of the groups, Appendices 7—18.)

Table X

Loadings picked from the most characteristic rotated matrix (cosine method, Appendices 7—18) when five (5) factors are extracted from both groups

	Control Group					Brain-Injury Group				
	I	II	III	IV	V	I	II	III	IV	V
1.			51			51	43			
2.	44	47				88				
3.		50				83				
4.	52					84				
5.	69			43		66				
6.	85					58				39
7.	56					67	24			
8.		80				76				
9.			78				63			
10.			73				68			
11.				70		54		34		
12.								34		49
13.				69				49		
14.				41				84		
15.				69					82	
16.				79					67	
17.				—53				61	—52	—50
18.				—44				48	—43	—47
19.					82		55			
20.					75		26			46
21.					42		58			
22.		—41								69

Decimal points and positive signs omitted

In general it can be mentioned that the factor pattern of the brain-injury group is not so articulated as that of the control group. Quite often the tests have loadings on several factors simultaneously. This may imply that some other method could be more suitable than the cosine solution for this type of structural analysis of a brain-injury group. The apparent diffusiveness of the structural pattern may, on the other hand, be due also to the spesific characteristics of the tests and not only to the possible changes caused by brain-injury.

Characteristic of the five-factor situation is the first factor, a factor of general intelligence or reasoning (see, for example, Table 12, Appendix 10). It is noteworthy that the eleventh variable has a loading on this factor. As pointed out earlier, this variable was consistently connected with the verbo-motor-speed variables in the analyses of the control group. The second one is obviously a visual factor. Typical, of the structural pattern of the brain-injury group, the reversal variables (or, in any case, some of them) are likely to have a high common variance with tests of visual ability. This observation is in agreement with the earlier finding according to which the degree of differentiation is smaller in the brain injury group than in the control group. From this point of view, the two following factors appear problematic. As was pointed out earlier in the control group, in all the analyses, the speed variables (reading, tapping, and aiming speed) were consistently represented in the one and the same factor. Now, it seems that in the brain injury group the aiming and tapping variables always form two distinctly different motor-speed factors. This peculiarity is repeatedly found in all the analyses (i.e. in all cosine rotations). In connection with these »aiming»- and »tapping»-speed factors, there further appear two extraordinary characteristics which may deserve mention here. First, the bilateral-asymmetry variables are represented in both factors but with opposite signs, and second, the twelfth variable which is the difference between the speed of reading black text and the speed of naming the color of the print. This latter variable is quite »indifferent» in the analyses of the control group. The fifth factor resembles the »flexibility» factor which was extracted in the original analysis (see Table IX), with the 12 th and the 22 nd variables usually having their highest loadings on this factor.

The results obtained with trials with six factors do not give much additional information about the specific characteristics of the factor pattern of brain injured subjects. There exists a trend toward clearer differentiation between verbal and other ability (intelligence) tests to form two factors, one being then a general reasoning factor, the other a factor of verbal comprehension. Remarkable is also the trend towards a more prominently dissimilar differentiation of the visual eye-hand coordination, aiming and simple motor speed area. In the control group three factors are repeatedly found independently of the variations of the determinant or communality requirements, namely: a kind of an eyehand coordination or a maze-factor, a motor (and verbomotor) speed factor, and a reversal factor. Instead, in the brain injury group there seems to exist a trend connected with the variation of communality level, the area mentioned above splits into three factors, namely, »aiming», »tapping speed» and a kind of visual factor (including maze and reversal variables). At the same time the reading-speed variable is consistently associated (in the brain injury group) with such primarily verbal comprehension tests as the Word Groups and Information. The results seem, however, to be too fortuitous to give rise to far-reaching conclusions.

6. *Discriminance Analysis of Anamnestic and Neurological Findings with a Group of Severely Injured.*

The results of the cross-validation study of the discriminance analysis are presented in the following table (Table XI):

Table XI

Discriminance Loadings of Anamnestic and Clinical Findings

Anamnestic Data		Clinical Findings	
motor disturbances (pareses, paralyses)	— 0.1009	pneumoencephalography	0.7010
		coordination disturbances (incl. fine motor dysfunction)	0.1668
vegetative disturbances	0.1312	vegetative disturbances	— 0.2548
loss of consciousness	0.0089	reflex disturbances	0.1084
primary unconsciousness	0.0850	perceptual disturbances	0.0924
aphasic disturbances	0.3461	electroencephalography	0.2076
sensory disturbances	— 0.1085	pareres (paralyses)	0.2689
balance disturbances	0.1876	aphasic disturbances	— 0.1145
mood changes	0.0740	haptic disturbances	0.0632
perceptual disturbances	0.1939	X-ray examination	0.0122
		mood changes	0.1356

If the loadings obtained are compared with the respective figures in Table I, quite remarkable differences attract attention. The positive loadings are generally much lower than in the original analysis. There also occur differences regarding the relative share of various subtraits as discriminator.

It is quite obvious that the relatively small number of cases included in the groups plays a certain role with regard to the differences between the figures in Tables I and XI. Most significant in this connection is, however, the fact that the group tested is much more homogeneous in respect to the criterical dimension, i.e. severity of brain-injury. The groups compared in the original analysis consisted of »almost pure» control cases and severely injured, whereas the cross-validation group involves only cases with medium or severe injury. It can be anticipated that, at least some of the variables with relevance as »discriminators» of brain-injury lose their value within a group of brain-injured persons because the selection decreases their variance within the group. It is no wonder, then, that some of the anamnestic variables seem to acquire relevance as to the differentiation between the more and less severely injured within a group of brain-injured persons. — However, when a correlation was computed between the two kinds of indices in a group of randomly selected subjects (including both »experimental» and control subjects, N= 70) it attained a value of r= + 0.54. When the decrease of variance caused by the selection is taken into account, the obtained values can be considered satisfactory.

7. Factor Analysis of the Ability Structure of the Group of Severely Injured.

The means and standard deviations of the variables included in the factor analysis is presented in Table XII. For the sake of comparison, the respective mean values of the brain-injury and control groups in the first part of the study are presented where applicable. As evident, the series comprices different variables, and some of the variables have undergone modification as to the method of scoring.

It can be observed that in respect to all the ability tests proper, the mean score of the third group is the lowest (with the exception of the Word Groups test where both brain-injury groups have the same mean result). The third group apparently consists of the most severely injured subjects. The same order is to be observed also with regard to the reversal and aiming variables, whereas in the speed of performance in the Maze and Color Naming tests the third group scores better than the original brain-injury group. With respect to age, the third group is the oldest, but the differences are not significant.

The correlation matrix of the 33 variables is presented in Table XIII.

Table XII

Means and Standard Deviations of Severely Injured

	Mean	S D	Brain	Control
	N= 62		N= 70	N= 70
1. Word Groups	23.44	13.34	23.43	30.00
2. Information	39.61	17.62	44.93	46.72
3. Synonyms	14.76	11.84	18.11	20.32
4. Opposites	20.53	13.09	21.46	26.47
5. Completion of Arithmetic Problems	9.258	8.924	10.76	13.19
6. Arithmetic Problems	28.48	15.53	30.79	35.05
7. Pieces	14.65	12.55	15.00	21.91
8. Completion of Squares	16.79	8.941	19.06	21.36
9. Finger Tapping, right hand	28.74	18.78		
10. » » , left hand	25.82	18.69		
11. Hand Tapping, right	36.89	26.34		
12. » » , left	33.16	25.45		
13. Silhouette, Reversals	6.677	7.794	6.586	4.057
14. Symmetric Drawing, Reversals	4.581	6.817	3.414	2.343
15. SAET, right	11.00	8.933		
16. SAET, left	11.50	9.564		
17. SAET, Symptom	.5161	1.127		
18. MFD, omissions	3.597	3.541		
19. MFD, errors	2.984	2.466		
20. Maze 1	87.73	104.3	93.47	68.00
21. Dot Aiming	46.53	24.08	50.13	59.89
22. Triangles	68.15	37.56	71.74	88.36
23. Color Text, reading time	66.06	56.75	77.46	58.16
24. Color Dots	105.1	68.41		
25. Colored Text, reading time	202.6	163.7		
26. Colored Text, errors	.2742	1.439		
27. Blue-green Confusions	.2742	1.133		
28. Color Dots, other errors	1.484	3.788		
29. Colored Text, other errors	4.532	7.050		
30. MFD, reversals	414.2	234.8		
31. Age	42.37	12.32	41.96	39.10
32. Duration of injury	4.274	1.918		
33. Severity of injury	—1094.	512.2		

Correlation Matrix

$N = 62$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1																																	
2	58																																
3	61	61																															
4	69	58	77																														
5	65	34	58	68																													
6	73	52	59	67	75																												
7	61	49	62	73	77	64																											
8	78	66	55	62	59	69	59																										
9	39	31	27	37	36	44	23	44																									
10	37	27	28	32	32	34	22	39	83																								
11	43	31	28	37	32	41	20	42	90	77																							
12	41	23	31	32	30	31	24	38	77	90	83																						
13	-32	-23	-16	-32	-22	-19	-27	-37	-17	-27	-13	-24																					
14	-47	-42	-30	-50	-40	-46	-47	-51	-39	-31	-34	-30	59																				
15	-14	-14	00	-01	-08	-17	-06	-09	04	08	06	16	18	-02																			
16	-11	-19	-05	-01	-04	-15	00	-10	15	18	16	28	04	-07	81																		
17	-03	-18	03	-03	07	04	12	-13	13	05	04	-11	-02	08	-47	-38																	
18	-44	-37	-33	-56	-36	-43	-45	-38	-46	-35	-40	-27	35	53	25	12	-03																
19	-25	-30	-22	-31	-34	-32	-35	-14	-23	-06	-21	02	05	30	05	-05	-18	32															
20	-46	-41	-31	-38	-31	-41	-33	-48	-21	-16	-21	-15	27	36	48	49	-12	37	15														
21	54	33	39	46	45	52	39	44	33	32	46	42	-09	-29	16	18	-25	-21	-17	-21													
22	56	43	40	43	33	44	35	50	37	34	45	41	-06	-30	15	13	-31	-24	-12	-29	87												
23	-45	-45	-28	-34	-27	-40	-26	-46	-24	-18	-27	-17	33	45	32	38	-09	42	09	74	-15	-21											
24	-59	-44	-37	-44	-35	-49	-38	-55	-33	-25	-30	-21	31	41	17	09	01	44	27	59	-33	-39	66										
25	-52	-46	-33	-37	-33	-40	-37	-50	-21	-18	-19	-15	51	60	12	09	03	33	20	43	-14	-21	73	70									
26	-30	-42	-20	-29	-17	-25	-23	-34	-11	-08	-13	-10	33	32	54	59	-03	40	-03	73	00	-07	73	40	36								
27	-03	-01	22	07	01	-01	04	-10	07	21	10	21	17	15	-01	-02	18	-06	18	05	10	02	19	39	41	10							
28	-28	-22	-18	-16	-19	-28	-15	-30	-15	-10	-15	-11	01	09	33	45	04	33	-08	48	-07	-20	44	48	20	65	17						
29	-40	-35	-20	-32	-30	-36	-34	-33	-26	-24	-26	-25	38	51	35	31	08	47	12	59	-08	-16	55	40	42	69	28	57					
30	-56	-61	-41	-58	-47	-50	-47	-57	-41	-37	-39	-27	38	51	15	09	05	50	47	42	-37	-37	40	54	48	36	19	29	45				
31	-30	07	04	04	-23	-13	-07	-15	-18	-22	-18	-22	09	12	-13	-24	02	02	18	-06	-28	-26	02	19	17	-24	02	-01	06	19			
32	07	04	09	15	06	03	02	10	01	10	-09	-01	-12	-10	24	13	-12	-03	06	15	10	13	-01	-02	01	10	08	14	14	00	-06		
33	30	26	22	18	09	09	09	36	18	13	26	19	-15	-22	21	13	-25	-13	-16	-13	25	31	-18	-12	-19	-10	06	-09	-08	-26	-28	-06	

Decimal points and positive signs omitted.

Some of the clusters and uncommon trends invite comment on the obtained correlations despite the fact that in the following an analysis is made in order to give a more systematic description of the interrelations of the variables.

The cluster of the first eight variables at the top of the matrix indicates that the group must be quite heterogeneous with respect to intellectual performance capacity. The intercorrelations between different ability subtraits are higher than expected. The second remarkable feature is that the Word Groups test and the Completion of Squares test systematically have high correlations with all the other variables of Aiming, Tapping tests, etc., with some exceptions (the very specific variables of the SAET, Blue-green confusion, etc.). The intelligence tests proper correlate, in general, quite highly with other performance tests. The third noteworthy fact is that quite many of the test variables assumed or observed to be »indicators» of brain-injury — as, for instance, reversal variables, color naming, and aiming variables as well as motor-speed variables — actually correlate very highly with intelligence tests (with the exception of the SAET variables). The correlations are almost as high as the intercorrelations of ability tests among themselves.
— There seems to exist quite an interesting relationships between the indicators which can be (deplorably?) wholly explained by referring to their common variance with intelligence.

The results of the factor analysis is presented in Table 21 (Centroid Matrix, Appendix 19), and in Tables XIV and XV (Rotated Matrices with five and six factors, respectively).

The impression is, again, somewhat confused. Quite many of the variables are simultaneously represented on two factors, and on some of the factors tests appear in very unusual combinations. Very »clear» example of this type of »diffusion» is the first factor in the *five factor case.* On the basis of the loadings of variables Nos 20, 23, 24, 26 (sic), 28, and 29, the factor could be termed a »speed of perception»-factor but the loadings of variables 15, and 16 are surprisingly high to say nothing of the possible role this factor plays on information test (!). The second factor is apparently a factor of general intelligence. The relative high loadings of some of the tests — assumed to be indicators of brain injury — on this factor could be anticipated on the basis of the intercorrelations (Table XIII). Most of the tests in question correlate higher with the tests of intelligence than with each other. Whatever the structure, degree of differentiation, etc., one factor

Table XIV

Rotated Matrix
Varimax solution

	I	II	III	IV	V
1. Word Groups	—20	—71	—25	—22	—25
2. Information	—56	—48	—09	—30	15
3. Synonyms	—16	—76	—12	—14	—06
4. Opposites	—14	—82	—17	—12	14
5. Completion of Arithmetic Problems	—05	—80	—17	01	12
6. Arithmetic Problems	—23	—76	—21	—07	13
7. Pieces	—08	—81	—04	—08	17
8. Completion of Squares	—30	—61	—23	—30	27
9. Finger Tapping, right hand	—06	—24	—88	00	13
10. » » left hand	—03	—18	—90	—05	07
11. Hand Tapping, right	—10	—21	—88	—13	06
12. » » left	—04	—15	—89	—22	01
13. Silhouette, reversals	11	19	15	—05	—57
14. Symmetric Drawings, reversals	10	40	24	10	—59
15. SAET, right	64	10	—08	—56	01
16. SAET, left	73	07	—21	—42	12
17. SAET, Symptom	—09	—08	—09	65	—08
18. MFD, omissions	28	41	31	—08	—30
19. MFD, errors	—12	42	05	—12	—27
20. Maze 1	71	28	09	—01	—26
21. Dot Aiming	—03	—49	—29	—59	—10
22. Triangles	—15	—40	—29	—68	—05
23. Color Text, reading time	62	20	11	05	—49
24. Color Dots, reading time	38	34	13	19	—54
25. Colored Text, reading time	25	28	05	11	—74
26. Colored Text, errors	100	32	08	11	—27
27 Blue-green Confusions	05	—14	—20	10	—55
28. Color Dots, other errors	68	05	08	09	—10
29. Colored Text, other errors	57	15	18	—01	—45
30. MFD, reversals	24	50	23	12	—42
31. Age	—20	09	21	18	—19
32. Duration of Injury	17	—11	02	—15	01
33. Severity of Injury	—04	—12	—15	—38	14

Decimal points and positive signs omitted.

Table XV
Rotated Matrix
Varimax solution

	I	II	III	IV	V	VI
1. Word Groups	—72	23	—23	22	—22	23
2. Information	—49	27	—13	36	—36	—45
3. Synonyms	—77	00	—14	06	—15	—20
4. Opposites	—82	20	—18	04	—12	—16
5. Completion of Arithmetic Problems	—80	11	—16	06	03	14
6. Arithmetic Problems	—76	13	—20	24	—07	13
7. Pieces	—81	20	—05	01	—07	—07
8. Completion of Squares	—61	30	—23	23	—31	00
9. Finger Tapping, right hand	—24	14	—87	06	01	12
10. » » left hand	—18	10	—90	—01	—04	—01
11. Hand Tapping, right	—21	07	—87	10	—13	14
12. » » left	—15	05	—89	—03	—21	—02
13. Silhouette, reversals	18	—61	16	—02	—05	12
14. Symmetric Drawings, reversals	39	—63	23	00	10	04
15. SAET, right	10	—01	—08	—72	—49	05
16. SAET, left	08	08	—20	—78	—33	16
17. SAET, Symptom	—06	—10	—08	20	64	09
18. MFD, omissions	41	—35	31	—23	—06	08
19. MFD, errors	41	—23	03	06	—15	—24
20. Maze 1	30	—29	09	—70	05	03
21. Dot Aiming	—50	—14	—26	06	—56	32
22. Triangles	—41	—08	—27	16	—67	27
23. Color Text, reading time	20	—53	11	—58	10	03
24. Color Dots, reading time	35	—52	10	—40	21	—27
25. Colored Text, reading time	28	—74	03	—21	12	—12
26. Colored Text, errors	34	—43	12	—81	22	54
27. Blue-green Confusions	—14	—50	—24	—09	09	—26
28. Color Dots, other errors	06	—12	07	—69	16	—01
29. Colored Text, other errors	16	—50	18	—51	05	08
30. MFD, reversals	50	—43	22	—21	12	—08
31. Age	08	—11	17	10	14	—44
32. Duration of injury	—11	03	01	—23	—13	—08
33. Severity of injury	—13	15	—15	—01	—38	04

Decimal points and positive signs omitted.

is repeatedly found in the analyses of brain injury group and this is »tapping speed». As pointed out earlier the group of brain injured subjects seems to be more differentiated in the psychomotor area than are clinical control subjects![1] — The gestalt of the following factor appears somewhat unusual too. It is noteworthy that a dominant part of the variance of the severity index can be explained with reference to this factor. (The very low communality of this variable must, however, be taken into account.) Of the three tests being represented in this factor two are typical aiming tests, variables 21 and 22, and the third is SAET. The intercorrelations of the critical variables do not offer any reasonable basis for interpretation neither. The combination of variables in this factor seems highly accidental also because the SAET does not correlate significantly neither with severity index not with aiming tests. (The test has, instead, correlations with Maze-test and with some of the Color Naming variables wich are, however, immaterial from the point of view of the present argument.) The last factor is also problematic. It has loadings on Reversal variables and Color Naming variables, which are, however, quite clearly represented also in the first factor. The composition resembles to a certain degree the factor termed flexibility factor in the first part of the study. Because of the puzzling character of his last factor we may delay a bit on this topic, which is on the other hand quite significant from the point of view of the problems of the study.

We may go back to the correlation table (Table XIII) on page 57 and list some of the trends and clusters observed in the order to help the interpretation of the problematic factor-structure of the group.

Firstly it is noteworthy that visual tests correlate rather highly with reversal variables and also with the reading speed variables of the Color Naming test. The correlations of the Completion of Squares test is in average somewhat higher indicating, probably, that the accuracy component is the more prominent one. Of the reversal variables the Silhouette seems to be most independent on visual ability and also on other subtraits of intelligence.

Secondly, it is interesting to note that the reversal variables correlate »best» with reading speed variables. It must be remembered that the

[1] This result may primarily have value concerning differential diagnosis of clinical groups, because, as we know the tapping and aiming tests are »normally» represented on different factors. (Mean age of the group may, however, be a factor of significance in this respect.)

Symmetric Drawing and Silhouette are done without any time limit! The correlations may therefore be due to the common variance of the variables with intelligence tests in general. Interesting is that of the reading speed variables it is just the last one (time in reading colored text) which correlates most highly with the reversals.

Thirdly, the Color Naming test appear symptomatic also in its connections with SAET, which correlates — besides the correlations with Maze test — significantly only with some of the Color Naming variables. Quite interesting is that of the reading speed variables the first (black text) has some correlation with SAET variables whereas the two variables measured in more difficult situations have not. Instead the errors in reading colored text has peculiarly rather high correlation with the reaction time variables of SAET. The error variable (26) correlates on the other hand, highest (besides the intercorrelations with other variables of the same test) with Maze test, the correlation being so high as 0.73.

Fourthly, worth of mentioning is the fact that the reading and tapping speed variables correlate quite modesty with each other and also that the aiming variables do not correlate with the speed variables either.

Now it appears that the complex and unusual variable combination of the last two factors (Table XIV) could be explained partly by reference to the brain injury itself and partly by referring to the possible indirect influence it has on the performance of the injured in different situations. As it can be observed the fourth factor which combines SAET variables and Aiming variables (which do have only very low correlations with each other) has also a loading on the severity index variable. Apparently the variable combination is a consequence of the fact that both SAET and Aiming tests (Dot Aiming and Triangles) have a common variance with the severity index. On the other hand, it seems to be possible that the variance of injury increases the possible role played by such general factors — besides intelligence — as general accuracy, attention, motivation, error tolerance, flexibility-rigidity, etc. Within some variable compositions those factors can naturally coincide. This type of »abnormal» transformation could explain such unusual variable combinations and factor-structures as observed in the present analysis and in the original analysis of brain injured (the flexibility-factor, Tables VIII and IX). This time, however, the use of the term »ability» is perhaps less warranted. The factor configuration may be assumed to be a result of the influence of (brain) injury on test behavior; a kind of general syndrome of brain injury. In the six-factor-solution the second factor may apparently be identified with this factor. Both have the highest loadings (again with the exception of SAET variables) in variables which were on the basis of earlier findings assumed to be sensitive to brain pathology.

Regarding the validity of the above argumentation it should be observed that, from a formal point of view, an excessive number of factors were extracted in the analysis. The results obtained may thus be regarded as a fortuitous outcome of this circumstance, rather than as an outcome of the effects of the injury upon behavior. It is seen, for example, that the communality of variable 26 already exceeds unity after the extraction of two factors. (Another noteworthy point is that the loading of the same variable on the first factor is already 1.00.) Consequently, if the formal criteria for the termination of factoring had been adhered to strictly, only two factors, at most, should have been extracted. Nevertheless, since there were grounds for assuming that the phenomenon was associated with the communality estimation method (use was made of the highest correlations) it was considered permissible to depart from the rigid formal criteria. Reconsideration of the matter led, however, to the decision to carry out a further rotation with four factors. This number of factors also meets rather strict criterion requirements. (The communality of variable 26 is essentially the same irrespective of whether two or four factors are included.) The result of the rotation is presented in the following table.

This four factor matrix is very clear-cut compared with many of the previously obtained matrices. The first factor is apparently a general intelligence factor, the second factor, again is, a simple psychomotor speed factor. The third factor is a test-factor accounted for by the inclusion of parallel test variables in the analysis. These form a factor on their own primarily on the basis of their intercorrelations with each other, rather than on the basis of their common variance with other variables (which is quite small in this case). It is remarkable that the peculiar type of group factor which was previously assumed to be a result of the influence of the brain injury itself, a kind of general syndrome of brain injury (factor V, Table VII, and factor II, Table XV) also appears in the four factor matrix. The result seems to imply, however, that the tests assumed to be sensitive to brain injury are by no means superior to the other groups of tests (general reasoning, motor speed) included in the battery. In agreement with this assumption the loadings of the severity index are, relatively, of the same

Table XVI

		I	II	III	IV
1.	Word Groups	80	24	00	—15
2.	Information	65	14	—24	—26
3.	Synonyms	77	10	—05	16
4.	Opposites	85	15	—03	03
5.	Completion of Arithmetic Problems	78	15	—01	11
6.	Arithmetic Problems	79	20	—11	00
7.	Pieces	81	03	00	03
8.	Completion of Squares	73	26	—02	—24
9.	Finger Tapping, right hand	25	89	—03	00
10.	» » left hand	20	89	05	02
11.	Hand Tapping, right	26	90	04	—02
12.	» » left	22	89	14	01
13.	Silhouette, reversals	—26	—16	04	45
14.	Symmetric Drawings, reversals	—49	—18	14	54
15.	SAET, right	—07	05	83	01
16.	SAET, left	—10	18	86	01
17.	SAET, Symptom	—08	07	—45	26
18.	MFD, omissions	—46	—31	22	20
19.	MFD, errors	—38	—02	—05	05
20.	Maze 1	—44	—13	54	37
21.	Dot Aiming	61	29	32	04
22.	Triangles	56	30	29	—08
23.	Color Text, reading time	—38	—16	41	57
24.	Color Dots, reading time	—51	—17	13	54
25.	Colored Text, reading time	—44	—07	04	67
26.	» » errors	—56	—15	71	50
27.	Blue-green Confusions	03	19	—07	57
28.	Color Dots, other errors	—21	—14	47	31
29.	Colored Text, other errors	—33	—23	39	51
30.	MFD, reversals	—61	—24	05	33
31.	Age	—10	—20	—29	12
32.	Duration of injury	12	—04	22	02
33.	Severity of injury	24	17	20	—21

Decimal points and positive signs omitted.

order of magnitude on all the relevant factors. But the matrix is again an example of the fact that the reduction of the number of factors, so commonly met with in connection with groups of the brain injured, does not in every case necessarily imply a lesser differentiation of the factor pattern.

C. Discussion

In reporting the results certain aspects were already presented and some hypotheses put forward concerning the interpretation of the results or the partial problems met with in the course of the study. Hence, in this Discussion chapter the writer does not primarily intend to reconsider the separate results in detail; instead, the discussion will be deliberately confined to an analysis of the significance of certain principal results. (The reader is also referred to the Summary and Conclusions chapter, where each of the sections of this study will be separately summarized.) The present discussion is concentrated on three themes. The first one relates to the results of the criterion analysis and the possibilities of developing it; the second one is concerned with single tests as indicators of brain injury, and the agreement of the results of this study with those previously obtained; and, finally, the conclusions to be drawn on the basis of the results of the factor-analytical study performed are subjected to discussion. The results of a discriminance analysis undoubtedly depend — just as the results given by factorial analysis, for example — upon the samples and the composition of the set of variables employed. The results may also be expected to be different depending on how the variances of the variables subjected to analysis are related to one another and upon the relationships between the groups that are to be distinguished from each other. The last-mentioned relationships cover both the average distances between the group means and the differences between the groups with regard to the intercorrelations of the variables. Can anything general then be said as to the feasibility of this method?

It should be emphasized that the present study is orientative particularly as far as the criterion analysis is concerned. It contains deficiencies and sources of error, which of course reduce the reliability of the conclusions. Although the results reported here seem to suggest that the method is capable of further development, it should obviously be borne in mind that some of the factors possibly affecting the results have remained outside the investigator's control. The non-systematic data collection is to be pointed out as one of the factors which may reduce the reliability of the results. It goes without saying that, from the standpoint of the reliability of the method it would have been highly important to ensure that the reliability of each of the sub-variables would have been at least approximately the same. There is little doubt that in this regard the difference is largest between the recorded anamnestic data and the clinical findings. The difference in discriminative power between the two variable groups probably reflects this state of affairs; this is likely to be the case with the first analysis, in particular. It is only natural that the results of active measurement or examination are recorded more reliably than what the patients report, mostly depending on their memory, about their observations and feelings. Furthermore, in this study the anamnestic interviews with the patients were in several cases deplorably unsystematic, so that a great deal was left to depend on the patients spontaneity. (When the method is elaborated further, an equal amount of attention should be paid to the differing requirements of the intraindividual and metric interindividual validity and reliability of clinical individual diagnostics.) On the other hand, there was a certain amount of non-systematicity also as far as the clinical examinations are concerned; this was due to the clinical harmfulness of the PEG test included in the series. It was assumed that the patients not subjected to this test because of clinical contraindications would have been proved to be negative cases. Even if this assumption were correct, efforts must of course be made to elaborate the method in such a way that it can be applied systematically without the danger of clinical complications. It is indeed possible that some minor changes, which might have been recorded as PEG-positive, would also have occured among the patients who were not tested. The impact of the direct PEG stress upon the psychological test results was a further variable outside the control of the investigators; such an impact is, however, likely to appear when the neurological and psychological examinations are close to each other in time. The existence of this possible source of error must be borne in mind, even though it is perhaps not likely to affect the results essentially. Among the sources of error that may influence our statistical inferences, attention should be called to the distributions of the neurological sub-variables and the small size of the samples. In point of fact, the procedure applied here was unorthodox, in that the correlations on which the discriminance analysis was based were computed for variables divided only into two classes. This may reduce the reliability of the correlations and increase random variation, just as the smallness of the samples does.

Considering how many possible sources of error there exist, the results appear statisfactory and seem to justify the expectation that the method is capable of further elaboration. In a later random sample the correlation between the two scales amounted to $+0.67$. This apparently indicates that the reliability of the method can be increased sufficiently high for practical purposes. It is possible, however, that the technique will prove to crude as far as the discrimination of other dimensions of injury are concerned. — As regards the relevance of the method, on the other hand, it may be advisable at this stage to refrain from advancing any far reaching conclusions. It may be sufficient here to refer to a previous paper (Weckroth and Pihkanen, 1962) where this topic was discussed. The topic will be further discussed in the second volume of this report. It is possible that the method will only prove appropriate in cases where the dimension may be considered to consist of a resultant effect of a number of different factors in an accumulative way, as it were, and this is obviously the case with the severity of brain injury.

Recently many investigators have strongly emphasized that brain injury is by no means a unitary trait in respect to which individuals could sharply be differentiated into brain-injured and non-brain-injured. Besides the individuals own casuistic etiopathogenetic picture, the brain-pathological condition can be described by means of several general dimensions, as dizease-injury, general etiopathogenetic quality, chronic acute, type of location, severity of trauma, etc. (cf., for example, Morrow and Mark, 1955). For the present, it has not been possible in any way to demonstrate clearly how these dimensions are related to one another. It is possible that some of these dimensions are simply linearly dependent on one another or that they are partly dependent on one another. In addition, it is possible that the correlations vary between different dimensions (e.g. between severity and duration, location and duration, etc.) or that some relations are complex and some are simple (e.g. the location of some injury — say — »vascular case» may be altered with increasing duration). Without a more precise explanation of the structure and intercorrelations of such dimensions as mentioned above, the study situation becomes irrational, because we do not know whether the groups we are studying or the individuals we are comparing with one another really should differ from one another. Literally we cannot demonstrate in what other respect the groups differ from one another except in regard to the dependent variable, as far as any difference exists. The criteria with which several studies have had to be satisfied have been in itself very crude. A mere subjective diagnosis as such cannot be considered valid from a scientific point of view. — Thus, the situation is irrational in the sense that in the scope of psychological brain-damage investigation at the moment the differential sensitivity of several psychological methods is in a way being sharpened to increase the validity of brain-damage diagnostics — as if the windows were already being cleaned in a house the foundation of which is not yet ready. The consequences of the situation manifest themselves in two ways. Seemingly similar groups may lead to contradictory results, and it is not known why. We do not know if supposedly different or similar groups are manifestly so. Thus, a relevant description cannot be offered of the traits which we assume we are dealing with. This further results in the fact that investigators use similar names for different operational concepts or different names for same concepts. It is clear that in this way we cannot go far, as long as there is the least desire to develop psychological theory or manner of description along with empirical expositions.

In quite a few studies there has undoubtedly been awareness of these simultaneously operating factors and their possible contribution to faulty conclusions. Thus, to eliminate errors of this type, for instance, attempt have been made to homogenize the groups in respect to such factors as type, duration, degree of severity, and/or location of injury. Now, however, it is not fully certain if we can work so simply on the assumption of linear relations in this area. It may be, for example, that duration of certain lenghth is always associated with a certain degree of severity or that a certain location is likely to be allied with a certain mean degree of severity, and so on. It may prove nearly impossible to obtain, for instance, a severity measurement entirely independent of the location of injury (cf., Piercy and Smyth, 1962). On the other hand, location may be of essential significance as to whether a trauma should be considered severe or not. For instance, a lesion of the left cerebral hemisphere may be severe if we consider verbal behavior but quite slight in respect to performance calling for eye-hand coordination. As far as differential-psychological theory formation is concerned, it would be essential to get an opportunity to analyze, for instance, the selective influence of focal traumas on different aspects of performance. Specific focal damage or lesions may, however, affect in different ways test performance in accordance with the relative degree of severity of injury. In addition, the degree of severity may be a certain kind of general intracranial quality or one concerning the whole personality, even though the damage or lesion causing the severity were very specific and strictly definable.

It seems to me that the best way to proceed while pursuing a solution to these complex problems would to be make a systematic structural analysis of the relevant traits that describe the variable under investigation or the so-called independent variable in different respects. In this, we may not be satisfied with the usual approach or, in other words, the manner in which homogeneous groups are formed on certain more or less subjective grounds and then compared with one another; instead, we may attempt to use as another basic starting point the variances within groups formed on the basis of different criteria (in other words, the differences between individuals in a deviant group or in a control group).

Not until an attempt is made to describe those differences — in short, the variance within a group — can we hope to obtain information on the extent to which such commonly-spoken dimensions as, for example, severity, location, etc., are real, and on the degree to which they are relevant. By no means is it a matter of attempting to make the groups under investigation heterogeneous instead of homogeneous, but only the fact that the variances, the interindividual differences, within the groups form the basic starting point of analysis. If one can find several measurable traits which bear a certain relation to the underlying independent variable that is being investigated, the covariance of these traits may be regarded as fixed points in regard to which some kind of idea of the »structural distance» of the groups can be formed. In this way it may, according to the present writers opinion, gradually grow possible to describe more accurately the investigated brain-pathological conditions on the basis of certain quantitatively varying dimensions.

When the brain injury investigation is considered as a whole, it would appear to be most important to arrive at an international agreement about the basic set of variables — at least a limited one — in terms of which the similarities and dissimilarities between different groups could be described. Thus a gradually increasing uniformity of the language used by different investigators might also prove possible, and more knowledge might be gained about the factors responsible for contradictory results. It might of course be difficult to reach agreement concerning the selection of variables to be used as a basic measurements. In point of fact, the results are in this connection influenced not only by the composition of groups subjected to investigation, but also by the choice of the sub-traits. As was pointed out above, the choice of the set of variables applied here may be critized on a great many grounds. In this respect the present study is an orientative experiment. It would appear, however, that agreement between different investigators could be reached concerning such a limited set of basic variables as would be as nearly objective as possible, could be systematically applied at different institutes, could be classified in greater detail, and so on. This might perhaps make it also possible to arrive, in the specification of the criterion sub-traits, »at methods which are complex enough to be adequate and simple enough to be manageable».

The validity correlations of the tests assumed to be »indicators» of brain injury show that, despite their multiple correlation of 0.74 with the criterion, fairly considerable overlapping between the brain injured group and the control group is found to occur in individual traits.

The results lend support to those obtained by Graham and Kendall (Graham and Kendall, 1946) as to the power of the Memory-for-Design test to discriminate between the brain injured and those with no brain injury is concerned, even though in the present study a scoring method different from the original one was used. Partly on the basis of Goldstein's wellknown results, it was desired to construct variables that would be associated with the abstractness-concreteness dimension. The difficulty of the mastery of abstract images or activities occurring in brain injured patients is revealed very clearly in a task as simple as when they are asked to draw a line symmetric with a model line. Likewise, in the MFD test the reversals manifested themselves in the concretization of a recalled gestalt. On the basis of the results of the transformation analysis it may be suspected, however, that a part of the significant differences encountered in the reversion traits stems from a general difficulty that the brain injured persons find in mastering visual images. In continuing the study, particular attention will be paid to the development of these test variables. The influence of spatial ability could possibly be diminished by administering the MFD test in a multiple choice form. The disturbances occurring in the area of simultaneous gestalting are also noteworthy in this context. It appears that the rotation of gestalts is not a disturbance specifically related to the memory performance, but, instead, a disturbance which may also occur in connection with a reproduction which the subject performs with the model pattern continually before his eyes. A multiphase series, where the most elementary task would be simple copying, the next task symmetric copying, and so on, might be capable of elucidating the area, i.e., the sub-function, where the disturbance is actually located. The plan for continuing the present project actually includes the elaboration of this kind of gestalting test.

Niilo Mäki,[1] for example, has previously given attention to the blue-green confusion in the brain injured when they are asked to name colors. It seems, however, that what is concerned is a comparatively specific trait, suspective to injuries with a certain particular localization only. A revalidation study is in any case necessary before anything can be said of the discriminative power of the trait in question. The comparatively high correlation with the reading speed variable attracts attention. The Stroops Test was included in the battery owing mainly to the complicated subtask contained in it; on the other hand, it was not expected that quite simple measures of the reading speed would also correlate as strongly as they did with the criterion. A concrete picture of the different degrees of significance of the complexity of the tasks in connection with brain injuries is given by the interrelations of the discriminative power of the various basic reading speed variables of the Color Naming test (Table III). The differences between the means will be commented on briefly at a later context. The Spiral test, too, seems to be comparatively specific. On the other hand, some of the control subjects were found to display the spiral symptom without any other signs of brain injury. The poor result may be partly due to the scoring method applied. As appears from Table XIII, the SAET is actually independent of the other component factors of intelligence. This fact would doubtless be advantageous in view of the useability of the test provided it does not mean that the variables formed in this way do not correlate with any other variables either. It is indeed possible that the time variables of the SAET have no relevance in cases of brain injury, and that the only relevant thing is whether the S sees or does not see an after-image. This problem too is intended to be taken into account in continuation studies.

Some remarks may be made on the results concerning the differences between the means. In the case of ability tests, in particular, the systematically weaker results of the brain injured deserve attention. The result was against expectations. Seen against this background, the very

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[1] Personal communication.

minor difference in the Information test appears to support the hypothesis underlying some of the deterioration indexes employed, viz., that, notwithstanding the brain injury, the mastery of the acquired amount of knowledge »holds», whereas the performance on verbal coprehension tests, for example, »does not hold». However, no differences between test variables were systematically computed. Particular attention should perhaps still be given to the discriminative power of such tests as the Aiming tests, the Maze test, and the Finger Tapping test. The verbo-motor variables were already referred to above. All of these tests with good discriminative power involve a motor (or verbo-motor) component. In describing the results of the factor analyses it was repeatedly discovered that the brain injury group was, in a sense, more differentiated than the control group with regard to the simple motor area. How far these two facts are symptoms of one and the same basic change remains an open question. On the basis of the results of the factorial analyses, however, one would be inclined to expect that the difference between the groups would have been marked particularly in the tapping variables. No alarmingly large differences were encountered in the variances of vabriables 14 and 15 either. However, no more detailed analysis of the results appears necessary here. The reader is referred to the comments presented in describing the results, as well as to the Summary and Conclusions chapter.

A few years ago the present writer carried out some pilot studies concerning the influence of physical stress on performances of mental arithmetic with university students. In the test situation the subjects had to do problems of mental arithmetic at the same time as they had to carry weights totalling 20 kg in the hands, whereas the Ss in the otherwise indentical control situation had to do the problems with no weights. (The experiment and control situations were, of course, randomized.) It was expected that the results in the test situation would prove inferior to those in the control situation. This was actually the case but — significant enough — with only a half of the group. It was found that the speed of the performance of the male students declined somewhat, but that the female students did the problems significantly faster under physical stress than without it. To account for the result it was hypothesized that the differences between the groups were perhaps due to alterations in motivation. Provided the hypothesis were correct (though it was not possible to verify), it might further be assumed that the differences in original physical *capacity* would correlate differently with inter-individual differences in mental capacity within the two groups. Now, if the physical capacity had actually been measured, it would (at least if the hypothesis concerning motivation would be correct) have had, in the female group, a negative correlation and, in the male group, a positive correlation with mental performance!

The present writer feels that the numerous changes and structural dissimilarities to which attention was repeatedly devoted in connection with the factor and transformation analyses described in the empirical part of this study are, *mutatis mutandis,* analogous with the structural change of a principal nature which appeared in a very overt shape in the preliminary experiment referred to. The appreciable differences which were encountered not only in the number of factors (that is, in the degree of their differentiation) and in their interrelationships, but also in the factorial composition of the variances of the different variables, may from this point of view be interpreted as reflecting the interaction between the brain injury and other concurrent, capacitory factors (such as age), on the one hand, and certain performance factor (such as response set, motivation, adaptation, etc.), on the other. Thus, the intention has not been to assert, on the basis of the results of the factor analyses, that what is concerned would actually be changes caused by the brain injury in the performance structure itself — granting that some kind of a basic structure can be spoken of. *What is wholly obvious, on the other hand, is that in the case of individuals suffering from the after-effects of a brain injury at least some of the mental abilities cannot be measured in the same way as in the case of intact individuals.*

Now the reader may be inclined to refer to the criticisms advanced by Super (op.cit.) and point out that structural distortions of this kind may even be expected to occur when use is made of so-called pure factor tests, which may in general give a somewhat artificial and superficial picture of the mental performance capacity itself. Furthermore, the following question may be asked. If an instrument (such as, say, a pattern method) is valid, is it necessary to know all the factors accounting for its validity? At this point the reader is referred to the Introduction. It must be emphasized that the ability structures are different and the changes are different in different tests and in different factors. No general change is discernible. (If not the observation that the factorial composition of many test variables is very susceptible to brain injuries is not regarded as such a typical change.) *It is obvious that if the variances of different sub-variables are accounted for by different factors, comparations of different groups in terms of the interrelationships of different sub-variables, for example, is not meaningful from a strictly scientific point of view.* On the other hand, it must certainly be considered an inherent characteristic of all factor tests that they are — if anything — intended to measure *certain dimensions.* In so far as differences may be demonstrated in these simplified and superficial tests, it is to be assumed that the same dimensions also influence in different ways-the more complex, multidimensional tests. Here a reference may be made to Cohen's results (op.cit.), although an IQ test battery is hardly more complex than the test batteries used in the present study. We may ask whether such sources of error and other influences could have been eliminated if use had been made of so-called power tests? Certain research results appear clearly to suggest that speed tests and power tests may pertain to mental performance components that are wholly independent from each other (cf., e.g., Nummenmaa, 1960). The answer to this question must be left to depend on the results of continuation studies. Here it may only be sufficient to point out that practical considerations place certain limits to its exploration. It is not impossible, either, that one-sided factor tests will prove somewhat more relevant when use is made of differential-diagnostic profile techniques, for example; but that, as far as general appraisal of an individual performance capacity is concerned, this may take place in a more valid way with a power tests. It is possible that the brain injured, who are easily irritated in general, are very allergic to the stress resulting from a time limit.

Finally, a short note should be added concerning the importance of the results for individual diagnostics. As far as diagnostic activity is at all conceived as consisting of the prognoses concerning certain component variables, it is clear that knowledge of the interrelationships between these component variables is regarded as important. In so far as it is possible to show that the interrelations of the basic dimensions involved in certain tests are different depending on whether the tests are administered to a brain injury group or to a control group, this evidently implies something concerning the probability of successful prognoses. Clinical experience may of course aid one in avoiding gross mistakes. From the psychometric point of view you must primarily seek to develop the tests in such a way that they invariably measure the same dimensions irrespective of the composition of the group to be tested.

SUMMARY AND CONCLUSIONS.

This research report consists of three parts, the first of which is a description of the set of problems under study, the second an account of the empirical investigation, and the third a discussion of the results obtained. The empirical investigation consists of two parts of which the latter must be regarded, in part, as a kind of cross-check of the former, even though it was primarily intended to supplement the first part. As to its general approach the investigation may be characterized as a psychometric.

The following procedures, statistical computations and analyses were adopted in the course of the study:

Part I

1. Criterion of Brain Injury.

In order to obtain a reliable unidimensional criterion of brain injury a discriminance analysis was carried out. The measurement of the severity of brain injury was assumed to be one of the possibly relevant criterion dimensions which may characterize the deviancy in question. (The study have been continued later on including the measurements of location and duration among the criterion dimensions.) The discriminance analysis was based on twenty anamnestic data or neurological findings which were chosen from the routine case records kept at hospitals according to the assumed relevance of the traits as a sub-measurement of the degree of severity of brain injury. When one hundred patients had been tested a neurologist subjectively estimated the severity of possibly brain injury of each subject on the basis on the individual symptoms on the twenty traits. The sample consisted of both brain injured and non brain injured subjects. On the basis of the four-point scale classification a discriminance analysis was carried out. A severity index was computed for each subject according to the discriminant coefficients obtained. To test the reliability of the rating an other neurologist was asked to rate the same sample of one hundred subjects. On the basis of the observed correlation +0.946 it was concluded that the subtraits had the same meaning for both neurologists.

2. Validity Correlations between Criterion and Test Variables.

Following the formation of the criterion dimension an orientative study was made to examine the validity of the tests included in the battery (of 18 tests) under the assumption that they are sensitive to brain pathology (Color Naming, SAET, MFD, Symmetric drawing, Silhouette). All the validity correlations were positive and, with the exception of SAET, significant (at the 5 % level). On the basis of observed multiple correlation between the test variables and the criterion R = + 0.740 it may be concluded that the tests have together a satisfactory status validity to discriminate more severe brain injured from less severely injured. This result gives simultaneously some evidence concerning the relevance of the criterion dimensions.

3. Comparison of the Mean Performance of Brain Injury and Control Groups.

The groups to be compared were formed on the basis of individual severity indexes. Seventy subjects were included in both groups. It was observed that the brain injury group was inferior to the control group without exception in all the ability and performance tests included in the battery. The differences between the groups were highly significant with regard to the following test variables: Color Naming test (Colored text, reading time, Difference in time reading black or colored texts Color dots, reading time); Verbal tests (Word Groups, Opposites); Aiming tests (Dot Aiming, Triangles), a Visual test »Pieces»; Memory for Design (reversals); and Silhouette, reversals. On the other hand, the Information test did not differentiate significantly the groups from each other. It may be concluded that the battery may be considered as a valid instrument to discriminate more severe injured from less severely injured in terms of the operational definition given but as a differential diagnostic tool it hardly has any value.

4. Comparison of the Ability Structures of the Groups.

Factor analyses and a transformation analysis were carried out on the basis of the intercorrelations between the 21 testvariables (+ age). It was observed that the ability structures of two groups differed remarkable from each other. In general the number of factors necessary for explaining the variances were greater in the control group (six and five respectively). There were also other not unimportant qualitative differences between the factor structures of the groups, indicating most probably that the brain injured subjects are liable to handle the tasks with the »aid» of different underlying factors than do the subjects of the control group.

Two different kinds of »abnormal transformation» were established in the brain injury group in connection with more prominent tendency toward a formation of »general factors»: First, tests normally appearing on different factors are likely to appear on one and the same factor. Second, tests normally representing distinctly different areas of performance may together form a factor of their own probably because some very specific characteristics common to the tests (e.g. a set, method of exposure, etc.) may come into operation under the influence of brain injury. In addition it was observed that the characteristics of the factors pattern were more dependent of the rotation method used in the brain injury group than in the control group.

On the basis of the results there seems to be convincing reason to stress the importance of a clarification of the structure of the variance within the deviant group before proceeding to a wider use of any kind of pattern analytical method based on a comparison of different performance subtraits. If we can accept the operational definition given the results indicate that some of the performance tests may have an entirely different character for a brain injured subject. Without such a general »analysis of co-variance» we do not have any idea what »holds» and what does »not hold» in a performance profile. Under such circumstances relatively large differences may easily be, and have been, found in comparisons of mean patterns of different groups partly because some of the testperformances do not be symptoms of indentical underlying abilities (dependent variables) in different groups.

Part II

5. Continuation of Analysis of Factor Structures.

A number of experiments were made with different types of factor solutions to test the dependency of the established factorial pattern on the mode of description. The structural characteristics being the main theme of the study special attention was paid to the number of factors and their degree of differentiation. A number of matrices were computed varying the number of factors, the determinant of the cosinus matrix (selecting more and less orthogonal pattern), and the level of communality required for a testvariable to be selected to a factor test (= test vector). — Again it was found that the factor pattern of the brain injury group was not so clear cut as that of the control group. Quite often tests have loadings on several factors simultaneously and tests being represented on two factors in the control group appear on one and the same factor in the brain injury group. Also one peculiar trend was observed. Whereas in the former, in all the analyses, the speed variables (reading, tapping, and aiming speed) consistently appeared on one and the same factor, the aiming and tapping variables always formed two distinctly different psycho-motor speed factors in the latter. The reading speed variable was likely to be associated with verbal comprehension tests in the brain injury group! It was established that with respect to this eye-hand-coordination-motor-speed area the brain injury group appeared to be the more differentiated one as to the factor structure! The practical implications are, of course, not less important.

6. A Discriminance Analysis of Anamnestic and Neurological Findings with a Group of Severely Injured.

A cross-validation study on the discriminance analysis performed during the first part was made on the basis of same measurements and subtraits. Also the ratings were made by the same neurologist. The traits were reanalyzed because in the original study the PEG, for example, was not made to all subjects (depending on its extreme characteristics as a clinical instrument).

The analysis was made on 62 severely injured subjects. Marked differences was observed between the figures of the two analyses. There also appeared differences regarding the relative share of various subtraits as discriminators (discriminant loadings). A correlation between the two indices — in a group of 70 randomly selected subjects — attained a value of $r = + 0.67$, which was considered satisfactory, having in mind that the last group was very homogeneous as to the relevant characteristics. However, especially the data collecting and recording system can be strongly critized. A thoroughly revision of the methods is needed in order to achieve a reliable set of subtraits which can be systematically carried out with every patient.

7. Factor Analysis of the Ability Structure of the Group of Severely Injured.

Factor analysis was carried out on the basis of intercorrelations of 33 variables, including 30 testvariables and age, duration of injury and severity-index (based on the results of the above mentioned discriminance analysis). Three different rotations were tried (with six, five, and four factors). The total variance within the group were satisfactorily explained — according to the authors opinion — by referring to four factors which were: a factor of general intelligence, a simple psycho-motor speed factor, then a test factor having the highest loadings on SAET variables, and a factor tentatively interpreted as »a general syndrome» of brain injury. This last factor is loaded on tests assumed to be sensitive to brain pathology. The loadings of the severity index were relative of the same magnitude on all the relevant factors. The correlations between severity index and various test variables were, however, in general very low. Also in this matrix (as well as in the other trials with five and six factors) the tapping speed variables form a factor of their own. The aiming and verbo-motor speed variables were more closely connected with higher functions.

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Table 1

Centroid Matrix
Control Group

	I	II	III	IV	V	VI	h^2
1	67	21	—12	28	22	09	64
2	66	33	27	—11	08	—20	68
3	73	33	19	06	—13	—12	71
4	71	44	19	—20	—04	21	82
5	69	21	34	—30	—11	03	74
6	61	38	11	—32	17	05	66
7	58	28	—04	—09	25	14	51
8	43	41	33	22	—07	—27	59
9	59	06	—20	29	34	12	61
10	53	—17	—30	22	29	—19	57
11	65	—26	30	—16	—07	10	62
12	49	—14	10	04	12	—12	30
13	56	—43	11	18	—13	14	58
14	42	—47	08	30	17	—10	53
15	48	—60	12	14	07	13	65
16	49	—56	19	15	—10	23	68
17	—25	29	08	23	19	29	33
18	—25	10	07	38	23	11	29
19	46	24	—50	06	—41	16	72
20	39	27	—42	04	—20	15	47
21	67	19	—09	06	—17	—10	54
22	26	—32	—44	—24	10	19	47

1. Completion of Squares
2. Word Groups
3. Synonyms
4. Opposites
5. Arithmetic Problems
6. Completion of Arithmetic Problems
7. Pieces
8. Information
9. Maze 1
10. Maze 2
11. Color Text, time
12. Diff.; black text-colored text
13. Dot Aiming
14. Triangles
15. Finger Tapping
16. Hand Tapping
17. Finger Tapping, diff. right-left
18. Hand Tapping, diff. right-left
19. Symmetric Drawing, reversals
20. Silhouette, reversals
21. Memory for Design, reversals
22. Age

Table 2

Centroid Matrix
Brain-Injury Group

	I	II	III	IV	V	h^2
1	61	—24	20	05	08	48
2	80	21	27	—19	09	80
3	69	19	22	—17	—22	64
4	74	22	21	—33	—20	79
5	74	10	23	24	15	69
6	70	—04	15	06	—18	55
7	63	—09	19	—20	03	48
8	55	40	19	—25	30	65
9	47	—20	—28	20	20	42
10	45	—43	—18	13	18	47
11	69	25	05	07	06	55
12	51	08	05	32	—31	47
13	80	09	—24	20	11	76
14	62	27	—36	35	06	71
15	48	22	—41	—37	—17	61
16	59	27	—46	—23	—03	69
17	12	27	23	29	30	31
18	—13	34	21	31	18	31
19	48	—36	06	—09	23	42
20	39	—42	24	15	—19	44
21	63	—18	—16	—16	26	55
22	47	—31	—05	17	—34	46

Decimal point and positive signs omitted.

Table 3

Rotated Matrix
Varimax Solution
Control Group

	I	II	III	IV	V
1	+45	+24	+31	—17	+50
2	+77	+11	+07	+00	+14
3	+73	+21	+32	—07	+06
4	+84	+02	+21	+09	+10
5	+81	+18	+06	+21	—06
6	+75	—07	+04	+18	+25
7	+55	+03	+12	+06	+41
8	+59	+09	+17	—35	—04
9	+28	+28	+22	—13	+61
10	+09	+37	+20	+04	+58
11	+49	+55	—04	+26	—02
12	+31	+38	+01	+06	+21
13	+07	+65	+27	+17	+16
14	+02	+67	—05	—05	+26
15	+05	+76	—07	+15	+16
16	+10	+77	+01	+13	—01
17	—04	—26	—10	—40	+06
18	—18	—07	—12	—46	+11
19	+18	+00	+78	+18	+11
20	+19	—07	+59	+12	+21
21	+49	+22	+45	+07	+15
22	—12	+16	+12	+50	+35

Decimal points omitted

Table 4

Rotated Matrix
Extended Cosine Solution
Control Group

	I	II	III	IV	V
1. Completion of Squares	+30	+28	+34	+45	+19
2. Word Groups	—14	+69	+05	+11	+02
3. Synonyms	—14	+68	+34	—06	+19
4. Opposites	+10	+56	+43	—14	+25
5. Arithmetic Problems	—19	+60	+17	—20	+29
6. Completion of Arithmetic Problems	—11	+39	+33	—02	+01
7. Pieces	+08	+21	+41	+15	+10
8. Information	.00	+79	.00	.00	.00
9. Maze 1	+38	+09	+21	+64	+18
10. Maze 2	.00	.00	.00	+78	.00
11. Color Text, time	—09	+33	—10	+06	+56
12. Diff.; black text-colored text	—21	+20	+04	+16	+24
13. Dot Aiming	+02	+12	+02	+14	+68
14. Triangles	—08	+02	—16	+36	+44
15. Finger Tapping	—08	—09	—06	+16	+70
16. Hand Tapping	.00	.00	.00	.00	+83
17. Finger Tapping, diff. right-left	+62	.00	.00	.00	.00
18. Hand Tapping, diff. right-left	+40	—07	—02	+02	+03
19. Symmetric Drawing, reversals	+05	+06	+73	+08	+04
20. Silhouette, reversals	.00	.00	+74	.00	.00
21. Memory for Design, reversals	—09	+44	+32	+20	+10
22. Age	—02	—45	+14	+44	+08

Decimal points omitted

Table 5

Transformation Matrix

	I	II	III	IV	V	VI	Σ × (Ch)	Σ × ²
1	+135	+143	—150	+043	+107	+022	+300	075
2	—148	—076	—086	+116	—025	+279	+060	127
3	+057	—089	—062	+009	+293	—164	+044	128
4	+057	—058	+091	+238	+170	—018	+480	101
5	—010	+147	—055	—389	—255	—167	—729	269
6	—062	—027	+132	—122	—023	+027	—075	038
7	+017	—058	—003	+216	—155	—142	—125	095
8	—112	—104	—012	+142	+024	+168	+106	072
9	+195	+051	+238	—012	—008	—111	+353	110
10	+023	+079	—031	+034	—072	—142	—109	034
11	+026	+072	—178	—105	—098	+259	—024	125
12	—004	—100	—149	—355	+226	+001	—381	209
13	—154	+126	—050	—210	—052	—063	—403	093
14	—149	—210	+024	—296	—011	+132	—510	172
15	+104	—080	+052	+390	+065	—165	+366	203
16	+033	+017	+132	+204	—017	+074	+443	066
17	—229	—014	—047	—156	—024	+207	—263	123
18	+000	—190	—166	—222	+024	—258	—812	180
19	—085	—039	—004	+020	—193	+289	—012	130
20	—025	—006	—126	—225	+095	—002	—289	076
21	—004	+070	+197	+088	—158	—215	—022	123
22	—260	—118	—139	—022	+108	+256	—175	179

Decimal points omitted

Appendix 4

Table 6

$(A_C L - F_B) \; (DL)^{-1}$

Number of test							ΣX	Ch	ΣX²
1	—01	+09	—21	+18	+13	—03	+14	+14	10
2	—14	—25	—93	+59	—47	+61	—58	—58	1.88
3	—06	+48	+35	+12	—06	—62	+20	+20	76
4	+62	—34	+33	+15	+17	—02	+90	+90	65
5	—69	+53	+21	—66	+14	—35	—82	—82	1.37
6	—17	+19	±00	—13	—21	+04	—28	—28	13
7	+63	—71	+61	—22	+57	—06	+83	+83	1.65
8	+08	—27	—48	+42	—29	+38	—16	—16	70
9	±46	—13	+77	—45	+40	—11	+94	+94	1.19
10	+23	—18	+42	—29	+41	—22	+36	+36	57
11	—59	+16	—1.04	+40	—39	+54	—92	—92	2.05
12	—12	+1.28	—52	+28	—77	—45	—1.34	—1.34	4.12
13	—47	+41	—10	—26	—10	—24	—76	—76	54
14	—94	+73	—62	+22	—87	+09	—1.39	—1.39	2.61
15	+1.07	—81	+86	—05	+68	—17	+1.57	+1.57	3.04
16	+62	—59	+14	+03	+22	+34	+75	+75	91
17	—66	+35	—89	+29	—67	+32	—1.26	—1.26	2.00
18	—66	+72	+36	—15	—12	—77	—62	—62	1.72
19	—17	—33	—82	+33	—35	+78	—58	—57	1.66
20	—73	+74	—37	+12	—41	—26	—90	—90	1.46
21	+71	—55	+1.01	—67	+69	—20	+99	+99	2.80
22	—62	+31	+1.13	+69	—85	+33	—1.26	—1.26	3.06
ΣX²	+8.22	+6.44	+9.07	+2.89	+5.07	+3.30			

Decimal points omitted

Appendix 5

Table 7

Principal Axis Factor Matrix Control Group

	I	II	III	IV	V	VI	VII	$h^2(5)$	$h^2(6)$	$h^2(7)$
1	—.688	—.056	—.236	.266	—.017	—.148	.022	.603	.625	.626
2	—.707	—.295	.227	.096	—.026	—.013	—.103	.649	.649	.659
3	—.763	—.225	.104	—.003	—.142	—.036	.122	.664	.665	.680
4	—.756	—.374	.088	—.090	.022	—.216	—.041	.728	.775	.777
5	—.733	—.195	.349	—.172	.102	.066	—.048	.738	.742	.744
6	—.659	—.363	.116	—.076	.368	.099	.039	.721	.731	.732
7	—.606	—.199	—.136	—.007	.285	—.077	.166	.507	.513	.540
8	—.501	—.358	.246	.298	—.322	.088	.015	.632	.640	.640
9	—.594	.107	—.316	.386	.102	—.028	—.209	.623	.624	.668
10	—.498	.278	—.298	.325	.072	.333	—.206	.525	.636	.678
11	—.635	.264	.320	—.111	—.044	—.050	—.203	.590	.592	.634
12	—.479	.170	.058	.009	.141	.076	.256	.282	.287	.353
13	—.518	.505	.032	—.083	—.134	—.041	.097	.548	.550	.560
14	—.378	.575	.033	.218	—.007	.054	.233	.523	.526	.580
15	—.421	.687	.110	—.023	.046	.008	.064	.663	.663	.667
16	—.431	.625	.137	—.096	—.111	—.274	—.005	.617	.692	.692
17	.198	—.194	—.027	.414	—.011	—.396	—.063	.250	.406	.410
18	.228	—.026	—.063	.371	.044	—.008	.274	.196	.196	.271
19	—.448	—.152	—.489	—.229	—.294	.068	—.005	.601	.606	.606
20	—.376	—.216	—.542	—.282	—.046	—.108	.196	.564	.575	.614
21	—.677	—.097	—.114	—.063	—.183	.166	—.010	.519	.546	.546
22	—.210	.316	—.324	—.222	.178	—.139	—.229	.330	.349	.401

Appendix 6

Table 8

Principal Axis Factor Matrix Brain-Injury Group

	I	II	III	IV	V	VI	VII	$h^2(5)$	$h^2(6)$	$h^2(7)$
1	—.587	.275	.167	.055	.166	.029	.096	.479	.480	.489
2	—.819	—.195	.175	.152	.049	.232	—.047	.766	.819	.822
3	—.712	—.214	.190	.280	—.132	—.214	—.214	.684	.730	.775
4	—.760	—.227	.072	.368	—.031	—.043	.001	.770	.772	.772
5	—.758	—.020	.230	—.149	.041	—.168	.047	.651	.679	.681
6	—.710	.094	.163	.097	—.182	—.146	.073	.582	.603	.608
7	—.633	.007	.104	.202	.180	—.207	—.019	.485	.527	.528
8	—.565	—.453	.128	.019	.237	.204	—.063	.598	.640	.644
9	—.453	.271	—.167	—.319	.202	—.168	—.169	.449	.477	.505
10	—.423	.456	—.123	—.123	.197	—.140	—.091	.457	.477	.485
11	—.704	—.173	.066	—.106	—.062	.252	—.049	.545	.609	.611
12	—.511	.064	.156	—.138	—.407	—.123	.087	.474	.489	.496
13	—.797	.034	—.126	—.270	—.045	—.008	—.047	.727	.727	.730
14	—.614	—.104	—.178	—.484	—.237	—.084	—.084	.710	.718	.725
15	—.496	—.243	—.589	.162	—.015	—.113	.298	.680	.692	.781
16	—.587	—.252	—.537	—.029	—.021	.051	.076	.698	.701	.707
17	—.125	—.244	.322	—.418	.130	.095	.090	.371	.380	.388
18	.111	—.287	.279	—.324	.102	—.240	.277	.288	.346	.422
19	—.448	.331	—.002	.049	.232	.367	.145	.366	.501	.522
20	—.361	.482	.222	.123	—.064	.053	.235	.431	.434	.490
21	—.626	.169	—.176	.010	.290	—.120	—.040	.536	.551	.552
22	—.438	.390	—.042	.011	—.365	.178	—.026	.478	.510	.511

Appendix 7

Table 9

Rotated Matrix
Five Factors, Cosine Solution, Communality Level=400,
Determinant=.558 Control Group

	I	II	III	IV	V
1	.118	.281	.513	—.034	.169
2	.437	.468	—.030	.151	.022
3	.289	.503	—.087	.288	.246
4	.517	.364	—.143	.175	.256
5	.687	.253	—.311	.430	.036
6	.849	.000	.000	—.000	—.000
7	.561	—.050	.235	—.043	.129
8	—.000	.795	—.000	.000	.000
9	.094	.085	.781	—.138	.013
10	.000	—.000	.725	—.000	.000
11	.341	.193	—.175	.698	—.027
12	.342	—.037	.153	.285	—.050
13	—.008	.073	.047	.694	.127
14	—.032	—.022	.433	.409	—.210
15	.155	—.166	.183	.692	—.138
16	—.000	—.000	.000	.785	.000
17	—.174	.161	.383	—.530	—.273
18	—.176	.004	.425	—.436	—.293
19	—.240	.276	—.058	.161	.821
20	—.000	—.000	.000	—.000	.751
21	.092	.382	—.012	.299	.418
22	.144	—.406	.157	.248	.266

Appendix 8

Table 10

Rotated Matrix
Five Factors, Cosine Solution, Communality Level=.400, Determinant=.431 Brain-Injury Group

	I	II	III	IV	V
1	.324	.255	—.131	.017	.479
2	.670	—.212	.152	.164	.478
3	.552	—.542	.267	.253	.596
4	.580	—.420	.065	.429	.570
5	.515	.031	.328	—.136	.368
6	.283	—.321	.373	.147	.653
7	.501	.069	—.181	.198	.422
8	.773	.000	.000	—.000	.000
9	.000	.670	.000	—.000	.000
10	—.067	.624	—.193	.107	.233
11	.418	—.141	.427	.056	.271
12	.027	—.485	.789	—.043	.491
13	.188	.171	.459	.135	.234
14	.000	—.000	.843	—.000	.000
15	.000	—.000	.000	.824	—.000
16	.046	.081	.189	.651	—.058
17	.434	.157	.312	—.626	—.272
18	.321	.060	.215	—.570	—.362
19	.152	.447	—.301	.125	.325
20	.000	.000	.000	—.000	.657
21	.246	.534	—.282	.296	.205
22	—.289	—.262	.470	.238	.619

Appendix 9

Table 11

Rotated Matrix
Six Factors, Cosine Solution, Communality Level=.400, Determinant=.582 Control Group

	I	II	III	IV	V	VI
1	.211	.198	.344	.258	.335	.315
2	.450	.461	—.058	.193	.037	.039
3	.280	.517	—.069	.269	—.040	.231
4	.554	.335	—.239	.294	.124	.312
5	.635	.307	—.207	.275	—.205	—.052
6	.855	—.000	.000	.000	—.000	.000
7	.618	—.100	.130	.125	.194	.214
8	—.000	.800	—.000	.000	.000	—.000
9	.195	—.007	.619	.174	.364	.170
10	.000	.000	.798	.000	.000	—.000
11	.297	.237	—.082	.591	—.168	—.100
12	.331	—.024	.201	.258	—.050	—.072
13	—.050	.113	.153	.601	—.153	.062
14	—.027	—.028	.463	.452	.021	—.203
15	.083	—.136	.281	.627	—.121	—.192
16	.000	—.000	.000	.832	.000	.000
17	.000	.000	—.000	.000	.637	—.000
18	—.094	—.073	.267	—.194	.304	—.165
19	—.300	.332	.078	—.018	—.214	.737
20	.000	—.000	.000	—.000	—.000	.758
21	.030	.442	.137	.117	—.227	.324
22	.126	—.420	.144	.301	.044	.288

Appendix 10

Table 12

Rotated Matrix
Six Factors, Cosine Solution, Communality Level=.400, Determinant=.328 Brain-Injury Group

	I	II	III	IV	V	VI
1	.424	—.048	.074	.106	—.154	.342
2	.194	.469	—.238	.303	.072	.333
3	.673	.097	—.314	.351	.108	—.091
4	.591	.140	—.406	.237	.262	.131
5	.322	.313	.298	.324	—.188	—.101
6	.453	—.076	—.113	.476	.032	.121
7	.726	—.000	—.000	.000	.000	.000
8	—.000	.800	—.000	.000	.000	—.000
9	.000	—.000	.691	.000	.000	.000
10	.261	—.305	.452	—.029	—.006	.223
11	—.249	.536	.011	.422	.105	.260
12	.000	—.000	—.000	.699	—.000	.000
13	—.188	.286	.410	.410	.193	.120
14	—.724	.491	.486	.592	.235	.012
15	—.000	.000	—.000	.000	.832	.000
16	—.332	.259	.147	.131	.740	.095
17	—.361	.765	.444	.093	—.477	—.277
18	—.028	.501	.447	—.063	—.455	—.656
19	.000	—.000	.000	.000	.000	.708
20	.405	—.410	—.165	.276	—.183	.496
21	.368	—.037	.336	—.112	.164	.151
22	—.147	—.351	—.210	.611	.212	.600

Appendix 11

Table 13

Rotated Matrix
Five Factors, Cosine Solution, Communality Level=.400,
Determinant=.539 Control Group

	I	II	III	IV	V
1	.100	.175	.524	.030	.156
2	.437	.489	—.062	.154	.047
3	.353	.470	—.123	.246	.273
4	.600	.310	—.150	.111	.261
5	.710	.340	—.397	.398	.104
6	.849	.000	.000	—.000	.000
7	.570	—.123	.252	—.026	.113
8	.000	.795	.000	—.000	.000
9	—.000	.000	.790	—.000	—.000
10	—.100	—.051	.701	.142	.012
11	.308	.343	—.336	.728	.096
12	.286	.023	.076	.349	.008
13	—.026	.149	—.102	.737	.240
14	—.183	.101	.300	.570	—.111
15	—.000	—.000	.000	.814	.000
16	—.055	.144	—.183	852	.139
17	—.270	.140	.463	—.446	—.336
18	—.291	.004	.480	—.332	—.337
19	—.000	.000	—.000	.000	.775
20	.222	—.282	.085	—.149	.683
21	.196	.280	—.034	.239	.433
22	.153	—.472	.125	.247	.289

Appendix 12

Table 14

Rotated Matrix
Five Factors, Cosine Solution, Communality Level=.400, Determinant=.422 Brain-Injury Group

	I	II	III	IV	V
1	.511	.433	—.134	—.166	.056
2	.875	.000	—.000	—.000	—.000
3	.829	—.263	—.129	.049	.261
4	.839	—.158	—.253	.233	.186
5	.663	.181	.308	—.267	—.063
6	.578	—.036	—.003	—.090	.390
7	.670	.238	—.209	.045	—.029
8	.757	.008	.187	.016	—.465
9	—.038	.626	.334	—.017	—.219
10	—.000	.676	—.000	—.000	.000
11	.535	—.019	.340	—.036	—.017
12	.266	—.256	.339	—.219	.485
13	.275	.255	.487	.045	—.005
14	—.000	.000	.843	.000	—.000
15	.000	—.000	—.000	.824	.000
16	.016	.053	.266	.672	—.094
17	.298	.042	.614	—.516	—.502
18	.155	—.086	.480	—.426	—.465
19	.264	.550	—.183	—.008	—.011
20	.284	.263	—.286	—.253	.459
21	.300	.583	—.045	.209	—.180
22	.000	.000	.000	.000	.692

Appendix 13

Table 15

Rotated Matrix
Six Factors, Cosine Solution, Communality Level=.400, Determinant=.551 Control Group

	I	II	III	IV	V	VI
1	.339	.056	.311	.266	.426	.332
2	.466	.444	—.062	.194	.048	.041
3	.374	.413	—.093	.275	.027	.243
4	.681	.195	—.272	.301	.214	.329
5	.614	.330	—.201	.273	—.220	—.055
6	.855	—.000	.000	.000	—.000	.000
7	.706	—.196	.107	.130	.256	.226
8	.000	.800	—.000	—.000	.000	—.000
9	.264	—.084	.601	.178	.414	.180
10	—.000	.000	.798	—.000	—.000	—.000
11	.256	.282	—.071	.589	—.197	—.106
12	.302	.008	.209	.256	—.070	—.076
13	—.024	.085	.147	.602	—.135	.066
14	—.109	.063	.484	.447	—.037	—.214
15	.004	—.050	.302	.622	—.177	—.203
16	—.000	—.000	.000	.832	.000	.000
17	—.000	.000	.000	.000	.637	.000
18	—.161	.001	.285	—.198	.256	—.174
19	.000	—.000	—.000	—.000	.000	.778
20	.309	—.341	—.080	.019	.220	.801
21	.162	.296	.103	.125	—.133	.342
22	.244	—.549	.114	.308	.127	.304

Appendix 14

Table 16

Rotated Matrix
Six Factors, Cosine Solution, Communality Level=.400, Determinant=.325 Brain-Injury Group

	I	II	III	IV	V	VI
1	.395	.296	.013	—.187	.340	—.062
2	.646	—.325	.271	—.030	.665	—.193
3	.854	—.000	.000	.000	.000	—.000
4	.750	—.162	—.063	.195	.297	—.040
5	.650	.323	.430	—.307	.084	—.268
6	.616	.200	.077	—.127	—.054	.208
7	.630	.317	—.074	.011	.156	—.226
8	.509	—.390	.448	—.005	.703	—.630
9	—.025	.661	.322	—.016	—.037	—.219
10	.000	.691	.000	.000	.000	—.000
11	.362	—.296	.524	—.052	.491	—.124
12	.393	.108	.321	—.248	—.310	.372
13	.235	.233	.558	.033	.127	—.078
14	—.000	.000	.847	—.000	—.000	—.000
15	—.000	—.000	.000	.832	.000	.000
16	—.055	—.111	.307	.684	.185	—.077
17	.210	—.091	.715	—.530	.253	—.581
18	.243	.161	.463	—.447	—.218	—.560
19	—.000	.000	.000	—.000	.708	—.000
20	.251	.261	—.221	—.268	.109	.396
21	.221	.484	.048	.201	.229	—.251
22	—.000	.000	.000	.000	.000	.714

Appendix 15

Table 17

Rotated Matrix
Six Factors, Cosine Solution, Communality Level=.500, Determinant=.297 Control Group

	I	II	III	IV	V	VI
1	.791	.000	.000	.000	.000	—.000
2	.089	.427	.437	—.097	.164	.003
3	.049	.353	.410	—.113	.258	.223
4	.397	.510	.167	—.428	.168	.162
5	—.409	.790	.360	—.041	.411	.117
6	—.000	.855	.000	.000	—.000	—.000
7	.475	.502	—.230	—.079	—.030	.026
8	—.000	.000	.800	—.000	.000	—.000
9	.768	—.066	—.138	.299	—.080	—.143
10	.000	.000	—.000	.798	.000	—.000
11	—.367	.414	.308	.073	.712	.048
12	—.131	.358	.017	.260	.300	—.021
13	—.251	.083	.102	.245	.687	.171
14	—.070	—.079	.068	.512	.470	—.185
15	—.328	.145	—.027	.430	.733	—.065
16	.000	.000	—.000	.000	.832	—.000
17	1.183	—.508	—.084	—.465	—.398	—.498
18	.475	—.365	—.033	.098	—.358	—.374
19	.000	—.000	.000	.000	.000	.778
20	.408	.133	—.370	—.241	—.119	.629
21	—.247	.268	.314	.200	.208	.446
22	.236	.142	—.566	.021	.229	.204

Appendix 16

Table 18

Rotated Matrix
Six Factors, Cosine Solution, Communality Level=.500, Determinant=.235 Brain-Injury Group

	I	II	III	IV	V	VI
1	.105	.181	—.125	—.345	.590	.280
2	.160	.737	—.146	—.040	.054	.406
3	.854	—.000	.000	—.000	—.000	.000
4	.534	.337	—.252	.196	.004	.227
5	.556	—.062	.436	—.429	.449	—.165
6	.640	—.133	.139	—.184	.206	.173
9	.481	.005	—.108	—.122	.491	—.056
8	.000	.800	.000	.000	—.000	.000
9	—.056	—.315	.449	—.229	.778	—.203
10	—.062	—.294	.111	—.229	.839	.053
11	.008	.569	.207	—.041	—.028	.315
12	.624	—.325	.508	—.229	—.078	.090
13	.115	.015	.526	—.067	.370	.060
14	.000	.000	.847	—.000	—.000	—.000
15	—.000	.000	—.000	.832	—.000	.000
16	—.189	.214	.188	.688	—.009	.088
17	.022	.267	.562	—.544	.059	—.351
18	.397	—.265	.608	—.462	.049	—.752
19	—.548	.638	—.388	—.126	.477	.664
20	.143	—.014	—.239	—.374	.391	.518
21	—.000	.000	—.000	—.000	.742	.000
22	—.000	.000	—.000	.000	—.000	714

Appendix 17

Table 19

Rotated Matrix
Six Factors, Cosine Solution, Communality Level=.500, Determinant=.279 Control Group

	I	II	III	IV	V	VI
1	—.589	.770	.493	.057	.313	.052
2	.235	.303	.437	—.053	.064	—.040
3	.212	.226	.394	—.078	.167	.186
4	.064	.645	.347	—.354	.164	.130
5	.861	—.000	—.000	.000	—.000	.000
6	.603	.432	—.113	.076	—.270	—.098
7	—.000	.716	—.000	.000	—.000	—.000
8	—.000	—.000	.800	—.000	.000	.000
9	—.618	.715	.350	.349	.244	—.085
10	—.000	.000	.000	.798	.000	—.000
11	.565	—.148	.024	.083	.436	—.023
12	.350	.053	—.112	.282	.136	—.070
13	.245	—.202	—.065	.234	.561	.145
14	—.004	—.108	.035	499	.468	—.180
15	.346	—.246	—.250	.420	.557	—.103
16	.000	—.000	—.000	.000	.832	.000
17	—1.239	.897	.721	—.424	.230	—.361
18	—.611	.279	.312	.100	—.055	—.301
19	.000	—.000	—.000	.000	—.000	.778
20	—.210	.465	—.133	—.199	.001	.641
21	.373	—.105	.124	.206	.026	.399
22	—.075	.302	—.438	.051	.277	.204

Appendix 18

Table 20

Rotated Matrix
Six Factors, Cosine Solution, Communality Level=.500, Determinant=.228 Brain-Injury Group

	I	II	III	IV	V	VI
1	.543	—.120	.136	—.195	.330	.013
2	.154	.804	—.164	—.027	—.075	.488
3	.594	.532	—.238	—.006	—.595	.604
4	.374	.668	—.399	.193	—.370	.603
5	.745	.006	.503	—.318	—.081	.031
6	.610	.137	.062	—.135	—.305	.506
7	.726	—.000	—.000	—.000	—.000	.000
8	.000	.800	—.000	—.000	—.000	—.000
9	.583	—.833	.848	—.030	.570	—.693
10	.627	—.854	.542	—.014	.616	—.477
11	—.017	.591	.191	—.048	—.025	.337
12	.371	.112	.296	—.253	—.488	.576
13	.375	—.142	.676	.027	.172	—.073
14	—.000	—.000	.847	.000	.000	—.000
15	.000	.000	.000	.832	—.000	.000
16	—.139	.102	.236	.687	.125	—.040
17	.063	.244	.585	—.529	.025	—.369
18	.315	—.048	.522	—.452	—.243	—.500
19	.000	—.000	.000	.000	.708	—.000
20	.412	—.167	—.086	—.275	.167	.393
21	.592	—.460	.366	.190	.506	—.429
22	—.000	.000	—.000	.000	.000	.714

Appendix 19

Table 21

Principal axis factor matrix

	I	II	III	IV	V	VI
1. Word Group	—81	—13	20	08	03	21
2. Information	—72	18	11	04	—30	—38
3. Synonyms	—64	—13	28	37	—04	—19
4. Opposites	—76	—13	28	26	10	—20
5. Completion of Arithmetic Problems	—67	—15	26	31	22	11
6. Arithmetic Problems	—76	—06	18	26	08	15
7. Pieces	—67	—08	38	24	16	—11
8. Completion of Squares	—80	—07	15	—01	—07	—01
9. Finger Tapping, right hand	—59	—44	—55	04	15	03
10. » » , left hand	—53	—49	—57	03	08	—11
11. Hand Tapping, right	—59	—46	—54	02	—01	07
12 » » , left	—52	—55	—53	—01	—08	—11
13. Silhouette, reversals	44	—10	02	30	—31	24
14. Symmetric Drawing, reversals	65	04	—07	28	—26	18
15. SAET, right	20	—70	27	—34	—12	—20
16. SAET, left	16	—76	17	—36	09	—15
17. SAET, Symptom	04	25	—28	38	41	18
18. MFD, omissions	62	—07	11	—03	—18	09
19. MFD, errors	33	07	—19	—04	—36	—16
20. Maze 1	64	—47	12	—01	13	—13
21. Dot Aiming	—54	—46	20	07	—36	30
22. Triangles	—57	—39	15	—04	—48	28
23. Color Text, reading time	65	—43	12	24	03	—05
24. Color Dots, reading time	70	—17	—06	29	—04	—26
25. Colored Text, reading time	63	—21	—13	45	—23	—03
26. » , errors	82	—63	14	01	33	34
27. Blue-green Confusion	08	—24	—15	52	—13	—19
28. Color Dots, other errors	42	—42	20	03	31	—20
29. Colored Text, other errors	60	—37	19	21	—01	02
30. MFD, reversals	72	—01	—07	10	—13	—03
31. Age	17	30	—02	19	—09	—33
32. Duration of injury	—03	—18	17	—04	00	—15
33. Severity of injury	—29	—19	07	—21	—19	—02

Decimal points and positive signs omitted