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PSYCHOPHYSIOLOGICAL CHARACTERISTICS OF CHILDREN CELL PHONE USERS. RESULTS OF 4-YEAR MONITORING

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This paper presents the results of a four-year monitoring of a complex diagnostics of the psychophysiological parameters of 196 children of 7 - 12 year-old. 147 children were cell phones users (test group) and 49 children constitute the control group. The main recorded trends in psychophysiological parameters of those children that were cell phone users are the following: an increase number of incorrect phonetic perception; reduced efficiency, voluntary attention and semantic memory; increased rate of fatigue. Another tendency was the considerable decline of psychophysiological parameters from high results to the lower limit of age norms.

Cell/mobile phones (MP), electromagnetic radiation, psychophysiological parameters, children

MATERIALS AND METHODS

The structure of any psychophysiological monitoring research, especially on children, must satisfy certain conditions. First, children should live and receive education in the same area, because it was previously shown [1] that the psychophysiological performance may differ significantly depending on living in areas with different environmental conditions.

Second, children's education should be carried out according to the same educational programs. It was proven that age-related changes in neurodynamic characteristics (especially the dynamics of changes in such cognitive processes as attention and memory) are different for children educated in different educational programs [2]. In addition, it is imperative to take into account that some children might attend additional developing remedial classes. Those classes imply changing certain parameters in the direction of improvement, such as attention and memory enhancement, speech therapy to eliminate difficulties in speech and writing, etc.

Thirdly, the selection of methods for the diagnostics has to be made as follows: tests should be carried out without apparent effort, even by children of preschool age, they should neither cause fatigue, nor to be prolonged in time. At the same time, they should examine age-related dynamics of the measured parameters and comprehensively assess possible changes in the psychophysiological performance of a child using cell phone.

And finally, the diagnostics should be made only with the written consent of parents or legal guardians of the child; the results should be kept confidential and without any chances to be transferred to third parties.

This set of requirements to the organization of monitoring studies implies one more condition – permission from an administration of educational institution participating in it.

All these requirements have been met in case of the monitoring studies conducted in Lyceum # 10, Khimki, Moscow Region.

Based on the literature review, presented in a Communication 1, it was created and implemented a complex diagnostics, consisting of several blocks.

Block 1. The study of psychophysiological parameters (using physiologist's workstations). It included an assessment of nervous system characteristics: (1) strength/weakness of the nervous system and its lability; (2) performance; (3) ability to fine sensorimotor coordination, which reflects the degree of muscle tension and can serve as an indicator of fatigue; (4) analyzers performance (speed of visual perception (latent period of the simple visual-motor response); (5) visual acuity at near vision; (6) speed of visual recognition; (6) the speed of sound perception (the latent period of a simple auditory-motor reaction); (7) the extent of phonetic perception disfunction; (8) the level of cognitive maturity (voluntary attention and semantic memory).

It should be noted that the validation (checking the compliance with accepted standards of such studies) of all of these techniques was done in advance. Besides, we performed an additional processing of the results received with their help [3, 5, 6].

Block 2. Recording of fine motor skills by using special computer program that analyses ten finger typing [7, 8].

Block 3. Neuropsychological evaluation: a study of lateral preference, motor and tactile functions; an assessment of the level of spatial representations and speech functions. Besides, some special computer tests were used to study the motor and sensory asymmetry. It tested latent period of the simple visual-motor and audio-motor reactions, which at first were assessed while binocular and stereo vision, and then at a mono-presentation of stimuli (separately for each eye and each ear). The ability to fine sensorimotor coordination was tested as well: first children performed tasks with one hand, then – with the other one, and both of performances were recorded and analyzed. While performing additional neuropsychological diagnostic tests some methods (mentioned in the literature reviewed for this article) were used for the final identification of the leading hands, ears and eyes.

Block 4. Questioning of children in order to determine their type of mobile phone use, use of computer, and their schedule of visits to correctional and developmental studies.

Block 5. The collection of anamnestic data. Questionnaires were filled out by parents at home and then were handed out in a sealed envelope to a specialist who was carrying out the diagnostics. Questionnaire analysis was juxtaposed with a child's type of mobile phone use, use of computer and dvd-player.

It should be noted that, when the computer tests (blocks 1 and 2) have been carried out, a visual observation was also set up. It allowed capturing the static and dynamic synkinesis, increased or excessive motor activity, children's verbal comments which were taken into account later on when carrying out general neuropsychological examination. Diagnostics was carried out in the first half of the day; the child was freed for one lesson (by permission of school administration and teacher).

Thus, the diagnostic system made it possible to perform a versatile examination of neurodynamic characteristics of those children whose parents gave written informed consent to participate in the monitoring.

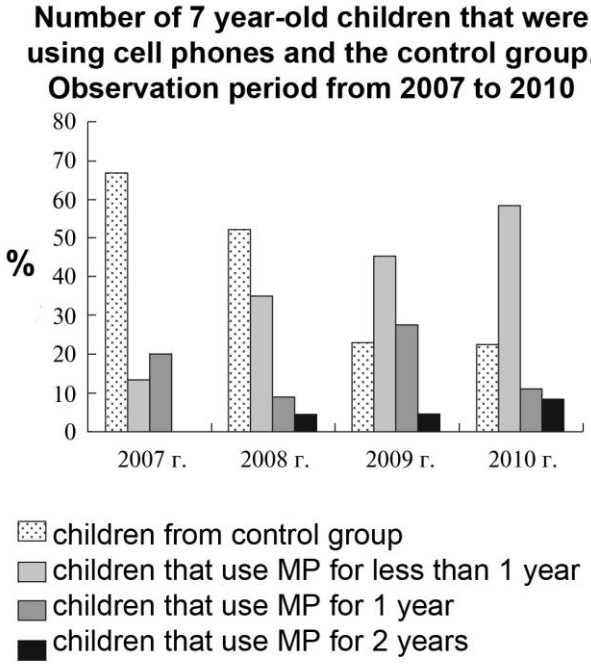
The above scheme (except for block 2) had been previously applied to monitor neurodynamic characteristics of four thousand children and teenagers living in different parts of Moscow and Moscow region over the period from 1993 to 2003, which allowed to define limits of psychophysiological variation for age groups from 4.5 to 18 years. In addition, in 1999-2003, 370 children (5-12 years) went through a similar complex diagnostics. Its results were used for this study as a kind of "historical control".

RESULTS

Questionnaires results

Based on the questionnaires results, all children were divided into two groups: test (147 children-users of mobile phones); and control (49 children). It should be noted that initially, according to parents survey on their children's use of mobile telephones (MT), the control group consisted of 63 people. However, the children survey revealed that even though some children did not have their own mobile phones, they were extensively using phones of other people (parents, older brothers and sisters). This fact showed that some parents have had quite a formal approach to the questionnaire. Therefore later on we'd be using the results of cross questioning of children and their parents. Besides, we took into account situations where a child was engaged in various correctional and developmental programs (classes with speech therapist, psychologist, neuropsychologist), since in such cases the psycho-physiological parameters may vary significantly.

Thus, the cross-questioning of children and their parents revealed a trend in the mode of MT use for children of primary school age. The figure shows the dynamics of change in the number of 7 y.o. children (the largest group: 91 children, of whom 32 children belong the control group, 59 children belong to the test group).



As we can see, for the period of observation (2007 – 2010) the number of children (%), who do not use mobile phones, declined from 66.7 to 22.2%. The number of children who begin using mobile phones when entering the first grade increased from 11% to 58%. In addition, there is an increase in the number of children who use mobile phones for more than two years, i.e. they started using MPs from the age of five. Also it was found that a significant increase in the number of children using MPs coincides with the beginning of the school age (6-7 years). When they are 10-11 year old, almost all the students have become users of mobile phones in one way or another. Surveys of parents showed that, with the beginning of school age, the number of adults who purchase a mobile phone for regular communication with a child increases. This is primarily due to the ability to control children when they're out of school after classes (especially, when a child cannot attend any after-school program). However, parents have no control of how much their children use MT.

Thus, our analysis of cross-questioning revealed the main trend in the number of children MT users of during the period of our observations (2007-2010): a qualitative increase in terms of children who begin using mobile phones from 5 years of age. These data are consistent with epidemiological studies on the use of cell phones, conducted by foreign researchers [13-15].

Change the psychophysiological state

Analysis of intragroup data psychophysiological parameters showed that a direct comparison of psychophysiological indicators of test and control groups is impossible. They are too heterogeneous when it comes to the use of cell phones, computers, music players, etc. (various types of devices and the total time of their use).

Nevertheless, the accumulated data have allowed to identify the main directions of changes in psycho-physiological characteristics of 7 year old children (as it was indicated earlier, the most numerous group). To do so, the data on children who use a cell phone less than 3 min / day (27 children) were analyzed. The results indicate that even a very little everyday use of cell phone influences psychophysiological indicators. For example, children with one year "experience" of MT use showed:

(1) an increased reaction time to an audio signal (225.71 ± 32.03 ms in the control group; 271.18 ± 58.393 ms in the test group);

(2) decline in the productivity of voluntary attention (control group – 113.98 ± 22.326; test – 102.554 ± 19.56);

(3) an increase in time necessary to do "semantic memory" tasks (the control group – 149.44 ± 55.45 s; test – 204 ± 37.82 s).

It should be emphasized that the recorded changes are not statistically significant, however the identified areas of change are well visible, and they are negative.

To identify any changes of psycho-physiological parameters, we used a method which is often employed in medical practice, namely individual monitoring indicators.

Table 1. Number of wrong phonetic perception and reaction time on the sound of two children with lateral preferences
(one keeps his MT close to the left ear and the other – to the right ear)

Year of observation	Daily use of cell phone (in min.)	Number of wrong phonetic perception			Reaction time on the sound, ms			
		Stereo	Right - right ear	Left - left ear	Stereo	Right - right ear	Left - left ear	Average group values
Child keeps his MT close to the left ear								
1	30	8	8	9	254.53	351.24	315.08	**273**
2	2	4	6	4	237.5	314.53	256.45	**230.5**
3	30	4	12	8	265.42	267.61	241.6	**200.51**
4	10	3	5	4	175.44	194.0	191.87	**172.01**
Child keeps his MT close to the right ear								
1	0	3	6	8	167.47	186.3	213.91	**273**
2	1	3	8	8	185.07	192.87	223.05	**230.5**
3	15	1	8	9	144.47	187.95	225.73	**200.51**
4	5	4	4	6	161.7	144.86	151.4	**172.01**

This paper presents examples of individual sensitivity to the exposure in question.

Based on the notion of the effects of electromagnetic radiation (EMR) on children's brain, one would assume that the major changes in psychophysiological parameters (speed of simple visual and auditory-motor reaction, the number of wrong phonetic perception) could be registered to a greater extent in those part of brain that is usually closer to the cell phone, i.e. ipsilateral effects of exposure.

We have reported an increase in the number of wrong phonetic perception for virtually all children using mobile phones and the severity of these changes is the higher the greater total time of use is (that is, the more a child is talking on a cell phone). However, in 79.3% of cases, we observed the contralateral effect (not ipsilateral one), i.e. the number of wrong phonetic perception increased on the side opposite from the impact: if a child is often bringing a device to the right ear, the changes are marked on the left and vice versa. Ipsilateral effect is registered only in 17.4% of cases.

Table 1 shows the quantitative comparison of wrong phonetic perception and reaction time to audio stimuli demonstrated by two children with different lateral preferences. This comparison demonstrates the contralateral effect in both cases. It means that the number of wrong phonetic perception is bigger on the side opposite from the impact. In the first case (the child keeps MP close to the left ear), changes in the number of wrong perceptions coincides with the dynamics of daily use of the MT. Contralateral effect (change in the number of wrong perception is more evident on the right side even though a cell phone is kept close to the left ear) appears to increase if a child uses a cell phone every day more and more. In the second case (the child keeps MP close to the right ear), the beginning of the MP use at first led to an increase in the number of wrong phonetic perception on the right side (ipsilateral effect), but with the increasing frequency of MP use the contralateral effect becomes more pronounced .

Changes in reaction time on the audio signal are also shown in Table 1. In the first case (the child keeps MP close to the left ear), the reaction time on the audio signal is longer than the average one for a group during the first year of observation, and this trend persisted throughout the whole observation period, both in stereo and mono sound.

In the second case (the child keeps MP close to the right ear), the increase of cell phone use changes the dynamics of the sound perception and expression. The intensity of this phenomenon is most evident at the 4th year of observation with increasing time of daily use of mobile phones.

Table 2. Efficiency and accuracy while performing test on semantic memory. Comparison of a child from the test group and the control groups. Both of them had initially low psychophysiological characteristics

Year of observations	Daily use of a cell phone		Efficiency			Results of tests on semantic memory		
						Accuracy ot test performing		
	Control group	Test group	Control group	Test group	Low limit of the age norm	Control group	Test group	Age norm
1	0	2	19	17.167	19.5	0.6	0.7	0.6
2	0	5	21	22.83	21.4	0.7	0.8	0.7
3	0	15	22.7	19.83	22	0.7	0.6	0.8
4	0	10	25.6	21	23.9	0.8	0.7	0.9

One more example. The teenager, 16 years old. At the moment of the first year of observations he was using his cell phone already for 2 years on average 20-30 minutes a day. He was always keeping his cell phone close to the right ear. During the first year of observations, a large number of wrong phonetic perception was registered both on the right and the left sides (the effect was more pronounced on the right, i.e. ipsilateral). During the second and the third year of observation, a significant reduction of the daily cell phone use was noticed (from 30 minutes to 3-5 minutes), but the number of wrong phonetic perception on the right side has changed slightly. Ipsilateral effect was preserved. Nevertheless, the reduction in the daily cell phone use has indeed led to a slight decrease in the number of wrong phonetic perception. It can be assumed that prolonged and intensive use of cell phones, which previously typical for this teenager, has led to a sustained deterioration of psychophysiological indicators. The further dynamics would rather confirm this suggestion: during the third year of observations, the persistent problem in the right ear was reported (lack of response to auditory stimuli, only 4 out of 20 responses on signals). The consultation of an otolaryngologist was recommended as a result of these observations.

Specialist conducting audiography registered an increase in the threshold response to a frequency range. This agrees well with previous results obtained by N. Pande, who showed that people aged 18-25, actively using their mobile phones (1 h per day), develops high-frequency deafness, i.e. under-recognition of phonemes consisting of voiced and unvoiced consonants [16].

Table 2 compares the dynamics in the efficiency and accuracy (while semantic memory was tested) demonstrated by two children from the same class (one was from the test group, and another one was from the control group). Both children had initially low psychophysiological arousal (tardiness). At the 4th year of observations, it was evident that the performance of the child from the test group fell below the lower limit of his age norm, while the child from the control group stayed within the normal limits. Both children were demonstrating lower accuracy of the test during the 4th year of the study, though such phenomenon was previously attributed to the effect of the Peterson's training program [2]. However, the results of the child from the test group deteriorated more than the ones of the child from the control group. Besides, it should be noted that the child from the control group was carrying out this test quickly and inaccurately. While the child from the test group was doing this slowly and inaccurately, i.e. we registered certain increase in time he needed to do an assignment.

The above described effects may first of all affect children's performance at school. Thus, the detected increase in the amount of wrong phonetic perception increases the likelihood of errors in speech and writing, in particular it may be noticeable when performing control tasks in the Russian language. The decline in efficiency and cognitive processes would impact the effectiveness of learning in general.

Nevertheless, it should be emphasized that the detected changes (fluctuations of psychophysiological indicators) in children of primary school age are within the age norms in 85% of cases. But this fact does not mean that the use of mobile phones have no negative effect on the psychophysical health of children. Once again, these findings suggest that the identified changes in psychophysiological indicators should first of all alert parents who purchase unsafe "toys" for their child. It should be noted that those parents who gave a written consent for their children to participate in this survey, were given a report about a dynamics of psychophysiological indicators for the entire period of observation on their child. This document contains information on changes in all indicators, the analysis of their causes and recommendations for their correction. For example, it was stated that the change in phonetic perception may be associated with the use of cell phone by a child, and the change of the visual perception might be associated with the use of a computer. In addition, parents meetings were held to cover issues of the possible impact of mobile communications on child's body, especially when it comes to younger students that are very sensitive to external influences.

Being brought to the attention of parents and Lyceum teaching staff, this type of information have already yielded initial results. First, most parents started to impose some limits on how much their children use cell phones, ask them to use more SMS-messaging, and refuse to comply with children's request to buy a cell phone because of its harmfulness. Second, children would no longer hang a phone on their chest, rather put it in a briefcase, backpack, etc. Third, teachers do ask kids to switch their phones off during their stay in school.

DISCUSSION

The analysis of the available approaches in studying of potential effects of cell phone radiation on child's body showed that epidemiological researches rely mostly on the use of different questionnaires. Their use, in particular, for an objective assessment of psycho-physiological characteristics (fatigue, for example, as done in [17]), in our opinion, is debatable. A few experiments were performed using a single exposure of a child's body to cell phone radiation (see post 1) with registering only one parameter (or rate of reaction to stimuli, or attention, etc.).

Our research implied registration of various psycho-physiological characteristics (see "Materials and Methods"). We recorded certain changes of following psychophysiological parameters: (1) reaction time to an audio signal; (2) productivity and accuracy of voluntary attention; (4) run-time necessary to perform tasks on semantic memory and accuracy of a result. These changes might be associated with the processes of a child's body adaptation to the electromagnetic effects of cell phones. From a biophysical point of view, they can be considered as a system transition from one stationary state to another. For example, some previous works [18-20] have shown that short-term and single cell phone's radiation was increasing for a while the reaction time to external stimuli and reducing the accuracy when it comes to the tasks on attention. It is possible that the daily exposure to radiation MT triggers the destabilization of psychophysiological parameters, which can then cause their deterioration. We believe that the integrated approach we have applied allows us to evaluate the possible effects of MT radiation on a child's body, in particular on his brain.

To sum up, the preliminary results of a four-year monitoring revealed the following.

1. All children from the test group showed an increase in the number of wrong phonetic perception (incorrect phoneme recognition). The contralateral effect was registered in in 79.3% of all cases.

2. 66.7% of children from the test group showed the increased reaction time to audio signal.

3. At the end of fourth year of observations, 50.7% of children from the test group demonstrated lower performance. Half of those cell phone users were performing at the lower level of their age norm.

4. Considerable increase in the fatigue was registered in 39.7% of all the cases, and these changes should be seen as substantial in 30% of the cases.

5. Registered declines in productivity (14.3%) and / or accuracy (19.4%) when the stability of voluntary attention has been tested; and lower accuracy (19.4%) and / or increasing the time (30.1%) when semantic memory has been tested, i.e. the deterioration of cognitive processes in general|.

6. Although in most cases, changes in psychophysiological indicators were staying within the age norms, we found steady decline from high results to the lower limit of norm (performance, voluntary attention and semantic memory, audio-and visual-motor reactions).

These data and continuous active children's use of mobile phones call for further research and observations.

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