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TOXIC EMISSIONS AND COGNITIVE DEVELOPMENT OF CHILDREN: PRELIMINARY FINDINGS

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In our research, which is projected for several years, we are studying a selected group of children (n=83), aged 8–10 years, who have been living in an area polluted by toxic emissions (As, Cd, Pb, Cl, SO_x, NO_x) since their birth. Comparing the affected group (AG) with the control one (CG) (n=81) we found a certain performance impairment in short term memory and attention tests. A deeper insight into basal cognitive mechanisms was made possible by the use of some experimental methodological procedures in field research. Analysing the findings confirmed that this problem is greatly affected by quality of life.

INTRODUCTION

Slovak Republic, the eastern part of former Czechoslovakia, was affected not only politically but also ecologically by the fact that it had a common border with the former Soviet Union. Emphasizing the so-called heavy industry (iron works, mining, chemical industry, solid fuel power plants, etc.) finally lead not only to the devastation of the countryside but also to a serious endangering of the health of the population, mainly children who are most sensitive to the negative effects of the environment.

Even though many research findings from the previous years were not allowed to be published, only professionals had access to them, the health state of the population in the polluted areas has been monitored regularly since the fifties. The occurrences of various diseases, the level of hemoglobin in children, bone maturation in children living in industrially polluted areas, anthropometric growth indicators, etc., were all registered. Only in the recent decades has attention been focused on the possible effects of toxins on the CNS structures and on relevant cognitive processes. Research concentrating on the CNS function in children from polluted areas was incited by the teachers themselves, since they noticed that "something was not right with these children". They had concentration as well as learning problems. An important impulse for our research consisted in the results from "behavioural toxi-

cology" which was established within the framework of the environmental health science.

PROBLEM

Today we can no longer doubt that the negative factors in the environment potentially threaten or damage the health of each man. The problem becomes even more pressing if we accept the progressive concepts which envision the health of man in a much broader context; as an optimal physical, mental and social state of man (Zikmund, 1992).

Findings in behaviour toxicology indicate that even small concentrations of harmful chemical substances in the environment can, after long term exposure, cause detrimental changes in the organism. They are first manifested by subtle changes in psychologically regulated behaviour whether it be in the sense of impairment of cognitive functions or changes in emotionality. Thus the answer to the question whether even small traces of toxins in the environment can cause damage to the CNS must presently be yes. The open problem lies in finding suitable methods capable of detecting initial, often very slight deviations in the behaviour of an individual which, however, can later cause serious clinical changes or irreparable damage. "Monitoring" these subtle changes is by no means self-serving. The activity of man is conditioned by internal and external factors. In a certain sense the manifested behaviour is an indicator of the relationship between man and his environment. R. Russell (1988), with respect to the concept of homeostasis (as a base of the adjustment of living organisms to the unlimited fluctuation of the external environment), works with the term plasticity (behavioural "homeostasis"). We can expect that this term will encompass a negative effect on behaviour in the case when the homeostatic process is no longer capable of coping with the extent (dose) of exposure, i.e. environmental toxic emission load. Along with this assumption we must also count on the fact that the negative effects on psychologically regulated behavior caused by harmful factors in the environment are conditioned by individual and sexual differences. They are also connected with an overall nutritional and health state of an individual and with other socio-cultural factors.

Therefore, for various reasons, it is very difficult to determine acceptable exposure to toxins; the children's population calls for special attention. D.N. Kane (1977) summarizes the preconditions for the increased susceptibility of children to air pollution which are dependent on the weight of the children, quicker breathing, breathing through the mouth, more frequent bronchial infections, greater activity, etc. It has become evident that children have smaller capacity to metabolize and detoxicate poisonous substances than adults. O. Árochová et al. (1988) point to findings indicating that the emissions of heavy metals are particularly harmful for their terratogenous effects, for their ability to cumulate in human organism and also for the extraordinary sensibility of nerve tissue to their effects, mainly in

childhood. With respect to this, V. Lipková (1992) states that the consequence of such an exposure is the weakening of the overall functional performance and defense of the organism of the child, including his/her neuropsychological prosperity.

When it comes to research of the effects of toxins on the children population, studies which deal with the effects of lead on the psychological development of children prevail (Feldman, 1992; Moore, 1980; Needleman, 1979; Winneke, 1985; Bergomi, 1985). Several of these studies have already proven that even low dose of toxins has negative effects on cognitive functions and it is necessary to take into account their terratogenous effects, as emphasized by G. Fein et al. (1983). The more recent approaches to this problem emphasize the combination of toxins in the air where they probably interact. Among the first are Ch. Moone et al. (1985) who indicate that the interaction of metal emissions is in a negative synergetic relationship to cognitive performance of the children tested.

RESEARCH

In view of the above problems we have designed a broadly conceptualized research project which is based on the assumption that small doses of toxins in the environment, in case of long term cumulative exposure, can damage nerve structures which are necessary for properly working cognitive functions. We took our study sample from an area in central Slovakia in the vicinity of a solid fuel power plant where the harmful emissions include mainly As, Cd, Pb, Cl, SO_x, NO_x. This locality (as well as the locality in which the control group lives) was determined by hygienic specialists on the basis of long term monitoring. M. Ursinyová et al. (1986) published a more detailed study of the characteristics of this area. They found that the values of metal emissions including arsenic in dust particles was 1.5 to 4 times the allowed concentration. More recent alarming data (from 1992) revealed that hair samples of children from the polluted area had significantly higher concentration of As, Eu, K and Se than the children from the control area.

Our research project is planned for several upcoming years. We are studying the same selection of children over time. We would like to record the dynamism of the found specifics in cognitive development and behavior of children with respect to ecological life conditions. It would not be appropriate to speak of a longitudinal intention since the basic requirement of a longitudinal research to use the same methodical procedure in repeated examinations is not met in this research. The requirement of the same methodical procedure can present problems since it is not clear whether children in various developmental stages use the same cognitive structure to "work" on the same concrete cognitive task (operation). We see a good example in the finding that while during preschool age close correlations between global IQ test and the performance in short term visual memory are well proven, in later age, however, these connections are no longer valid. In our research in the re-

peated examinations (with the increasing age of the children) we use the same methods and adjusted methods depending on the intermediate results.

Behavioural-toxicological research is presently characterized by its preference of the so-called processual methodological approaches to global methods such as IQ. Philip J. Smith (1985) emphasizes the advantages of the processual methodological approach focused on observing basal elementary components when he states that in observing a certain disorder, using such a complex measure as the WAIS test, the "subjects may have available a number of alternative processing strategies or resource allocation plans. If one cognitive system is impaired, the subject may select a strategy that minimizes the load of the system. Effectively hiding the impairment". In this connection the author speaks of the so-called "compensatory shifts" by which the subject can compensate for, hide a handicap in a certain area of the CNS. In this project we firstly tried to "map out" cognitive functions of children. We designed a battery of methods including, among standard diagnostic procedures, methods from experimental or cognitive psychology since these correspond best to the processability requirement.

In this project we began to work with two groups of 8–10 year old children (in September 1991). The affected group (AG), i.e. a group of children (n=83) who were born and still live in a polluted area in a small industrial town (population below 5000) was compared with a control group (CG) of children living in a relatively unpolluted area in two larger villages (n=81). As mentioned before, both localities were determined by hygienic specialists on the basis of long term monitoring. Children were selected on the basis of extensive questionnaires given to the teachers and parents of the children. Based on such data we tried to balance the children in terms of socio-economic status of the families and in terms of health, educational and behavioural problems. This "quasi" longitudinal research is a close follow up of an interdisciplinary research carried out in the same area several years ago (Árochová et al., 1888). Their results are analogous to ours.

BASIC SCREENING

Children of both groups underwent a battery of psychological examinations which were to determine a broad spectrum of performances, from the elementary senso-motoric to the analytical-synthetic ones. Based on this extensive battery of tests we obtained the first data about the differences between the two groups (the AG showing an impairment) summarized as follows: A) Both groups had similar results in sensorimotor tests (tracing, tapping, dotting). There was a statistical difference only in dotting – right hand.

B) Serious differences were manifested in the area of attention and memory, where the performances of the AG and the CG differed statistically in the majority of the tests (i.e. in the numerical square, cross out test, immediate and delayed recall, graphic reproduction).

C) At the level of complex thought operations (Raven) no statistical differences were found between the two groups. These preliminary data as well as data obtained from a detailed analysis of the questionnaires given to the parents and teachers incited three studies with the following orientation:

I. An intensive probe into the area of attention-memory activities for children from the affected and control groups.

II. Experimental analysis of short-term memory performance of children from the AG and CG as functions of the serial position.

III. The impact of the quality of life of the AG and the CG children.

I
ATTENTION-MEMORY ACTIVITIES PROBE

In the first stage of the research we found a certain impairment in cognitive performances and in attention and memory tasks in children from the AG which was obvious, while the impairment in simple sensorimotor tasks (except for dotting – right hand) and in rather complicated thought operations was not obvious. That was the impulse for us to concentrate in the next study (in 1992) on attention and memory processes which appear to be particularly sensitive to negative effects of toxins in the air as well as learning, reading and searching processes which are more or less part of attention-memory activities. We expanded the battery of tests to include a psychophysiological examination using an evoked galvanic skin response. We consider combining psychophysiological and psychological measures in this type of research more than useful. This is based on the presumption that psychophysiological measures are a more sensitive and immediate way of detecting the negative effects of toxins in the environment on the CNS than psychological indicators. True, these measures in themselves are unspecific, i.e. they can be meaningfully interpreted only through psychological approaches. In any case, they can strongly emphasize the significance of psychological findings.

We used the following measures:

1. The activity of the electrodermal system in its spontaneous action, including the evoked response which is considered to be a correlate of the so-called orientational response of the organism.

2. Performance in attention test represented by a 7.5 minute programme with visual-acoustic stimuli. The Ss were to selectively react to a signal by pressing a key. This signal appeared 48 times within the 120 stimuli. An instrument registered the response time and the number of errors (i.e. pressing the key when an unsignalled stimuli appeared).

3. The memory tests consisted of a written recall of three lists of randomized two-syllable nouns (each list had 25 items) read by the experimenter:

a) a list of items differing from each other by meaning;

b) a list of items belonging to 5 categories (trees, clothing, animals, vegetables, musical instruments);

c) a list of items from a simple story about friends going on a trip together.

4. Learning performance was derived from the three above given memory tests in such a way that the Ss were presented repeatedly with these lists after a periods of one and two hours. After each presentation the Ss reproduced in writing the remembered items and the differences in performance after each presentation were evaluated as increases in learning.

5. A simple search time for a given target on a 7x7 matrix with alphanumerics (for example A4, D8). The task became loaded when the Ss had to remember two given targets and find the one present on the matrix, meaning that the other one was false. The experimenter registered the search time and the number of blockades. Time exceeding one minute was considered excessive.

6. Reading performance which is considered to be an orientational measure only. The experimenter registered the number of text lines read in 2 minutes and the number of errors (i.e. misread and repeated words, etc.).

One year after the initial measurements the number of children was reduced to 76 for the AG and 75 for the CG. Comparing both groups' galvanic skins response measurements we found no significant difference between them in skin response. On the other hand, differences between the two groups in measures of latency response of the electrodermal system to stimulation were found to be statistically highly significant. On average, the AG children have a longer latency time ($t=3.99$, $p<0.001$). Similarly, in the dynamics indicator, which is the immediate rapid change of skin resistance as a response to stimuli, differences between the groups were highly significant. These data are consistent and indicate an increased vulnerability of the electrodermal system of children from the AG to stimulation with poorer restoration of the evoked changes. In children from the CG these characteristics are opposite, i.e. a decreased sensitivity of the vegetative response with a quicker return to the prestimulation level. A study by V. Bíro (1993) analyses galvanic skin response measures in more detail.

The results of psychological measurements are consistently to the advantage of the control group.

If we compare the performance of the AG and the CG in the attention test in terms of latency response time to signal stimuli we find that they are balanced. The comparison of the two groups in terms of erroneousness is another matter (i.e. pressing the key following an unsignaled stimulus). The AG's erroneousness is significantly higher than the CG's at $p<0.05$.

The recall performance of the randomized list of mutually independent items is significantly better in case of the CG ($p<0.05$). In the remaining two lists the performances of the two groups do not differ significantly. Looking at the learning curve (fig. l) we see that the AG lags behind. In the final (third measurement) the

Figure 1. Learning curve of AG and CG from the unrelated items list (A), categorizable items list (B) and list of items from a story (C)

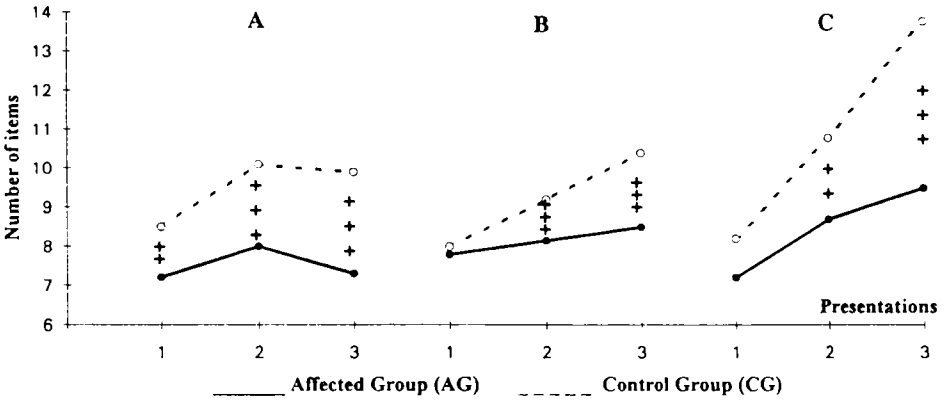
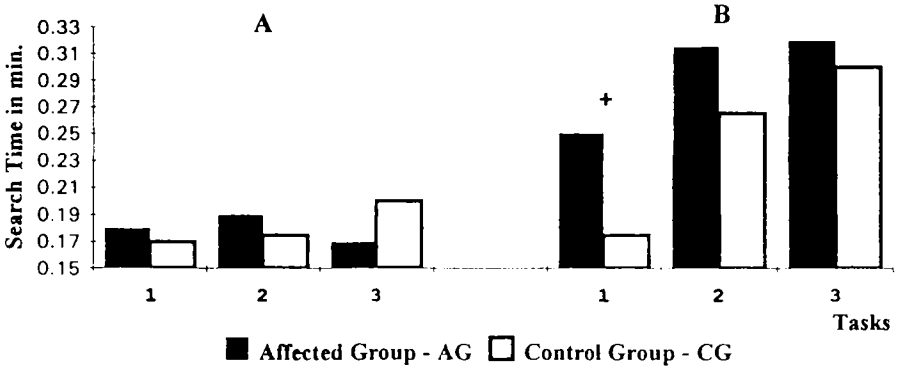


Figure 2. Average search time (in min.) of AG and CG in simple searching (A), searching with a Load (B)



groups differ highly significantly, to the advantage of the CG in all three tests ($p<0.01$).

The performances in simple as well as loaded search tests were systematically better on the part of the CG (with a lower number of blockades as well), however, only in one case, i.e. searching for target with load, did the difference prove to be statistically significant (fig. 2).

The compared groups differed greatly in reading performance ($p<0.001$). The poorer performance of the AG was accompanied by a greater erroneousness as well.

A great many findings indicate attention problems associated with the deterioration effect of toxins on the CNS and psychological functions of children. It is partially because the relatively well measurable performances in attention tests are evidently connected with the presence or the lack of toxins in the environment (D.M. Ferguson et al., 1988, Ch. Gillberg et al., 1982, O. Árochová et al., 1988). It is also important to consider the fact that attention processes which accompany any kind of cognitive act can be the key to this problem. One of the hypothesis for poorer performance in attention tests can be based on the generally observed hyperactivity in children with an increased content of metals (H. Chaiklin et al., 1985, O.J. David, 1984). The symptoms of hyperactivity can explain not only poorer attention and with it poorer cognitive performance but also behaviour or emotionality changes (M. Marlowe et al., 1982, 1985). The results of our study justify the presumption that the AG children will be more active which is not a desired trait. We think that the significantly shortened latency response of the electrodermal system to stimulation can be taken as a physiological indicator of hyperactivity in the AG children. If that is the case, on the basis of the presumed relationship between hyperactivity and attention disorders we can explain the statistically significant increase in erroneousness in attention tests on the part of the AG. The role of attention in recall performance is of fundamental importance for information processing. The three lists of items used in our research differed in a way which made the Ss use memory strategies at various levels of item processing. While the list of mutually independent items is memorized mainly mechanically, the second list makes it possible to utilize categorization strategy and the third one mediation strategy of memorization. Perhaps it is not a too daring construct if we assume that the statistical difference to the advantage of the CG, found only in case of the list of independent items, is connected with increased demands on attention in this test where higher level memorization aids (strategies) are absent. In the learning process the attention handicap of the AG cumulates and the differences in performances are significant in all tests. It is precisely attention disorders which cause the lengthening of search time as well as the significantly poorer performance in reading on the part of the AG.

II
SHORT-TERM MEMORY PERFORMANCE AS A FUNCTION OF THE SERIAL POSITION EFFECT

The processual approach brings basic information which can signal possible consequences of the effects of harmful environmental toxins on individual psychological functions. This approach is less informative when it comes to understanding the character of the damage. Therefore, it is useful to add to this approach specialized research probes which can penetrate closer to the core of the phenomenon and tell us more about the character of the possible damage. The analysis of short-term memory performance with respect to the serial position represents a probe under

the superficial quantitative data of the number of recalled items because it reveals which parts of the stimuli series the subject remembers and which not. The performances of the AG and the CG children in immediate as well as delayed recall of several digit numbers, i.e. in their extent of memory, which differed significantly to the advantage of the CG were evaluated as a function of the serial position effect. The methodologies for measuring memory extent are generally known. The children from both groups were presented (acoustically) with 5, 6 and 7 digit numbers. The test had two versions:

a) In the immediate recall the children were to write, immediately following the presentation, the numbers down in the right order;

b) In the delayed recall (can be considered a load version of the test) an interpolated activity was inserted in between the stimulus and its recall – children had to articulate the letters A, B, C.

In this method, the recall performance, i.e. the memory extent, is usually expressed by the number of individual elements (numbers) correctly recalled in the correct order after one presentation. We can get much more differentiated data about this performance if we analyse the correctly recalled items as a function of the so-called serial position effect (for more detail see Potašová, 1992).

The serial position effect is known from classic learning experiments. It can characterize quite well even the recall of stimuli series presented once. It is a phenomenon which expresses the unequal difficulty of individual parts of the stimuli set. The beginning and the end are the least difficult, the most difficult place is in the middle and toward the end of the set. The U shaped curve has the left arm, i.e. the primary effect, higher than the right, the recency effect.

The serial position effect was explained traditionally by the so-called delayed inhibition. It is expected that each element on the list has the tendency to call forth the next one. However, this tendency is later balanced by an opposite inhibiting tendency until another reinforcement comes and the inhibition falls again toward the end of the list (in the last decades cognitive psychology brought a number of innovative hypothesis which describe this dynamically retentive phenomenon using their own terminology). Figures 3 and 4 present the recall performance in stimulus series of children from the AG and the CG as a function of the serial position effect. Looking at the curves we can deduce that the differences in performances which are systematically to the disadvantage of the AG are mainly in the second part of the recalled series, i.e. the recency effect.

In immediate recall (fig. 3) the difference in performance is more obvious when the stimulus set is lengthened. In delayed recall (fig. 4) on the part of the AG there is a characteristic sharp decrease in the recallability of items in the second half of the stimulus set of shorter (5 digit) and longer (7 digit) stimulus series. On the other hand, the recallability of the first 2–3 items in the set is similar for both groups. Based on this comparison we could say that it is the matter of "suppressing" the recency effect on the part of the AG group.

Figure 3. Percentage of correctly recalled figures as a function of serial position of five-digit and seven-digit stimulus series in immediate recall

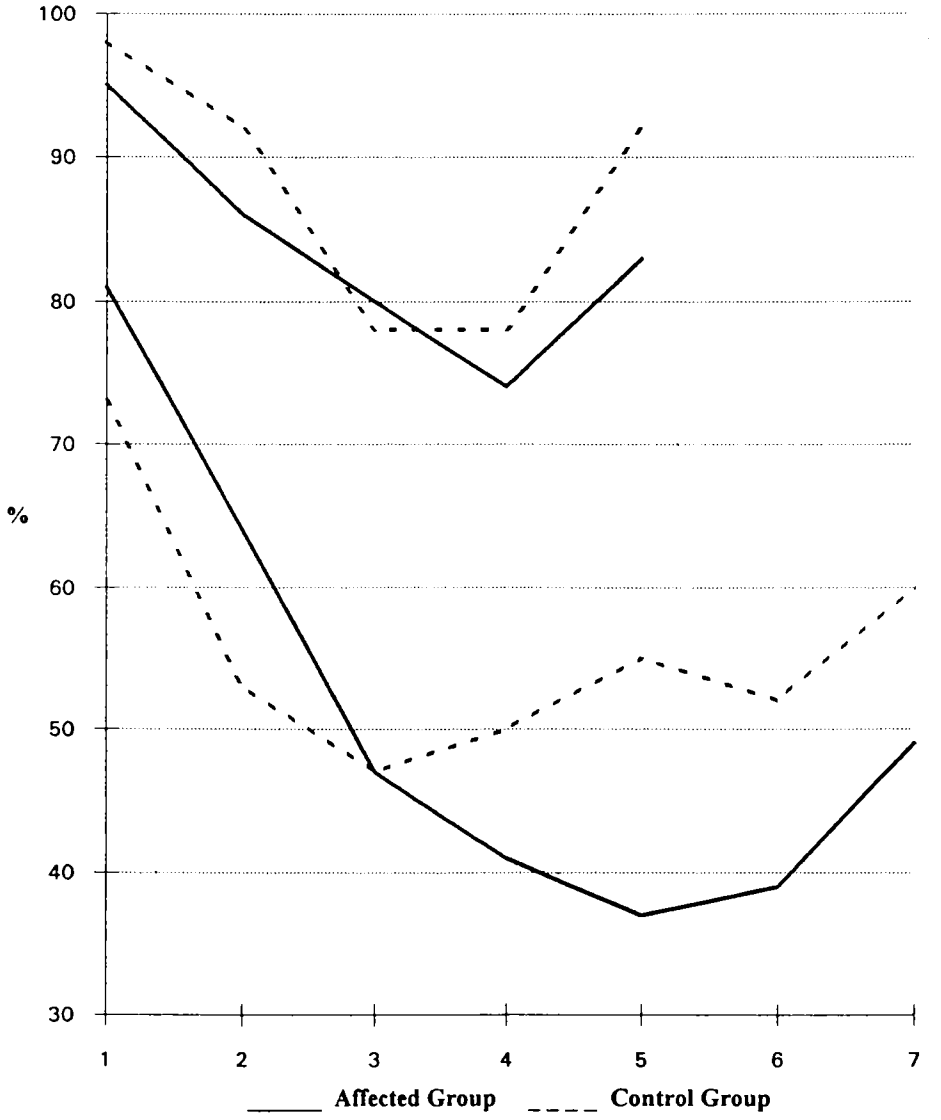
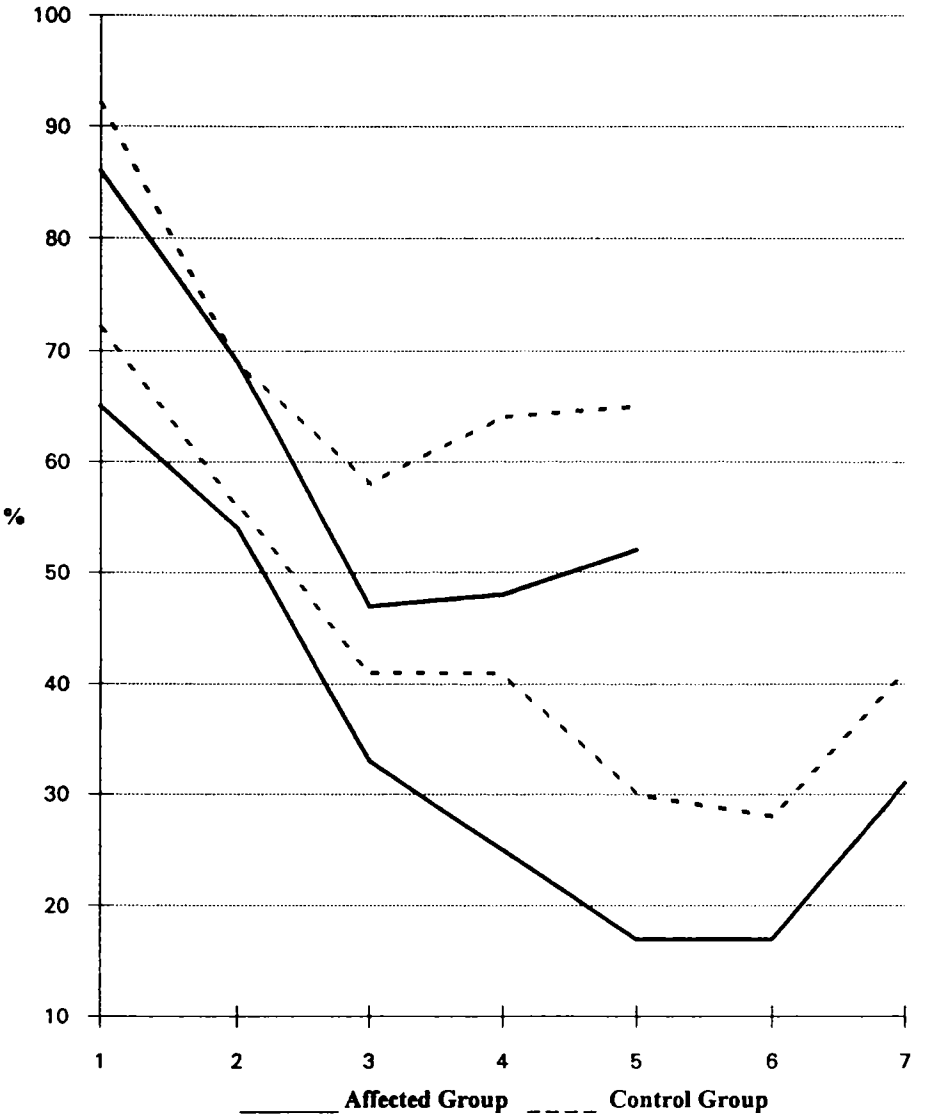


Figure 4. Percentage of correctly recalled figures as a function of serial position of five-digit and seven-digit stimulus series in delayed recall



Our finding, in view of the delayed inhibition hypothesis, seems to indicate that in case of the AG in the recall of the stimulus series the dynamics of opposite reinforcement and inhibition tendencies (more accurately that inhibition lasts longer in the AG subjects) is disrupted. These tendencies characterize the basal mechanism of short-term retention.

III
ASPECTS OF QUALITY OF LIFE

Social environment is a great source of factors intervening in this problem area. Various studies have found that positive socio-economic and cultural stimuli cover up or compensate for, to a significant degree, the negative effects of toxins in the environment.

In our project we also came across this problem of social background in spite of the fact that the control area is socio-culturally and geographically close to the affected area and that we balanced the two groups by means of extensive questionnaire scales developed just for this purpose. Two questionnaires for teachers (EKU) and parents (EKOR) mapped the socio-economic status, the family environment in which the children were growing up, as well as possible problems in education, behaviour and health status of the children. Data from the questionnaires formed four basic problem areas:

a) socio-economic conditions of the family
b) the children's health problems
c) the children's behaviour problems
d) educational problems or problems in the cognitive area.

In the global measures in these problem areas the affected and the control groups did not differ which we considered to be a sufficient criterion for the balancing of the two groups. Later, however, after analysing individual items, we came across differences which were "lost" in the global measures. The teachers of the children from the AG indicated certain problems (less care given to the children by their families) in the area of personal hygiene for 55% of the children, in the area of nutrition for 56% (teachers of the CG children indicated only 25% in these problem areas). In 61% of the AG children the teachers indicated a suspicion of alcoholism in the family (in the CG families only 20% were suspected of alcoholism). From the information from the parents we found that 25% of the AG children live in family houses while 75% of the CG children live in family houses. We emphasize that these differences were found even though the children's financial situation, how well the household was equipped, education and status of the parents and other parameters were all comparable for both groups.

In assessing the results we also considered whether the differences in the questionnaire items are not relevant to cognitive development (performance) of the children. These are circumstances which can signal differences in the value system of

the AG and CG families and thus certain differences in the parameters of the quality of life of the children. This signal led us to try to make the project even more accurate in the sense that we expanded it by another group of children (n=79), the so-called affected rural group (ARG) which approached the CG in the critical questionnaire items (the teachers indicate a lower personal hygiene in 32% of the children, nutritional problems for 49% of the children, suspicion of alcoholism in 26% of the cases, 62% of the children live in family houses). The parameters of toxic emissions in the ARG's environment are comparable to the conditions of the AG. We found that the ARG places in between the AG and the CG in the majority of the tests. On account of this trend we are inclined to believe that the intervention of social factors into the problem studied cannot be understood only in the sense of socio-economic status. It is a part of much broader social-economic-cultural context which encompasses life values and life style and is directly relevant to the questions of quality of life (quality of life can be understood as a function of the degree of accord or discord between individual or group abilities and needs and what the environment can offer). It has become evident that the quality of life forms a reference framework for the assessment of any aspects of the man-environment relationship.

CONCLUSION

Our research confirmed the hypothesis of behavioural toxicology concerning harmful effects of toxic emissions, mainly of metal character, on neural mechanisms which secure the basic cognitive processes. The study presents groundwork findings of a long-term monitoring of a select group of young school children who were born and continue to live in an area affected by harmful industrial emissions and who are compared with a group of children living in a relatively unpolluted area. The groundwork measurements using a battery of cognitive tasks did bring signals about a certain cognitive impairment in the area of short-term memory and attention.

When we tried to look at this finding more closely we used the measures of the evoked galvanic skin response which indicated an empirically observable sign of hyperactivity in children from the affected group. We can assume that it is hyperactivity, which is in a close relationship to attention disorders, that is behind a certain impairment in the attention-memory performance of the affected group children. The analysis of the recall performance as a function of the serial position effect gave us a reason to consider the possibility that the basal dynamic phenomenon (i.e. the relationship between reinforcement and inhibition) is disturbed. This phenomenon is characteristic for short-term retention.

In preliminary processing of the research material and additional data (including the so-called affected rural group of children in the sample) our attention turned to the extensive context of quality of life as a relevant reference framework,

not only for the evaluation of the problem but also for revealing potential possibilities of intervening with the problem.

In our research, methods from experimental or cognitive psychology, which are sufficiently sensitive to detect changes – damages to basal psychological processes, were very useful.

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