

BEHAVIOURAL NEUROTOXICOLOGY – CURRENT INTERDISCIPLINARY STUDY

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The relationship of man and his environment is no longer only the subject of biological or medical disciplines; it has become the subject of research interest of many other disciplines, of which psychology plays an important role. It concerns, above all, a more recent research area – the so-called behavioural neurotoxicology, which studies the effects of small doses of neurotoxic substances present in the environment on psychological functions and behaviour of man. With this aim psychology faces a demanding task: to carry out research using sufficiently sensitive methods, which would indicate possible subtle changes caused by the disruption of the homeostasis of the CNS by neurotoxic substances.

Behavioural neurotoxicology is a more recent scientific discipline, which studies the effects of toxins present in the environment on psychological functions and behaviour of man at various stages of his ontogenesis. This new scientific discipline is very much up-to-date, especially in countries which have placed great emphasis on heavy industry, on the development of solid fuel power plants, metal processing plants and chemical industry, without paying adequate attention to the health threatening pollution caused by this type of activity. Nowadays, positive changes are occurring in society's attitudes toward environmental problems. An exceptional example of these changes can be seen in environmental care exercised in the state of California, USA, where excessive industrial emissions were successfully decreased in record time. Undoubtedly, these changes are occurring also under the pressure of research knowledge in the area of behavioural toxicology.

The problem of toxic substances in relation to human beings has its practical as well as theoretical context. It is generally known and verified in research (particularly by the so-called prospective epidemiological studies carried out in the USA using all population groups) that neurotoxins in the environment, which enter the human organism, can, in case of long-term exposure, disturb the homeostasis of the CNS system and have a negative impact on the effectiveness of psychological functions. The danger of even small doses of these substances, such as, lead, mercury,

cadmium, magnesium, etc., entering the organism lies in their cumulative properties. As a result, greatest research attention has been paid to the child population, where the overall cognitive development is under threat.

Behavioural neurotoxicology is a typical interdisciplinary applied research. Research teams usually consist of medical specialists, public health workers, neurologists, pediatricians, biochemists, pedagogues and last but not least psychologists. It is expected that psychologists will use the appropriate, sensitive psychological methods to measure subtle changes in the area of cognition and behaviour, which are the two key problem areas in this type of research.

It is often said that a certain discrepancy in research findings in this area is mainly due to conceptual unclarity in the methodological area. Indeed, researchers often work with insufficiently homogenized samples (in terms of age, socioeconomic status, education, etc.). It is evident that children in early age or even prenatally are most susceptible to the effects of toxins – this is called the teratological effect of neurotoxic substances. There is also a practical methodological problem and that is the so-called “spinning effect”, meaning that neural damage from early childhood may not manifest itself until later, for example in pre-school age (G. Fein et al., 1983).

In any case, it is assumed that certain inconsistency in research results is due to the time at which the maximum impact of the toxic substance occurred. Early exposure, i.e., until two years of age, has a different impact than later exposure, i.e., after two years of age. According to research results, early impact affects those neural structures which ensure language development (C. Ernhart, T. Green, 1990). In this connection, we can point to Lurija's model, according to which language functions, which are associated with the maturation of secondary cortical areas, are more threatened by early exposure to lead. On the other hand, spatial-symbolic functions, dependent on the maturation of tertiary cortical areas, are threatened later in life. Simply said, if we compare research results homogenized with respect to the “timing effect” we can see significant differences.

The fact, that behavioural toxicological research of children requires more than careful monitoring of social factors in the family and outside, belongs to the fundamental problems with this type of research. It is known that these factors affect, to a great degree, cognitive performance of children. What we are talking about is mainly the parent's education, the amount of social stimulation, the overall atmosphere in the family, etc. Indeed, a good quality social environment compensates, to great extent, for the possible deficit caused by toxic substances or other sources. Thus, discussions about the degree to which the deficit observed is due to toxins or unfavourable social influences of the environment are still very much up-to-date.

The accuracy of every research project expects exact definition of the object of the study, determination of theoretical bases and the appropriate methodological procedures. In this specific case, the situation is especially demanding because it involves an interdisciplinary research area, the findings of which affect practice di-

rectly. Summaries of findings, particularly from the so-called epidemiological projects, which are carried out using large population samples, indicate that even small doses of neurotoxic substances present in the environment and subsequently in the child's organism, cause subtle, usually only subclinical changes. But, from the point of prognosis, there is a risk of functional damage to the nervous system with possible impact into the adulthood. This problem area is amply presented, mainly in a specialized American journal titled *Neurotoxicology and Teratology* (e.g., D. Bellinger, 1995).

In recent years there is talk about a radical decrease of lead in the environment (lead is justifiably a frequented subject of research interest as a ubiquitous neurotoxic substance). The improvement of the quality of the environment is ascribed to unleaded gasoline, to special technological procedures in the chemical industry, various filtering procedures, etc. In spite of this, the problem is not solved because even highly specialized experts can only guess the impact of various combinations of substances – compounds, which are formed practically uncontrollably in polluted areas, on the physical and mental prosperity of the population living in such areas. The measuring itself of the concentration of pollutants in the free environment, in the ground, water and air is extremely demanding. It requires special laboratory procedures and costly monitoring of the equipment. Even more demanding is to determine the concentration of the toxins directly in the organism. Collecting biological material (blood, hair, nails, etc.), mainly drawing blood in children, presents problems in terms of research ethics and, usually, the parents do not allow such procedures. By the way, during the socialist regime, such blood drawing was done without the parents' permission.

In any case, the greatest problem in this type of research are suitable psychological methods, which would indicate even subtle changes in cognitive functions. It seems that even commonly used psychological methods, such as IQ tests, are not sufficiently sensitive for this type of research. Common IQ tests allow for the use of an entire set of "compensatory strategies" /compensatory shift/, by means of which a partial cognitive deficit can be "covered up". It seems that the so-called processual methodological approaches are more suitable. They are focused on specific cognitive functions, such as short-term memory, perception, attention or language production, etc.

In professional literature, authors claim that damage caused by toxic emissions in children is similar to the one called "minimal brain dysfunction", which, according to D. Karch (1989), typically affects only some specific areas of cognitive behaviour (perception, short-term memory, attention, fine motor functions, etc.). The general intellect level of the child expressed by the IQ measure, can, at the same time, be within the norm or even above it. Thus the behavioural-toxicological research brings demanding methodological problems for psychology.

The fundamental question is whether psychology has enough sensitive methods, by means of which it would be possible to detect minimal deviations in cognitive

performance and thus, albeit hypothetically, prove possible subclinical neural damage. Let us ask, what kind of research procedures for detecting subtle subclinical cognitive deficits can psychology offer to behavioural-toxicological research?

Proof of insufficient sensitivity of standard methodological procedures stimulates researchers to look for other methodological sources. We have at our disposal procedures used in psychological laboratories in experimental research of cognitive processes. It seems that the greatest number of methods can be found in short-term memory research, in memory research itself (attention tasks with placing a load on memory), furthermore, experiments with the so-called Stroop effect, which basically represents tasks requiring the suppression of various interference distractions. It involves elementary tasks which are very similar to real life situations.

Laboratory researchers tend to emphasize the "sterility" of experimental methods, which means strict definition of experimental variables, methodological procedures, possibility of repeating the experiment with stable methodological procedure and expected results. The norms for conducting "non laboratory experiment" in field conditions are naturally "less strict". However, the advantage is that experiments can be done with greater number of subjects than in laboratory conditions, on the basis of which greater ecological validity can be achieved, which increases the trustworthiness of the findings. This represents motivation for researchers to carry out prospective neurobehaviourally demanding projects using really large population samples, where several thousand people can be studied (e.g., the Boston study, Cincinnati, Cleveland, St. Pirie, Sidney, Glasgow as well as Kosovo).

J. Richardson (1989) pointed to the possibilities of practical use of laboratory experimental methods of cognitive psychology, which use stochastic methods as well. The author presents the possibilities of a broad application of cognitive psychology in clinical practice, particularly in various memory disorders such as the Korsakoff's syndrome, chronic alcoholism, bilateral temporal lobotomy and various other brain damages.

Although, as we have said, non laboratory conditions do not allow for the "purity" of the experiment, these procedures of cognitive psychology do offer an insight into the phenomenon under study. The advantage involves not only theoretical bases but model constructs as well, which, regardless of the "in field" character of the research, allow for an interpretation of the phenomena observed and, within the theoretical concept, not only state but "name" the cause of the decreased or changed performance.

In recent years, in our research project we showed the advantages of using cognitive psychology methods. The basic characteristic of the project was a comparison of two groups of children. The so-called affected group consisted of children (compiled with the help of a public health worker) who have been living in a industrially polluted area since birth. Arsenic, along with other toxins: Pb, Cd, Hg, Cl, SO_x and NO_x, is in the foreground of the problem. The affected group was compared in many indicators of psychological and physical development with a control group, which is liv-

ing in a relatively clean environment. Based on the examination of biological material, a simultaneous medical research study determined that children from the polluted area, compared to the control children, have statistically higher content of Hg in their hair and nails (G. Šimko, 2000).

With respect to the following research activities, we would like to stress that presenting the research results is not the primary goal here. In this text we would like to point out select research activities which illustrate the efficacy of experimental methods of cognitive psychology in the area of behavioural toxicology; in other words, to point out the advantages of the methodological intradisciplinary of psychological research.

One such method is the so-called searching tasks, which test the searching activity. Searching activity is actually a perceptory-cognitive, specifically recognitive process, which is regulated by increased activation of the organism (Halmiová, 1981). In these tasks the subject is required to use a picture matrix to find certain pictures – targets (in this case it was a set of pictures of commonly used objects on a 7x7 matrix). The simple searching task means that the subject searches for one target. Combined search with distraction involves the subject having to look for two or three targets at the same time, but only one is actually on the matrix (the subject does not know which one), the rest serve as distractions, loading the memory during the searching process.

When working with this method we found that in the simple searching tasks the affected children did not differ from the control group. However, in the searching tasks with a load the groups manifested statistically significant differences, the control group performing better. We based our interpretation of the differences on the theoretical concept of the so-called “reserve capacity” as explained by S. Dornič (1986) in his research of psycholinguistics, more exactly bilingualism. In comparing monolingual and bilingual subjects, S. Dornič found that differences between the two groups were not apparent until their tasks were combined with a secondary load, when the subjects had to reach in their “reserves”. We see a certain parallel between the lower performance of bilingual subjects and our affected group of children; i.e., in case of a hypothetically decreased effectiveness of attention and memory functions of the affected children, the overall cognitive load exceeded (similarly as in bilingual subjects) their reserve capacity (Potašová, Árochová, 1998).

In terms of our research subject area, it seems that a decrease in performance on the part of the affected group is not apparent until there is a load situation, when the subject has to reach into his/her reserves or use compensation strategies (as this mechanism is called by P. Smith, 1985). In case of only a mild load the performance of both groups seems equal. Therefore, we can assume that a certain subtle handicap in the cognitive area does not have to appear in common situations nor in common tests. It becomes apparent under load, and then increased efforts are required. The interpretation using the theoretical concept offers a chance to better un-

derstand the problem. It can also have a certain impact on everyday life situations, such as teaching methods used for the so-called affected children – children living for a long time in polluted areas. In these cases load situations (i.e., solving tasks under a time limit, competitive situations, etc.) should be limited. Perhaps it should be noted that years ago teachers teaching in polluted areas raised an initiative involving paying more attention to the behaviour of their children in classrooms. The teachers wanted people from the Preventive Health Care Institute to come and “look” at their children with psychologists. They claimed that the children are fidgety during class, had concentration problems, did not understand the material being taught, were not spontaneous enough, etc. In reality, a research project conducted 25 years ago in a locality near a solid fuel power plant confirmed certain decrease in cognitive performance (attention, memory) and fine motor hand functions of the children (Árochová, et al., 1988). In other words, it indicated what was later, in the 1990s, confirmed in research.

In behavioural toxicological research some authors, such as C. Ernhart et al., (1990), prefer studying language, particularly in case of early impact of toxins within the second year of age when language development is very rapid. The author studied mainly syntax, which is extremely demanding for the experimenter. Here we can point to experience from our own research using the so-called connected associations method. We worked with a list of 30 signal words belonging to three lexical groups (nouns, adjectives and verbs). We wanted an association response to these words from the children. In evaluating the association responses we concentrated mainly on whether the response word had a syntagmatic or paradigmatic character. A syntagmatic association is when the response is a lexically different word from the original stimulus (e.g., apple – red, apple – mama bought) and in a paradigmatic association the response word is of the same lexical group as the stimulus word (apple – pear, plum – tree).

Although there are certain individual preferences in the production of associations along the syntagmatic or paradigmatic axis, the prevalence of paradigmatic responses in children around 7 years of age testifies to a higher level of cognitization in the arrangement of internal dictionary in the semantic memory of the child. The effect of a disruption of the homeostasis of the nervous system, should, theoretically, slow down the transition from the mainly syntagmatic to paradigmatic responses; i.e., a delay in the so-called “syntagmatic-paradigmatic shift”, which K. Nelson (according to L. Maršalová, 1982) places in the 7th year of age. This shift is synchronized with the onset of the “concrete operations” stage, which, as Piaget says, precedes the stage of the so-called formal operations, the highest stage in the development of cognitive processes in ontogenesis.

Although a statistically significant difference did not confirm the hypothesis of the relationship in association production between the affected and control children, the children from the control group over 6 years of age produced on average greater number of paradigmatic association responses than the affected children. In the

children from the affected group we also found a greater number of the so-called syntactic opposites, such as red – not red, light up – not light up, etc., which also represents developmentally lower type of association responses (mechanical addition of the word “not” to the signal word (even if the meaning of the word was destroyed).

We have presented the methods of memory searching activity and connected associations as examples of effective utilization of special methods of cognitive research in behavioural toxicology. The results of research projects, along with these methods, can be put in the context of the theoretical concept or model for the verification of which they were originally designed, and thus obtain the bases for the interpretation and more in-depth understanding of the phenomena under study. Such an interpretation allows for a qualified recommendation for practice, which is the primary goal in applied research. Precisely these are the advantages, compared to the commonly used screening methods, which undoubtedly systematically map the level of cognition. However, the interpretation of the findings is limited.

The efforts placed in innovations or research methods, or in other parameters of interdisciplinary behavioural-toxicological research, have an impact not only on the knowledge base but on ethical aspects as well. After all, the physical and mental prosperity of future generations, perhaps even the quality of entire populations living in unfavourable conditions, are at stake here. The fact that when stressing the need for technological investment (better filtering equipment, etc. which decrease the emissions of toxins into the air) our colleagues, public health workers, argued using findings from our research represents an important impact of scientific research.

In spite of many measures already taken in the interest of the improvement of the environment, toxins in the free environment in our country is still a very pressing subject. Therefore, the impact of behavioural-toxicological research should be seen not only in the cognitive area but also in terms of the fact that solving the quality of the environment problem is under significant pressure of the new knowledge from this type of research.

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