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PSYCHOLOGICAL TESTS FOR MEASUREMENT OF MENTAL FUNCTIONS IN INDIVIDUALS EXPOSED TO NEUROTOXICANTS AND NOISE

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Abstract. According to Sternberg's additive factors methodology two computer tests have been prepared in the Work Psychology Department of IOM. Several studies which allowed the assessment of effectiveness of experimental factors, manipulation and psychometric tests characteristics have been carried out. As well, effectiveness of experimental factors manipulation as reliability of both tests (IPT-Perception and IPT-Memory) appeared to be satisfactory. So these techniques are good enough to recommend using these tests in psychological examinations.

INTRODUCTION

There is more and more evidence that psychological methods are useful for the early detection of the detrimental effects of exposure to environmental and occupational hazards. All psychologists, engaged in neurobehavioral toxicology, are used to measuring these effects by means of traditional psychometric test. The test performance decrease may be intepreted in terms of brain damage or impairment of general psychological functions like: eye-hand coordination, perceptual-motor speed, memory, attention etc.

Ekberg (3) was the first author who suggested changing the approach to measurement of the effects of exposure to neurotoxic agents. Instead of using traditional psychometric tests she has proposed adopting a cognitive approach to the measurement of psychological phenomenon. One should be less occupied with "determining whether in fact any adverse effects follow long-

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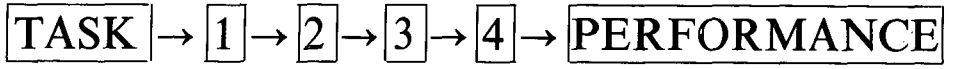

Fig. 1. A model of a test item performance.
1, 2, 3 – information processing stages.

-term solvent exposure and more towards determining how intellectual performance is affected". To recognize better the need for a cognitive approach let us analyze the following scheme (Fig. 1).

In the psychometric approach a psychologist measures only the task performance and all the intermediate stages, between the task presentation and its performance, are ignored whereas in the cognitive approach a researcher's interest is focussed on the measuring of these intermediate stages which are elements of information processing involved in performance of a given task. During the last two decades there has been growing interest among experimental cognitive psychologists in identyfying mental processes. It seems that the application of these experimental findings in neurobehavioral toxicology should give very promising results. We have decided to use Sternberg's additive factors methodology as a theoretical basis for our measuring techniques (6). According to Sternberg and his followers (5) there are some experimental factors which can separately influence mental functions, namely, the quality of the stimulus affects the encoding function, and the size of the displayed set influences the comparison function: the size of the memorized stimuli set influences the retrieval function, and rotation of the stimuli exerts an impact on the comparison function. If we prepare a psychological test in which manipulation of the above mentioned experimental factors is possible we will be able to measure the effects of different harmful agents on a single mental function. Figure 2 presents a way of estimating effect.

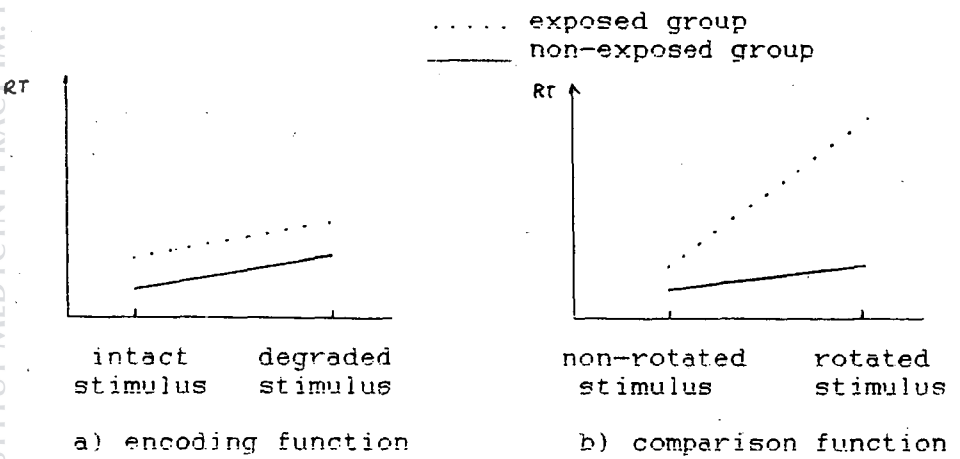

Fig. 2. An example of the estimation of exposure influence on mental functions (encoding & comparison).

In Figure 2a we can see a lack of interaction between exposure to a harmful agent and quality of stimulus and there is evidence that this agent has no influence on encoding function. The interaction between exposure and rotation of stimulus is quite evident in Figure 2b. It means that the agent has affected the comparison function.

METHODS

Two tests have been prepared, one of which is called IPT-Perception. Two sets of letters separated by a vertical line are the items of the test. The subject's task is to compare these sets and press a button whenever the letters in two sets are the same. The items are differentiated. Examples of items are presented in Figure 3. The set can consist of 1, 2 or 3 letters displayed on an intact or masked background, and the letters can be rotated or non-rotated. There are 12 stimuli categories (2 × 2 × 3). The easiest category of stimuli is: 1 element, intact and unrotated group of items. Every category of stimuli consists of five items. Three of them are positive, meaning that two sets of letters on both sides of the vertical line, are the same, and two items are negative. The total number of items is 60. The average reaction time for each group of stimuli is calculated.

The second test is called IPT-Memory. In this test a set of letters varying in size is displayed on a monitor and the subject is asked to remember the letters. Next, after a short break, a single letter is presented and the subject is

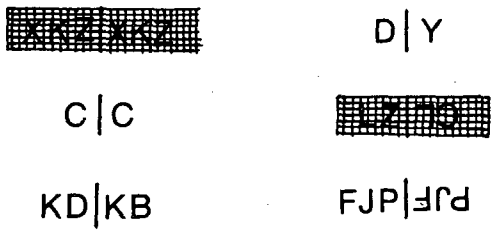

Fig. 3. The examples of stimuli in IPT-Perception.

Fig. 4. An example of stimulus in IPT-Memory.

asked to recollect if the letter presented was among the letters of the memorized set or not, and to press the button in each case of a positive answer. The example of item is presented in Fig. 4. A set of displayed letters consists of 2, 3, 4, 5 elements. Letters were presented on a clear or masked background and they could be rotated or unrotated. As the result there are 16 item categories ($2 \times 2 \times 4$). Every category of items is represented by five items. Three of them are positive and two items are negative. The IPT-Memory consists of 80 items: 48 positive and 32 negative ones. Correctness and reaction time are registered separately for each item.

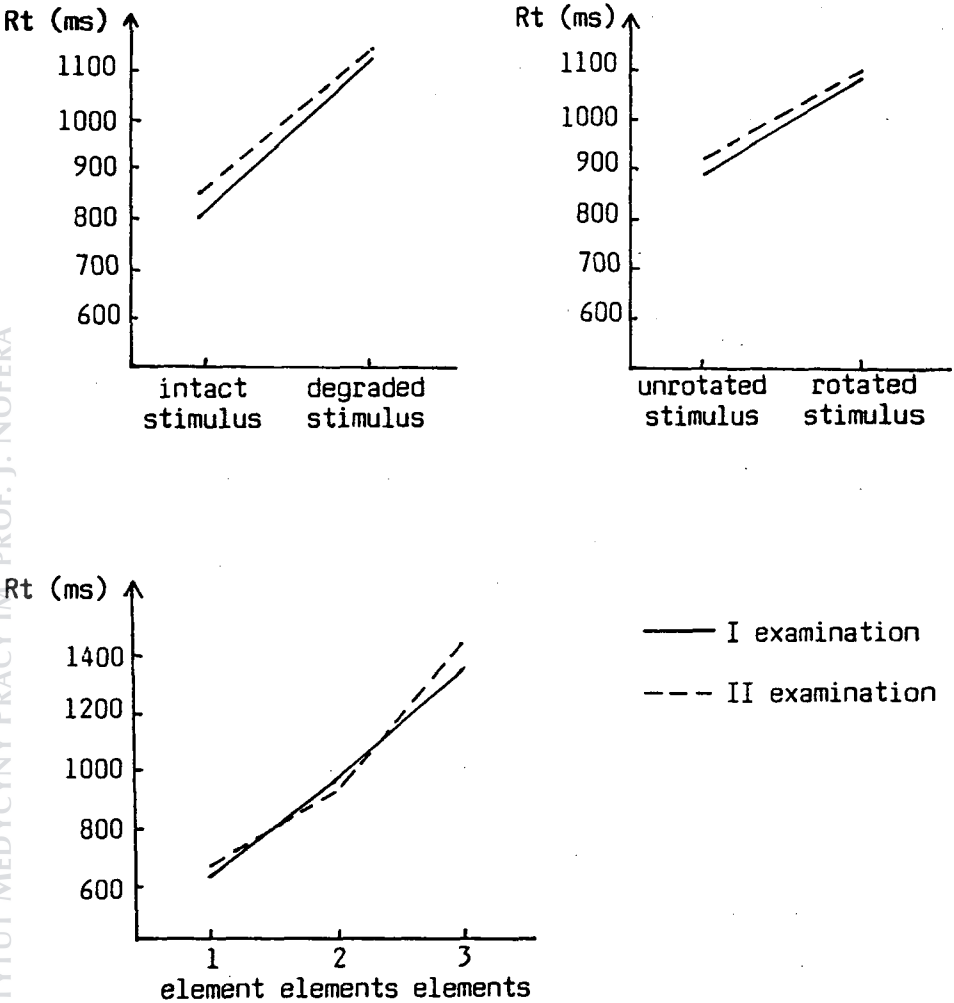

Fig. 5. The effectiveness of experimental factors manipulation (IPT-Perception).

RESULTS

In the Work Psychology Department we have carried out several studies which have allowed to assess the psychometric characteristics of the tests. The results of these studies will be classified into three groups of problems.

Effectiveness of experimental factors manipulation. It has been assumed that degradation and rotation of stimulus as well as enlargement of set size will prolong duration of reaction time. This assumption has been tested in an experiment in which 18 subjects were exposed to noise for one hour (2). The subjects were examined twice. These results are presented in Fig. 5. A solid line shows the results of the first examination and a broken line represents the results of the second one which was carried out after an interval of 20 minutes. The results obtained by means of the IPT-Perception test are presented in Figure 5. We can see in the three figures, that reaction time to more difficult

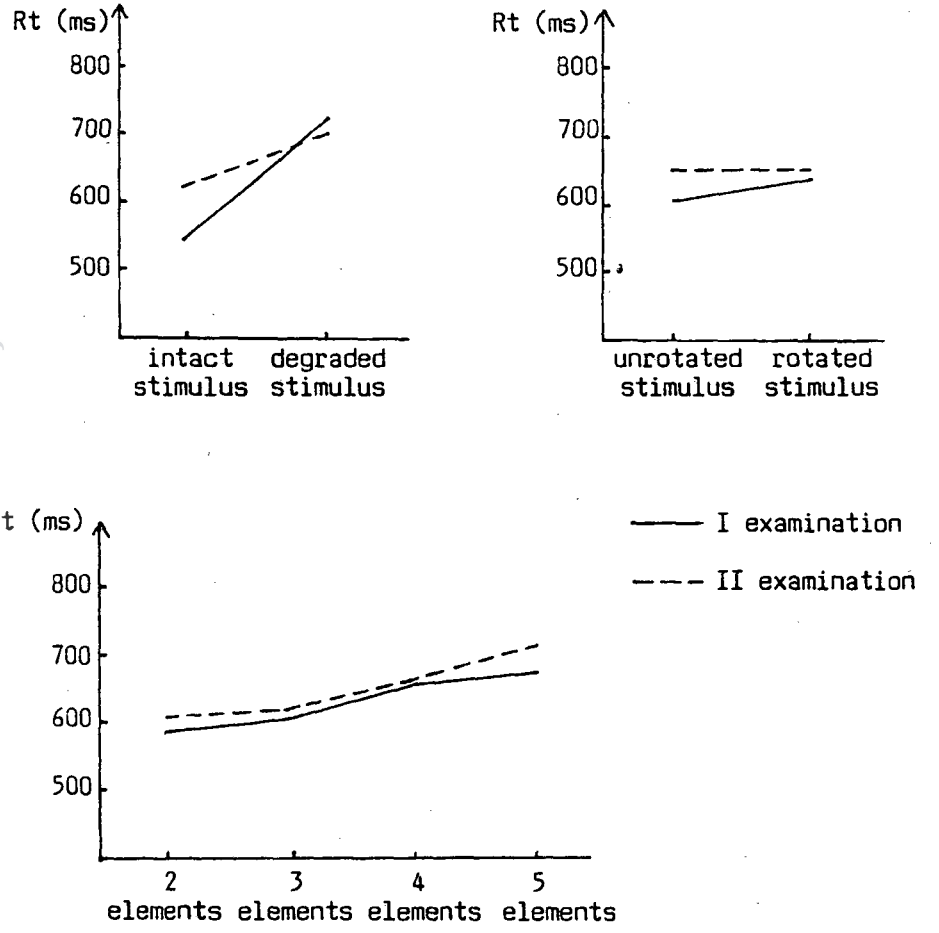

Fig. 6. The effectiveness of experimental factors manipulation (IPT-Memory).

simuli (degraded, rotated, bigger set size) are much longer than to simpler stimuli. The same tendency can be observed during the first and second examinations. It means that manipulation of experimental factors in the IPT-Perception test was effective.

The same group of subjects, in the same conditions, performed the IPT-Memory test twice. The results obtained are presented in Fig. 6. We can see that manipulation of stimuli quality results in the prolongation of reaction time from 500 ms to 700 ms (first examination) and from 600 ms to almost 700 ms (second examination). The manipulation of stimuli set size appeared to be effective also. We can observe an almost linear regression. Every additional element has resulted in a prolongation of reaction time and this tendency was statistically significant. However rotation of stimuli in the IPT-Memory test did not cause a significant change in reaction time. It indicates that the reaction times to unrotated and rotated stimuli are very similar. This result may be of great importance for cognitive psychologists who are interested in the modelling of mental processes. It can be concluded that mental rotation of stimuli in perceptual task is much slower than in a memory task. In the latter a pattern of stimuli is kept in mind and therefore mental rotation is very quick or it is not necessary because of the nature of the mental pattern of stimulus (4). However, this problem will not be discussed in detail because it is rather a by-product of our investigation.

Reliability. Three studies were carried out to assess the reliability of the tests. In one of them a group of 55 students (male) from technical high school were the subjects. Their age ranged from 17 to 19 years.

Because of some doubts concerning the results obtained we have twice repeated an assessment of the test's reliability. In the second study 33 elder individuals were subjected to two examinations carried out at weekly intervals. An experiment on the influence of noise on mental functions was the third study. Eighteen subjects performed tests presented twice under the silence and noise conditions with a 20 minute intervals. The results obtained under the silence conditions were analysed to assess the stability of the tests.

In Tables 1 and 2 reliability coefficients for particular parts of the IPT-Perception test are presented. The level of homogeneity of the test appeared to be satisfactory from a psychometric point of view. The lowest correlation coefficient is 0.54 for the 1-element stimuli, and the highest 0.83 for the intact stimuli.

TABLE 1. Split-half-reliability of IPT-Perception.

	Kind of stimuli						
	intact	degraded	unrotated	rotated	1 elem.	2 elem.	3 elem.
I examination interval – 1 month n = 55	0.83	0.81	0.71	0.75	0.54	0.68	0.79

TABLE 2. Test-retest reliability of IPT-Perception.

	Kind of stimuli						
	intact	degraded	unrotated	rotated	1 elem.	2 elem.	3 elem.
I examination interval – 1 month n = 55	0.22	0.13	0.57	0.14	0.52	0.14	0.17
I examination interval – 20 min. n = 18	0.86	0.91	0.88	0.91	0.75	0.85	0.88
I examination interval – 1 week n = 33	0.83	0.80	0.85	0.69	0.49	0.83	0.86

The coefficients of stability of the particular parts of the IPT-Perception are varied. In the case of the students the level of reliability appeared to be very low; too low to recommend application of the test in psychological investigations. However, such low results obtained may have been due to too small motivation on the part of the students performing the test during the second examination. They complained that it was boring and, therefore, they were reluctant to come to the laboratory. Some of them told us that they neglected the second examination. That is why we have decided to check the test once again. Table 2 shows the results obtained in this additional study. This time the results stability appeared to be satisfactory to recommend using this test in future studies.

The IPT-Memory test was prepared later than the IPT-Perception test and therefore it was used only in one study, the experiment on noise effect. However, as this test was performed twice with 20 minute intervals we were able to assess the stability of the test results. Table 3 presents the results obtained. The correlation coefficients range from 0.60 to 0.81. This level of stability may be regarded as satisfactory enough to recommend using this test in some other psychological examinations.

Validity and sensitivity. In two laboratory experiments we have tried to determine the sensitivity of the tests. The IPT-Perception test was used in a laboratory experiment in which 10 subjects were exposed to toluene (T),

TABLE 3. Test-retest reliability of ITP-Memory.

	Kind of stimuli							
	intact	degraded	unrotated	rotated	2 elem.	3 elem.	4 elem.	5 elem.
II examination interval – 20 min. n = 18	0.77	0.81	0.73	0.81	0.54	0.69	0.72	0.60

xylene (X) and a mixture of these organic solvents. Their performance in the test appeared not to be sensitive to the impact of experimental conditions (100 ppm of T, X, mixture for 4 hours) (1).

This lack of influence can not be explained by the low level of exposure as in some other tests used – Flanagan test, SRT and ChRT tests appeared to be the sensitive ones.

Both tests (IPT-Perception and IPT-Memory) were used in an experiment in which 18 subjects were exposed to 95 dBA noise for an hour. The results of the tests were not sensitive to that experimental factor. However, in this experiment the SRT and the ChRT tests were not sensitive either. The level of exposure was too low to exert an influence. Only the time of test administration (fatigue effect) influenced the comparison function.

An attempt to determine the test validity was also made. The earlier mentioned group of 55 students was examined by means of the IPT-Perception test as well as, the SRT test and the ChRT test. Taking into account the mental processes engaged in performance of the SRT and ChRT tests it may be assumed that the SRT test is less loaded by mental processes than the ChRT test. The difference between choice reaction time and simple reaction time is extremely loaded by mental processes. As the IPT-Perception test is meant for measuring mental processes the lowest correlation coefficients between subtests of the IPT test and the SRT test should be expected. The highest level of correlation should be found between the IPT test and the difference in the two average reaction times (ChRT – SRT). The results presented in Table 4 tell us that our reasoning was correct. It was confirmed by a lack of correlation

TABLE 4. The correlation coefficient between reaction time to different kinds of stimuli in ITP-Perception and Simple Reaction Time (SRT) (a), Choice Reaction Time (ChRT) (b), difference between ChRT and SRT (c)

Kind of stimulus		a		b		c	
		r	p	r	p	r	p
Quality of stimulus	intact	– 0.07	ns.	0.22	p = 0.040	0.33	p = 0.005
	degraded	0.10	ns.	0.41	p = 0.000	0.38	p = 0.001
Rotation	unrotated	– 0.01	ns.	0.31	p = 0.007	0.37	p = 0.002
	rotated	0.40	ns.	0.34	p = 0.004	0.35	p = 0.002
Size of set	1 element	0.30	ns.	0.30	p = 0.009	0.33	p = 0.005
	2 elements	0.20	ns.	0.32	p = 0.006	0.35	p = 0.003
	3 elements	0.20	ns.	0.30	p = 0.008	0.34	p = 0.004
x		0.20	ns	0.34	p = 0.003	0.38	p = 0.001

between the subtests of the IPT test and the SRT test presented in the first column of Table 4, and very evident and statistically significant correlation coefficients – ChRT results (second column of that Table). We had expected to find the highest correlation coefficients between the subtest of the IPT test and the difference between the ChRT test and the SRT test. In the third column of that Table there are some coefficients very similar to those presented in the second column. However, this result is not contradictory to our assumption. The reliability of the differences must be lower than the reliability of the component measurements. This reliability decrease is responsible for not obtaining higher correlation coefficients in the third column.

In our opinion the results presented in Table 4 have confirmed our assumption and they can be treated as the primary evidence that the IPT-Perception test measures mental processes involved in performance of the test.

CONCLUSIONS

1. Effectiveness of experimental factors manipulation (degradation of stimulus quality, item rotation, set size enlargement) is satisfactory enough to accept a proposed form of these factors.

2. The reliability of both tests appeared to be good enough, from a psychometric point of view, to suggest using these tests in a psychological examination.

3. The sensitivity of the IPT-Perception and the IPT-Memory tests to measuring the neurobehavioral effects of exposure to harmful agents related to work place has not been proved up to now in our two experiments. We can suppose that using letters in the test items is responsible for diminishing test sensitivity. Individuals are very experienced in the recognition of letterrs. This activity is overlearnt thanks to the very long and effective process of education. Therefore this activity is resistant to the disturbing effects of different factors. That was the reason why it was decided to prepare a new form of presented tests.

In the new versions we decided to use geometric abstract figures and very simple drawings of different objects like trees, animals, birds etc. instead of letters. Recognition of these figures is not overlearnt and performance in this kind of test seems to be more sensitive to distraction. The new-generation tests have been prepared. We plan to use these three versions of tests to assess effects of drugs taking (tranquilizers and antidepressants).

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