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Nous serons très reconnaissants à tous ceux qui voudront bien échanger
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Z A G R E B
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**ANALYSIS OF FACTORS IN INTELLECTUAL PERFORMANCE
UNDER FATIGUE AND WITHOUT FATIGUE**

I Introduction

Working several years on the problems of fatigue and the tests of fatigue (1), we have become more and more inclined to assume that under fatigue there occurs a certain disintegration of the structures that are best adapted to the task and then a new integration at another level. As is well known, the majority of the tests meant to be applied as the tests of fatigue have given no satisfactory results, since it has been proved that a subject under fatigue is also able to perform the test successfully. However, some of the experiments by various authors, though interpreted by these authors in some other ways, suggest that the performance of work under fatigue is produced by the mechanisms somehow different from those which are in action when the subject is not tired. For instance, if a subject is asked to hold a certain load at a constant height, he will at first perform this task by the isometric contraction of the muscles which are best adapted to this task, but after a certain time some other groups of muscles, which at the beginning were not engaged, will gradually be included into action. Finally, towards the end of the work, contraction will affect a great number of muscles which at the beginning were out of function. All this happens without any change in the work output, i. e. the subject is still able to maintain the load.

In the course of prolonged mental work, for instance in the case of mental calculation going on for several hours, the »immediate« insight into the results gradually gives way to the attempts to decompose the task into simpler components to finish up with a mechanical operation with figures. After that, the subject regains his ability of mental insight for a certain time, since such changes in the structures do not seem definite. It appears that in the state of fatigue ever new disintegrations and integrations of the structures occur. Bill's blocks in mental work may be considered an instance of temporary disintegration occurring before the subject succeeds in producing a new integration at another level.

All these changes need not necessarily affect the work output, and this is why the changes in the work output have not proved a satisfactory criterion of fatigue.

Finally, that under fatigue a certain disintegration of the originally integrated functions does occur is shown by the results of some experiments with perceptive illusions. For instance, the Charpentier's illusion* based on the integration of perception and the subject's experience is less pronounced under fatigue than without it. This is probably because under fatigue perception and experience are no longer closely integrated, and muscular sensation by itself makes the evaluation of weight more accurate.

II Problem

The hypothesis of the disintegration of functions cannot be proved in a direct way very easily, since introspective observations of the possible changes in the pattern by which the work is performed are not reliable, and objective manifestations of disintegration and integration do not manifest themselves — for the reasons already mentioned — in a uniform way. However, besides introspection and »fatigue tests«, there is one more possibility of finding out whether under fatigue certain changes in the complex structures that are the basis of the present activity do or do not occur. This possibility lies in factor analysis, i. e. in the analysis of correlation profiles as a simpler form of factor analysis.

The main problems of this preliminary study were as follows: (1) to use factor analysis and the analysis of profiles in order to see whether the working hypothesis of disintegration and the changes of the mechanisms that underlie the activity under fatigue is justifiable, and (2) to investigate whether factor analysis, and the analysis of correlation profiles respectively, can be used as the method suitable and sensitive enough to register the changes that are supposed to occur in the complex structures underlying the intellectual activity of a subject performing work under fatigue or without it.

Since factor analysis and the analysis of correlation profiles were designed to be carried out with the results obtained in the intellectual tests, and the state of fatigue was to be provoked by physical strain and loss of sleep, an additional assumption consisted in that »fatigue« could be regarded as a general state of the organism, i. e. a state that did not relate only to the organs previously forced to intensive or prolonged activity.

* As is known, the illusion consists in that by comparing the weight of two boxes, which are of the same weight but of different size, the smaller box appears heavier.

III Methods

One more point why factor analysis and the analysis of correlation profiles appeared suitable is that they are based on the intercorrelation of different tests and that correlation as a measure of co-variability does not directly depend on the average results of the tests and the standard deviation. This fact was considered important, since a great many investigations by various authors had shown that the results obtained in the study of various intellectual functions performed under or without fatigue had differed very little, either in average results or variability.

In this preliminary work the Thurstone multifactor analysis of the centroid type was used. Its advantage as regards other methods is that it involves no additional hypothesis of the number of factors in action. The second procedure used was Tryon's cluster analysis.

The study of the changes that are supposed to occur in the factorial structure underlying the performance of intellectual tests requires a very careful selection of tests. Since it was not possible to foresee either the extent or the kind of the changes supposed to occur in the factorial structure, it was considered most appropriate for the preliminary experiment to use such a test battery as was composed of both factorially comparatively »pure« tests, i. e. the tests saturated with a single factor, and other less »pure« tests which included a reasonable number of different factors.

A battery of 12 intellectual ability tests was chosen, i. e.:

- Test 1. Perception test (number identification)
- Test 2. Reasoning test (verbal problems)
- Test 3. Numerical test
- Test 4. Reasoning test (analogy test, verbal form)
- Test 5. Reasoning test (finding two essential characteristics of a thing)
- Test 6. Reasoning test (understanding of the principle of composition in a series of words)
- Test 7. Spatial test (Thurstone's »flag test«)
- Test 8. Spatial test PP
- Test 9. Verbal test (after Thurstone)
- Test 10. Perception test (identification of printing errors)
- Test 11. Identification speed test (recognition of a given silhouette)
- Test 12. Reasoning test (»Domino« D 48)

Since it appeared probable that retesting would produce significant changes in the factorial structure*, it was decided to use the control group. For this purpose the first-year psychology students, who were meant to take part in the experiment, were divided by random sampling into two groups, the control group numbering 25 and the experimental group 24 subjects.

* This was experimentally proved by Fleishman and Hempel (2) who applied the same tests to the same subjects several times in turn, and then determined the factorial structure.

Fatigue was provoked in the following way. In the evening, the experimental group was gathered in the lecture-room and spent the night without sleeping but discussing, reading, listening to music, dancing, etc. At 6 o'clock in the morning they went for a 10-kilometre-long quick walk. After that the whole group was tested for 2 hours. The control group was tested by the same tests after a normal night sleep.

On a scale ranging from 0—4 each subject, both in the control and the experimental group, was asked before being tested to indicate the degree of his fatigue. The number of the subjects declaring fatigue was higher in the experimental group. In this group there was no answer stating »no fatigue« or »slight« fatigue, whereas the control group had 28% answers of that kind. Furthermore, in the experimental group there were 87.5% of the subjects feeling »very tired« or »exhausted«, while in the control group only 12% of the subjects felt »very tired« and none was »exhausted«.

IV Results

In accordance with previously known results, the two groups used in the experiment, though small in number, showed very similar average results in the tests performed, so that no difference in the means was statistically significant. There was no significant difference between the standard deviations in the two groups either. Table 1 shows the arithmetic means (M) and standard deviations (σ) as obtained in different tests in the experimental and the control group.

Table 1

Means and standard deviations of the control and the experimental group

Test	Control group		Experimental group	
	M	σ	M	σ
1	24,60	4,90	23,58	5,05
2	8,28	3,05	7,83	3,72
3	19,28	5,04	19,13	6,22
4	6,28	2,87	6,17	3,01
5	9,44	1,80	8,54	2,01
6	7,88	2,80	8,21	2,07
7	8,20	4,12	8,00	3,58
8	20,56	5,92	17,54	7,97
9	22,32	6,57	24,38	6,99
10	16,08	3,55	15,71	5,40
11	45,52	2,50	45,17	2,62
12	22,08	6,61	20,96	5,68

No significant difference existed in the distribution of the results of the whole battery either (Fig. 1).

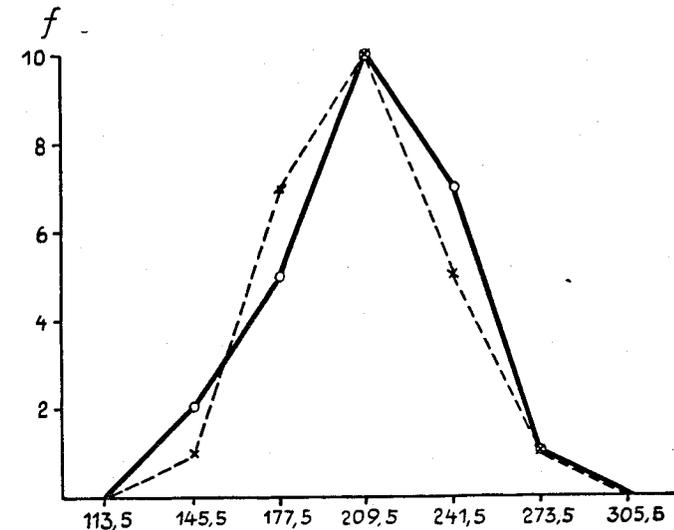


Fig. 1. Distribution of results of the whole battery. Full line: control group. Dotted line: experimental group.

The intercorrelations between all the tests are shown in Tables 2 and 3.

Although the results of multifactor analysis were similar to those obtained by the analysis of correlation profiles, these results were not taken into account, because first, the number of both the subjects and the tests was unfortunately too small to secure reliable results, and secondly, owing to the shortage of good calculation machines only two rotations of the reference axis in the factor analysis were made, whereas for a full analysis at least as many rotations as was the number of tests would have been necessary.

Table 2

The intercorrelations between all the tests in the control group

	1	2	3	4	5	6	7	8	9	10	11	12
1	—	0,26	0,18	0,53	0,19	0,39	0,22	0,03	0,38	0,30	0,03	0,43
2		—	0,42	0,54	0,42	0,50	0,29	0,29	0,31	0,51	0,30	0,49
3			—	0,28	0,10	0,22	0,13	0,24	0,02	0,43	0,05	0,39
4				—	0,60	0,79	0,44	0,43	0,44	0,53	0,03	0,69
5					—	0,49	0,21	0,14	0,16	0,22	-0,36	0,40
6						—	0,48	0,29	0,29	0,53	0,04	0,73
7							—	0,71	0,43	0,13	0,25	0,45
8								—	0,22	0,05	0,13	0,27
9									—	0,12	0,08	0,42
10										—	0,25	0,49
11											—	0,18
12												—

Table 3

The intercorrelations between all the tests in the experimental group

	1	2	3	4	5	6	7	8	9	10	11	12
1	—	0,11	0,38	-0,15	-0,22	-0,07	-0,07	-0,10	0,08	0,42	0,19	0,34
2		—	0,38	0,37	0,42	0,47	0,29	0,33	0,48	0,18	0,28	0,25
3			—	0,44	0,14	0,52	-0,04	0,34	0,56	0,15	0,26	0,53
4				—	0,48	0,67	-0,14	0,36	0,39	-0,01	0,36	0,34
5					—	0,27	0,24	0,19	0,39	-0,23	0,06	-0,12
6						—	0,21	0,41	0,45	0,32	0,36	0,52
7							—	0,56	0,23	0,07	0,10	0,08
8								—	0,44	0,20	0,18	0,42
9									—	-0,02	0,48	0,40
10										—	0,10	0,23
11											—	0,38
12												—

In Tryon's cluster analysis we started with the assumption that the group tested without fatigue should show a certain logic in the factorial structure, and that this structure in the group tested under fatigue, might be deranged, if fatigue produced disintegration. Of course, what one could expect from such a fairly insensitive method was only an orientation estimate, but this was the very thing at which this preliminary study was aiming.

Comparing the intercorrelation profiles of the control group, it was found that they formed logically justifiable clusters: the intercorrelation profiles of all five reasoning tests comprised one cluster, both spatial tests one cluster, and both perception tests one cluster. The numerical test, the test of the speed of identification, and the verbal test formed no clusters with any other tests, since there were no factorially similar tests in the battery.

However, the tests forming clusters in the control group did not any longer formed clusters in the experimental group. While in the control group (K) the intercorrelation profiles of all reasoning tests gave the cluster as seen in Fig. 2, in the experimental group (E) the same tests gave evidence that the factorial structure engaged in the solution of the problems under normal conditions disappeared in the state of fatigue. Fig. 3 shows a cluster formed from two perception tests in the control group (K), while in the experimental group (E) there was no cluster at all. Even in the relatively high-loaded spatial tests (Fig. 4), which in the control group (K) gave similar intercorrelation profiles, in the experimental group (E) this similarity was decomposed.

In the experimental group there appeared some other intercorrelation profiles which were all similar in shape, but we have not as yet been able to explain them. For instance, we could identify a cluster composed of a reasoning test and a spatial test (Fig. 5), a cluster composed of a numerical, a perception, and a reasoning test (Fig. 6), and a cluster

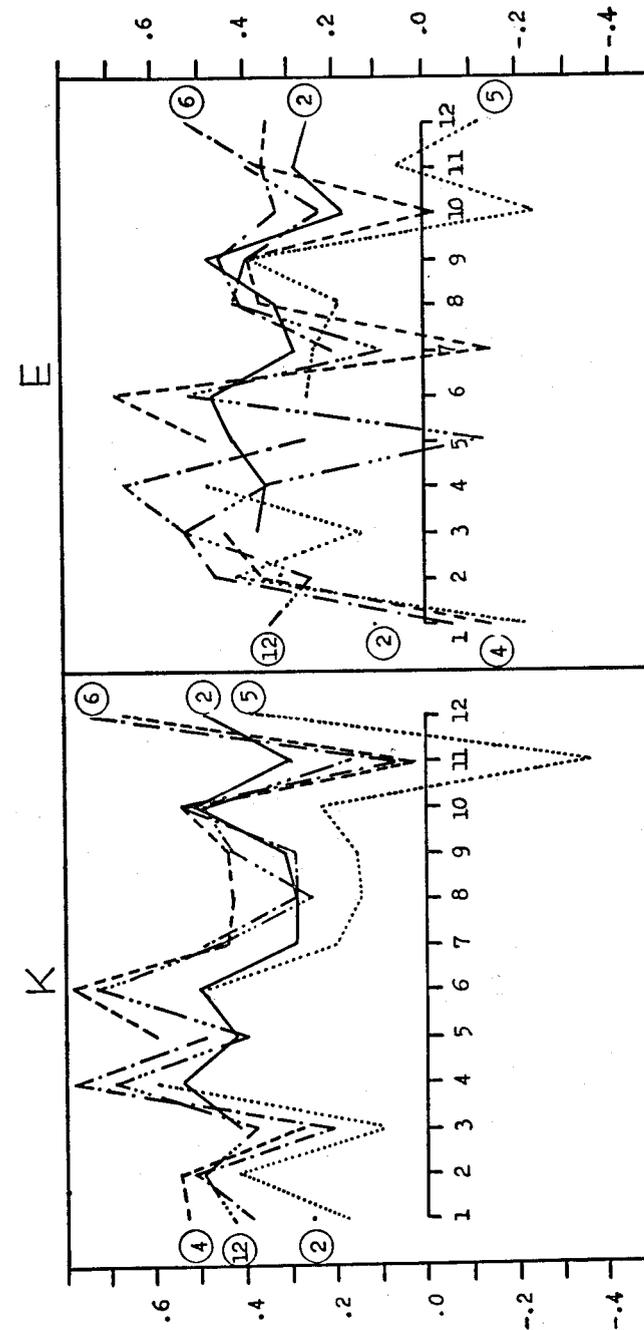


Fig. 2. Intercorrelation profiles of all the reasoning tests. On the left: control group (K). On the right: experimental group (E). On the ordinate: the correlation coefficient r . On the abscissa: tests from 1-12. Numbers in circles: Test numbers. — As is seen, the results of reasoning tests in the control group form a cluster, while in the experimental group there is no defined cluster.

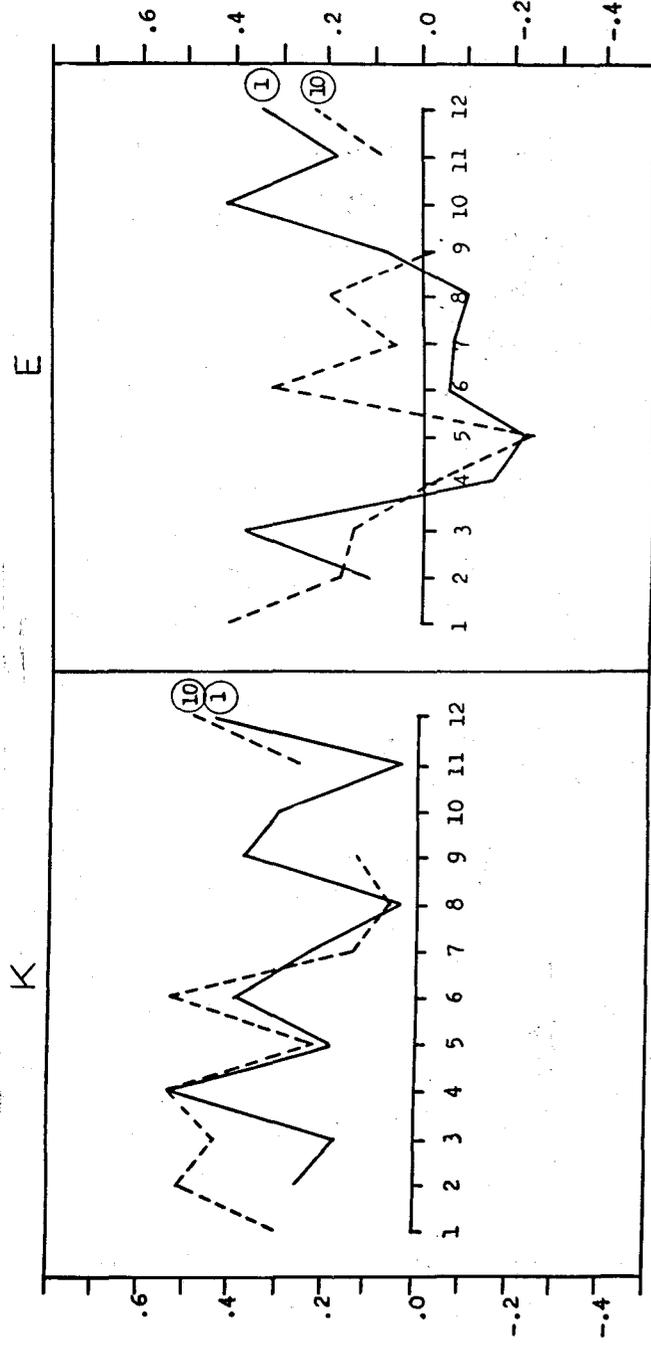


Fig. 3. Intercorrelation profiles of perception tests. On the left: control group (K). On the right: experimental group (E). As is seen, in the experimental group the two perception tests do not form a uniform profile.

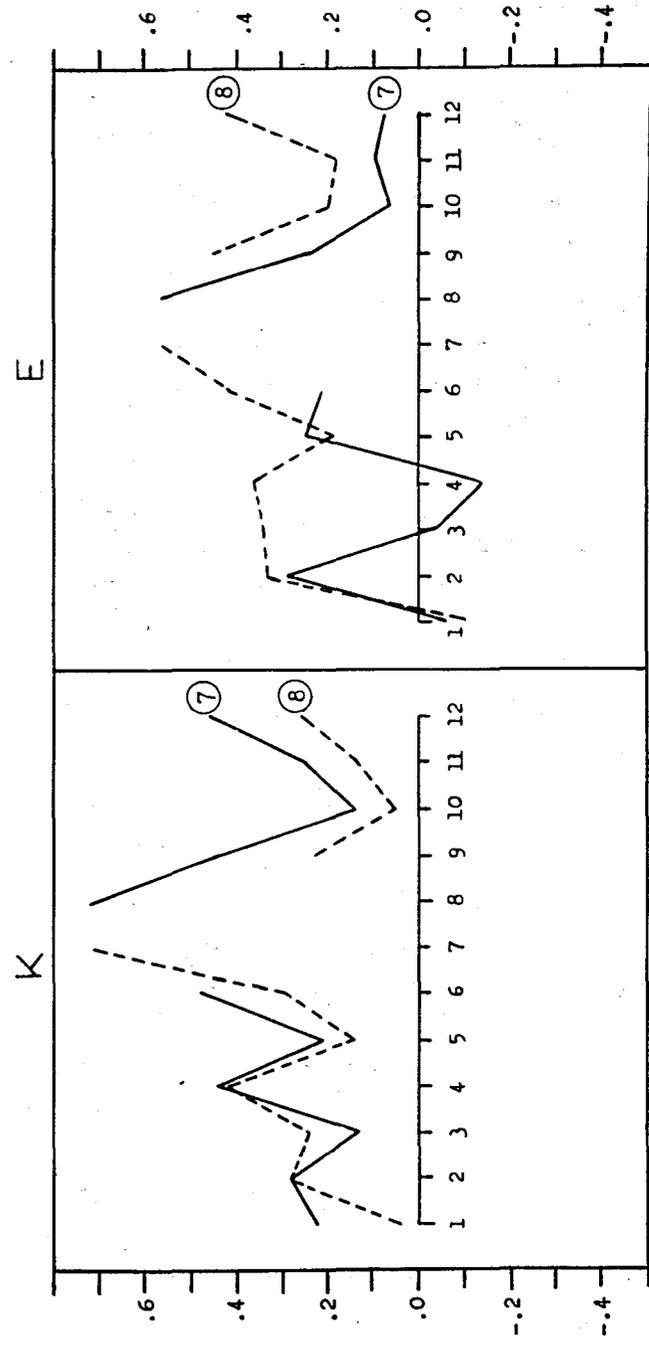


Fig. 4. Intercorrelation profiles of spatial tests. On the left: control group (K). On the right: experimental group (E). The similarity of profiles is reduced in the experimental group.

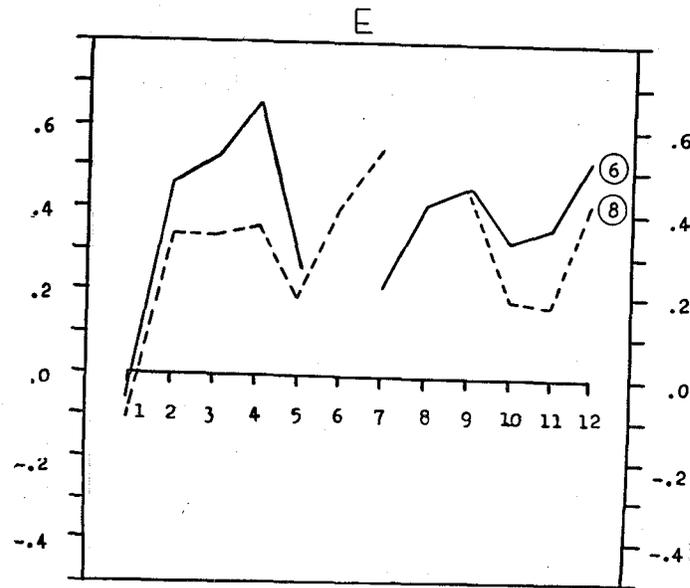


Fig. 5. Intercorrelation profiles of a reasoning test and a spatial test in the experimental group.

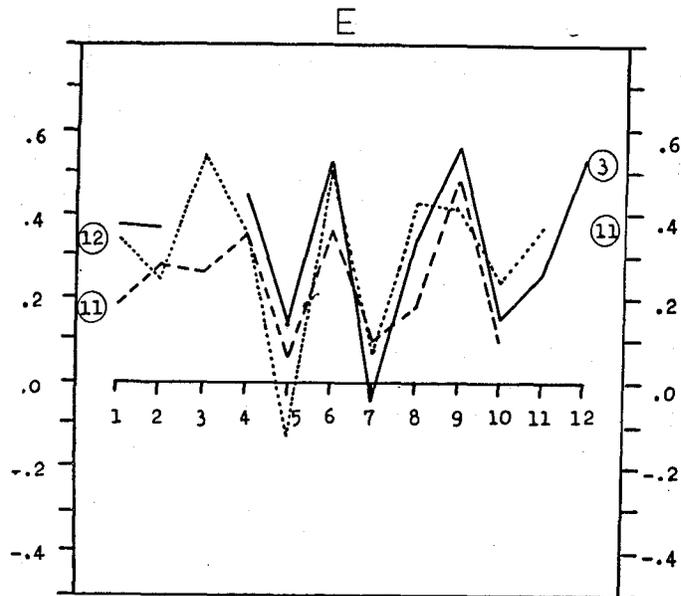


Fig. 6. Intercorrelation profiles obtained in the experimental group from a numerical test, an identification speed test, and a reasoning test.

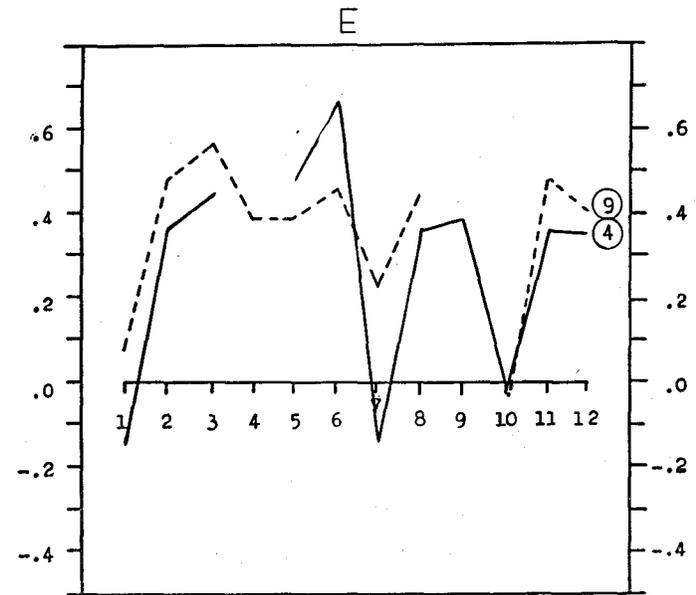


Fig. 7. Intercorrelation profiles of a verbal and a reasoning test in the experimental group.

composed of a verbal and a reasoning test (Fig. 7), but all these clusters were less pronounced than those in the control group.

V Discussion

We are not going to analyse and interpret the results of the experimental group in detail, since the material available in these preliminary experiments does not allow us to do so. This could only be done on the basis of a complete factor analysis. Nevertheless, even on the basis of the results obtained so far, it seems justifiable to answer the question of whether in fatigue there occur some changes in the factorial structure of mental functions. In the control group we obtained a structure logically corresponding to what could be expected on the basis of the tests applied. However, in the experimental group we found a quite different structure, in which we could no longer trace the same logical link between the intercorrelations as was found in the control group. It seems, therefore, that under fatigue a change did occur in the structures that were originally best adjusted to the task, and that some new structures were formed by which the subjects, at least for a while, were able to perform the work as successfully as they did without fatigue.

As has already been mentioned, some preliminary work is being done for the preparation of a larger experiment of this kind, under the

assumption that a complete factor analysis carried out on a great number of subjects and with well chosen tests might throw more light on the qualitative and quantitative changes occurring under fatigue.

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