ELSEVIER

The Science of the Total Environment 180 (1996) 87–93

the Science of the Total Environment
An International Journal for Scientific Research into the Environment and its Relationship with Man

Motor and psychological functions of school children living in the area of the Skrunda Radio Location Station in Latvia

A.A. Kolodynski*, V.V. Kolodynska

Institute of Biology, Latvian Academy of Sciences, 3 Miera Str., Salaspils, LV-2121, Latvia

Abstract

This paper presents the results of experiments on school children living in the area of the Skrunda Radio Location Station (RLS) in Latvia. Motor function, memory and attention significantly differed between the exposed and control groups. Children living in front of the RLS had less developed memory and attention, their reaction time was slower and their neuromuscular apparatus endurance was decreased.

Keywords: Electromagnetic field; Adolescent; Motor reaction; Memory; Attention

1. Introduction

An early warning military radio location station (RLS) has operated for more than 25 years in a populated region of Skrunda, Latvia. However, the study of chronic effects of electromagnetic radiation on the population at Skrunda has only recently started. Studies of motor and psychological development of children and adolescents that live close to the RLS may provide evidence of effects.

The Skrunda RLS is an pulse radar station that operates at frequencies of 154–162 MHz. The duration of pulses is 0.8 ms and time between pulses is 41 ms, i.e. the pulses occur at a frequency of 24.4 Hz [3,7]. The electromagnetic field (EMF) effect of this frequency range on human motor and psychological function is insufficiently studied, however, there are already data available on the inhibiting effects of EMF [2,5,6,8]. The literature indicates that EMFs may influence human motor and psychological processes [5,9].

This report summarises the results of a study of the development of some motor and psychological functions of children who were born and constantly live under conditions of chronic EMF exposure in the Skrunda area.

2. Materials and methods

2.1. Subjects and groups

The studies were performed on 966 children (425 males and 541 females) aged 9–18 years. A

* Corresponding author

SSDI 0048-9697(95)04924-P

total of 609 children were examined in the Kuldíga and Saldus regions within a 20-km radius of the Skrunda RLS. Of these, 224 pupils live in directly exposed areas. The Skrunda RLS is located in a valley, and the exposed population lives on the slope in the direction of the field of view of the station (westward). Exposure decreases with distance from the radar [3], and field intensities behind the radar are background levels. The control group of 357 pupils lived in the Preiļi region. Girls and boys were divided into five age groups with 2-year intervals (Table 1).

According to the Ministry of Environment Protection and Regional Development of Latvia, both of these regions have similar and low pollution levels (Table 2) [1]. Both are agricultural, without major point sources of pollution, with the exception of small boiler houses.

For the populations of children living in front of the radar and behind it, and for the control group, groups of similar age and sex were selected. We examined similar social groups of farming communities, and 95% of subjects lived on small farms. The tests were carried out in the spring, from April to May.

The studies were performed with a psychophysiological diagnostic system 'Polytest-8802'. The 'Polytest-8802' is a specialised computer that uses reaction to determine human functional state. In total, 11 tests were used for each child. A rest break was included and the test duration was 70 min. Each test included twenty measurements, which were used to obtain the arithmetical mean, standard deviation and standard error of the mean [4].

2.2. Tapping-test

To evaluate the functional state of the neuromuscular system, we used a tapping-test. The children examined had to press two keys with their right and left hands at maximum rate for 30 s. The rate of key pressing per second was registered for each hand separately.

2.3. Reaction time

Red light diodes were used to present light stimuli at the centre of the table and on the left and right sides. The visible diameter of the light was 2.5 mm and the stimulus duration was 40 ms [4]. Sound stimuli were given with stereo earphones (intensity, 60 dB; stimulus duration, 100 ms; frequency, 1 kHz). The interval between both light and sound stimuli was randomised (2.5–4 s). The children had to rapidly press and release keys

Table 1
Mean age ± S.E. (years) of five groups of children from the Skrunda area, further classified into unexposed and exposed, and the Preiļi region (control group

Region	Age group (years)				
	9–10	11–12	13–14	15–16	17–18
Skrunda, unexposed					
Females	9.7 ± 0.1	11.5 ± 0.1	13.7 ± 0.1	15.3 ± 0.1	17.4 ± 0.1
n	31	73	49	41	23
Males	9.8 ± 0.1	11.4 ± 0.1	13.5 ± 0.1	15.3 ± 0.1	17.3 ± 0.1
n	30	64	35	31	8
Skrunda, exposed					
Females	9.6 ± 0.1	11.4 ± 0.1	13.7 ± 0.1	15.1 ± 0.1	17.6 ± 0.1
n	14	26	40	41	17
Males	9.6 ± 0.1	11.4 ± 0.1	13.4 ± 0.1	15.3 ± 0.1	17
n	19	20	22	24	1
Preiļi, control					
Females	9.7 ± 0.1	11.5 ± 0.1	13.7 ± 0.1	15.3 ± 0.1	17.4 ± 0.1
n	26	53	49	38	20

Table 2
Estimated rates of emissions (tons/km^2) from all sources in Kuldiga and Preiļi districts in 1991

Region	Particles	SO_2	NO_x	CO	Total
Kuldiga	790.1	1052.8	80.7	571.5	2496.2
Preiļi	1250.7	2011.4	352.3	1195.8	4818

after stimuli. Presentation of stimuli from the table centre or biaurally (RTB) required the child to press both buttons simultaneously. When the stimulus was presented from the side of the table (RTL), or in one earphone, the subject had to press the key on the side corresponding to the stimulus. In the cross variant of the test (RTC), the subject had press the key at the side opposite that of the stimulus. The response time, duration of press contact and the number of errors were registered.

2.4. Attention

The capacity for attention switching was tested according to a modified Shulte's procedure. The procedure used a double-coloured table of 64 squares. Each square consisted of two numbers: large black colour and small red (index), as well as a response button. At the beginning of the test the monitor displayed a number which the child was required to find among the black numbers. When the required black number was found, the child was required to press the appropriate key and memorise the associated red number. This new number was then searched for among the black numbers and the process was repeated 20 times.

The stability and capacity to focus attention were studied with an 'entangled lines' test. The test table was covered with entangled lines. Each line began with a number on the left side and finishes with another number on the right side. The child was required to rapidly follow each line visually and press the button at its finish. The time taken to follow every line and the number of errors were registered.

2.5. Memory

Memory was tested by the capacity to remember numbers. During one test, three numbers were displayed on a monitor at 1-s intervals. The child then entered the three numbers on the keyboard. This was repeated seven times, progressively increasing the number of numbers displayed from three to nine. The volume of operative memory was determined according to the formula $V = A + (m/n)$ where A is the largest numbers of digits in the operation which was successfully reproduced by the child in all experiments, n is the number of experiments, m is the number of correctly reproduced number series. During the experiment, a series of numbers of increasing complexity was presented, beginning with three digits and ending with nine. White digits of 6 × 10 mm, on a dark-grey background were presented on the computer monitor.

2.6. Statistics

Statistically significant differences were evaluated by Student's criteria for quantitative variables.

3. Results

Preliminary data analysis showed that among grade 9 children, there were 16% fewer boys in Skrunda, and 25% fewer in the area exposed to the Skrunda RLS. This is uncommon in Latvia for Grade 9 school children and the reasons for these differences are not known. The rates of all motor reaction (tapping-test and reaction time) tests in boys were better than in girls, both in exposed and control groups, and hence male and female groups were treated separately.

The reaction time to both sound and visual stimuli in the children living around Skrunda was somewhat longer than in Preiļi children, for both girls and boys, although the differences are statistically significant only for younger groups (Fig. 1). The duration of retention of keys in the pressed

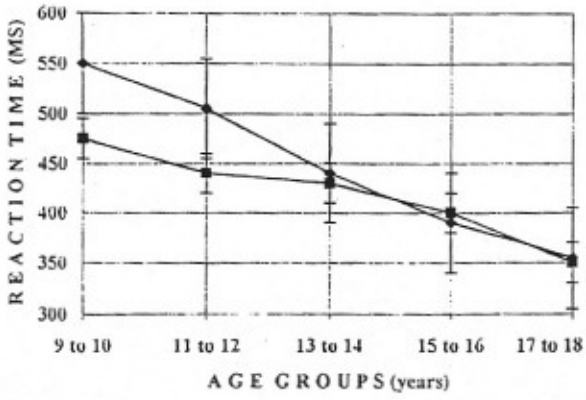

Fig. 1. Means ± standard errors of the cross response left hand reaction time (RT) to sound stimuli in children (female) in five age groups from Skrunda (♦) and Preiļi (■). For ages 9–10 and 11–12 years, the differences are significant at $P < 0.05$.

state was also significantly longer for all age groups in Skrunda, compared with Preiļi.

A similar tendency was also observed in memory and attention tests. In Skrunda, the memory and attention of children were worse than in Preiļi, but the differences were not significant. In the tapping test (Fig. 2), boys and girls from Preiļi performed better than those from Skrunda. Performance in this test improved with age.

More significant differences were observed when the Skrunda population was divided into exposed and unexposed groups and compared with the Preiļi group. Memory (Fig. 3) and attention (Fig. 4) were considerably less ($P < 0.05$) in the children living in front of the Skrunda RLS. Motor reaction was also delayed in girls living in Skrunda, but not in boys (Fig. 5). For girls, the retention time of keys was almost always significantly longer for the Skrunda exposed group, compared with the unexposed group (Table 3). In males, however, only in some age groups for each test were the effects significant.

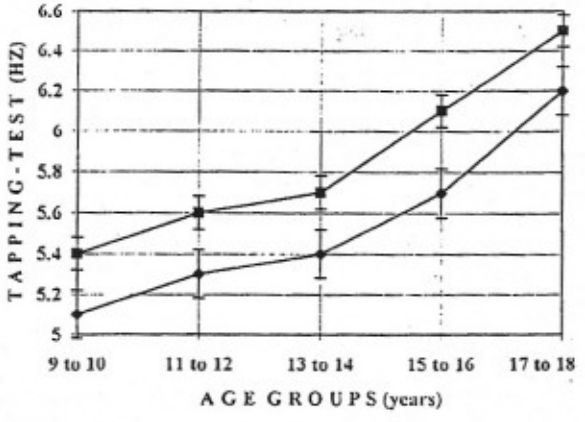

Fig. 2. Means ± standard errors of the tapping test frequencies of male children in five age groups from Skrunda (♦) and Preiļi (■), using the left hand. The differences for all age groups are significant at $P < 0.05$.

Every subject's address was registered, with the length of time they had lived in the given district. It was thus possible to determine the distance from the Skrunda RLS to the subjects' home. Generally, exposure decreases with distance from the RLS, but field intensities are extremely variable temporally and spatially due to factors such as local topography, operating regime, tree canopy, etc. [3]. For this reason, and the lack of large numbers of permanent field intensity recorders, it was not possible to measure the intensities at each home. There was a weak positive correlation (0.27, $P < 0.05$) between the distance from the RLS and rates achieved in the tapping-test and a negative correlation (-0.29, $P < 0.01$) between the distance from the RLS and contact retention time in motor reaction. In this case, Pearson's coefficient was used.

4. Discussion

Measurements and calculations performed by the Air Material Command of the Royal Danish Air Force [7] demonstrated that the mean power density of the Skrunda RLS is insignificant. For example, at a distance of 3.7 km from the RLS the mean power density measured was only 3.205 mW/m^2. However, the peak power density is 50 times higher (164.27 mW/m^2). It is more likely that the peak power density, rather than the mean value, is the factor which could cause effects on organisms. The literature lacks data on motor and psychological effects of weak pulsed radiofrequency fields of the range studied (154–162 MHz), with a pulse frequency of 24.4 Hz. This 24.4-Hz frequency coincides with that of

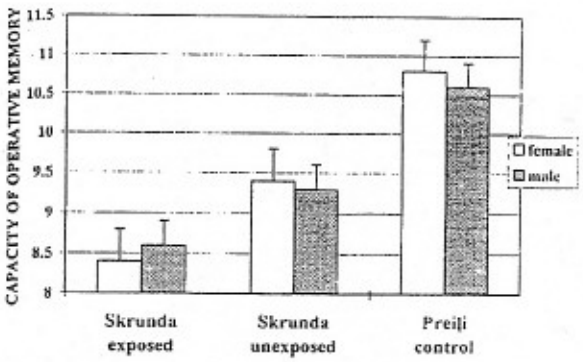

Fig. 3. Means ± standard errors of operative memory in male and female children aged 15–16 years, living in the Skrunda exposed and unexposed areas and the Preili control area. The differences are significant ($P < 0.05$) between the Skrunda exposed and unexposed areas, as well as between the Skrunda unexposed and Preili areas.

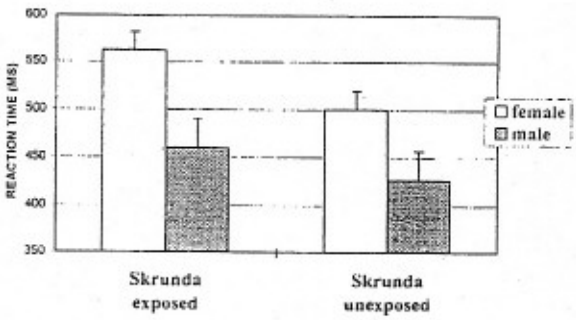

Fig. 5. Means ± standard errors of the cross response reaction time using the right hand to light stimuli in male and female children living in the Skrunda exposed and unexposed areas and the Preili control area. The differences are significant ($P < 0.05$) only between girls living in the Skrunda exposed and unexposed areas.

human electroencephalogram β-rhythms, and it is not excluded that low frequency pulses are one of the reasons for the observed alterations. Lyskov et al. [5] showed that low-frequency magnetic fields induced inhibition of motor and nervous process. Our earlier research [4] also demonstrated that a weak low frequency pulse EMF causes shifts in neurophysiological parameters, even after 15 min.

The weak correlations between the distance from the children's homes to the RLS, and the children's responses, are certainly consistent with the idea of an electromagnetic field effect. The exposure of each child cannot be monitored, due to spatially and temporally variable intensities, and the fact the subjects move out of and within the exposed zone. The children living in front of the Skrunda RLS have less developed memory and attention, slower reaction times and decreased endurance of neuromuscular apparatus. On the basis of the data obtained, one could propose the working hypothesis that the decreased endurance of neuromuscular apparatus, slower reaction time and less developed memory and attention are the results of chronic electromagnetic radiation effects. Evidence for a factor other than electromagnetic field having caused the observed results was not found, but its existence cannot be ruled out, for example, differences in the past experiences of children, local small pollution effects, differences in family behaviour, etc.

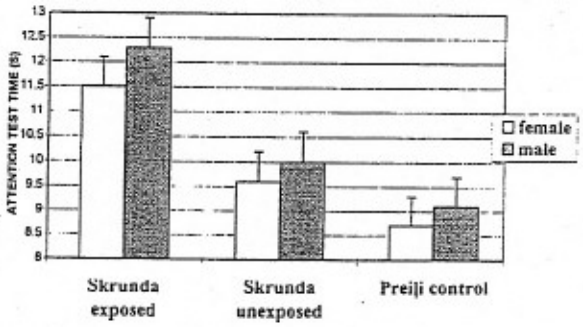

Fig. 4. Means ± standard errors of time of attention switching test duration in male and female children aged 15–16 years, living in the Skrunda exposed and unexposed areas and the Preili control area. The differences are significant ($P < 0.05$) between the Skrunda exposed and unexposed areas, as well as between the Skrunda exposed and Preili areas.

At present, we can only state that the children living in the exposed zone in front of the Skrunda RLS performed worse in the psychological tests given than the children living behind the RLS, and even worse again when compared with the control group.

The validity of a statement that the RFEM field at Skrunda has caused these differences can only be claimed with continuous and accurate assessment of dose, and close to exact standardisation of subjects. The measurement of dose is problematic, since the children move in and out

Table 3
Mean values ± S.E. of retention time of keys in the pressed state for right hands by male and female children from the Skrunda unexposed area and Skrunda exposed area, in reaction to sound stimuli presented biaurally and monaurally

Region	Age groups (years)				
	9–10	11–12	13–14	15–16	17–18
Biaural stimuli (RTB)					
Female					
Unexposed	214 ± 10	206 ± 8	164 ± 13	128 ± 8	126 ± 7
Exposed	250 ± 11	258 ± 12	228 ± 15	182 ± 14	167 ± 10
P-value	< 0.05	< 0.05	< 0.01	< 0.01	< 0.05
Males					
Unexposed	191 ± 9	182 ± 9	145 ± 11	105 ± 7	99 ± 6
Exposed	211 ± 10	223 ± 11	200 ± 8	156 ± 9	124 ± 10
P-value	NS	< 0.05	< 0.01	< 0.05	NS
Monoaural stimuli (RTL)					
Female					
Unexposed	224 ± 9	220 ± 10	221 ± 11	173 ± 10	192 ± 10
Exposed	265 ± 11	239 ± 11	249 ± 16	219 ± 15	224 ± 10
P-value	< 0.05	< 0.05	NS	< 0.05	< 0.05
Male					
Unexposed	212 ± 10	208 ± 9	202 ± 11	190 ± 12	110 ± 12
Exposed	243 ± 11	227 ± 10	210 ± 9	202 ± 11	133 ± 11
P-value	< 0.05	NS	NS	NS	NS
Cross variant of test (RTC)					
Female					
Unexposed	209 ± 11	197 ± 8	221 ± 11	199 ± 11	222 ± 10
Exposed	259 ± 14	238 ± 10	246 ± 11	237 ± 12	239 ± 11
P-value	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Male					
Unexposed	199 ± 9	175 ± 8	200 ± 11	170 ± 7	199 ± 10
Exposed	232 ± 10	207 ± 11	221 ± 8	191 ± 9	181 ± 9
P-value	< 0.05	NS	NS	NS	NS

RTL, key pressed at same side as stimulus; RTC, key pressed at opposite side as stimulus; NS, not significant.

of the radiation zone, and the temporal changes in intensity are high [3]. However, the results presented, especially the weak correlation between performance and distance to the RLS, certainly suggest that this path of research is worthwhile. Further work is continuing to increase the sample size and to attempt to arrive at estimations of dose.

Acknowledgements

The authors extend their thanks to G. Brūmelis for improving the language of the text, and to I. Nunévica, a teacher at the Skrunda 1 High School, for logistical help during the project. Financial assistance was obtained from the Latvian Science Council Project Nr. 136.69.

References

[1] Ministry of Environment Protection and Regional Development, Air environment protection, Report for 1991, Riga, 1992, pp. 54.

[2] H.A. Hansson, Effects on the nervous system by exposure to electromagnetic fields: experimental and clinical studies, in M.E. O'Connor and R.H. Lovely (Eds.) Electromagnetic Fields and Neurobehavioral Function. Progress in Clinical and Biological Research, Vol. 257, Alan R. Liss Inc., New York, 1988, pp. 119–134.

[3] T. Kalniņš, A. Krisbergs, A. Romancūks, Measurement of

the intensity of electromagnetic radiation from the Skrunda radar, Sci. Total Environ., 180 (1996) 51–56.

[4] Kolodynski A. Human Psychophysiological Reaction to Lateralized Signals Under Monotony Conditions, AVK Press, Riga, 1993, pp. 48 p.

[5] E. Lyskov, J. Juutilainen, V. Jousmaki, J. Partanen, S. Medvedev and O. Hanninen, Effect of 45-Hz magnetic field on the functional state of the human brain. Bioelectromagnetics, 14 (1993) 87–95.

[6] S. Medvedev, E. Lyskov, Z. Alecsanian, V. Iousmiaki, J. Jutilainen, I. Partanen, I. Rutkovskaja, T. Safonova and O. Khaninen, Dynamics of brain bioelectric activity and reaction time after exposure to an alternating magnetic field. Fiziol. Cheloveka, 18 (1992) 41–48.

[7] Air Material Command of the Royal Danish Air Force, Report: Non-Ionising Radiation Measurements around the Russian Radar Site in Skrunda, Latvia, Skrunda, 1994, 19 pp.

[8] A. Novini, Fundamental issues on electromagnetic fields. Acupunct. Electrother. Res., 18 (1993) 23–31.

[9] M. O'Connor, Psychological studies in non-ionizing electromagnetic energy research. J. Gen. Psychol., 120 (1993) 33–47.