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Zero Magnetic Field Effect Observed in Human Cognitive Processes

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In our previous works, we reported that compensation of the geomagnetic field to a level less than 0.4 μT ("zero magnetic field," or ZMF) affected human cognitive processes. ZMF exposure increased the number of errors and the task processing time by 2.4% in average. However, in the array of the magnetic effects calculated from the experimental data, some readings have been found to deviate from the mean magnetic effect by more than three standard deviations. This finding could give rise to doubt as to whether the magnetic effect observed was a mere sequence of the presence of such unlikely data values. In the present work we examine the results of the unlikely data elimination and show that the corrected magnetic effect in tested humans remains statistically significant, though at a reduced magnitude 1.5%.

Keywords Biological effects of magnetic fields; Magnetoreception.

Introduction

The present work is based on the data of personal testing under the exposure to a so-called "zero magnetic field" (ZMF). Tested people who all have given their informed agreement to take part in the experiment were tested for the perfection of their cognitive processes. Each person has been tested twice: in ZMF and, for comparison, in sham conditions. The second session was organized usually in 30–50 days after the first one. Measured were the parameters (task processing times and errors) of the following tests: (i) the rate of a simple motor reflex, (ii) colored words recognition, (iii) short-term color memory, and (iv) recognition of rotated letters. There were eight measurable parameters altogether. Under ZMF, the number of errors was grown and the task processing times were increased by about 2%, on average (Sarimov et al., 2008). Particularly marked were reactions to ZMF of women and elderly people. Besides age and gender, a predisposition to allergic reactions, how one felt to the time of testing in general, and the order of testing in Sham or ZMF condition proved to be among factors that exerted influence on the magnetic effect magnitude. Temperature and atmospheric pressure have also been recorded, but they affected the results inappreciably.

The difficulty was in that the magnetic effects were significantly less than the natural random data spread and possible bias of the aforementioned factors. Moreover, the size

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of the tested group, 40 people, was comparatively small, and personal responses to ZMF varied not only in magnitude but also in the sign of the effect depending on the combination of those factors. In such conditions, estimates of mean values are not effective, because, for example, different groups of tested people could react to ZMF oppositely. Multivariate analysis of variance (MANOVA), factor, cluster, and discriminant analyses have allowed us to reveal such groups. In-group magnetic effects were markedly greater and reached 20–30% in the test of rotated letters recognition (Sarimov et al., 2008).

However, readings that deviated from the mean by more than "three sigma" have been found in the array of magnetic effects calculated from the measured parameters. At that, practically all of them had the same sign as the observable mean effect. It was unclear to what extent could these readings change the main result of the work, the statement that ZMF affects the parameters of the people's cognitive processes in average.

Results

The table contained all the data of 80 test sessions has been the initial, or original, source of data for the present analysis. The table was composed of two blocks, for Sham and ZMF exposures, correspondingly. The blocks included 40 rows, associated with order numbers of tested people, and 8 columns with normalized data of measurable quantities in eight tests. In this way, values S_{ik} in Sham block and Z_{ik} in ZMF block were the readings of the table. Here, $i = 1, 2 \ldots 40$ is the sequence number of a person and $j = 1, 2 \ldots 8$ is the number of a test.

The readings Z of the table were the mean of values measured in ZMF condition and normalized to the similar values measured in control condition, i.e., to the values, which were individual reference values for each person. The readings S differed from Z by only change: instead of being exposed to ZMF, tested people continued staying in the control condition, though they were not aware of it. In accordance to this normalizing procedure, the readings of the table deviated from unit; the more the difference between the data in experiment (Sham or ZMF) and in control, the greater the deviation. The complete description of the computerized testing, normalizing to individual reference values, and the system of whole-body magnetic exposure has been given in a previous publications (Sarimov et al., 2008; Binhi et al., 2005; Binhi et al., 2006); for the purposes of the present work these details are not essential.

Altogether, blocks Sham and ZMF each contained 320 readings. The value of magnetic effect was calculated as the relative difference in values obtained in ZMF and Sham conditions: $E_{ik} = 100\% \, (Z_{ik} - S_{ik})/S_{ik}$. An empirical distribution for the array E is shown in Figure 1 by a dashed line.

When building distributions, instead of a histogram, we used a kernel density estimation, for example (Wand and Jones, 1995). It has some advantages at visual presentations, because unlike histograms the kernel estimations give continuous curves. In this approach, the density function is approximated by a sum of kernel functions over the data points of an array. The kernel was taken here to be a standard Gaussian function, so that the density approximation for the array x_i of a random variable was as follows:

$$d(x) = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{1}{2} \left(\frac{x - x_i}{w} \right)^2 \right],$$

where n is the number of data points and w is the smoothing parameter. All the distributions in the present work are the kernel estimations, normalized per unit area, with w equal to 0.2 of the empirical standard deviation.

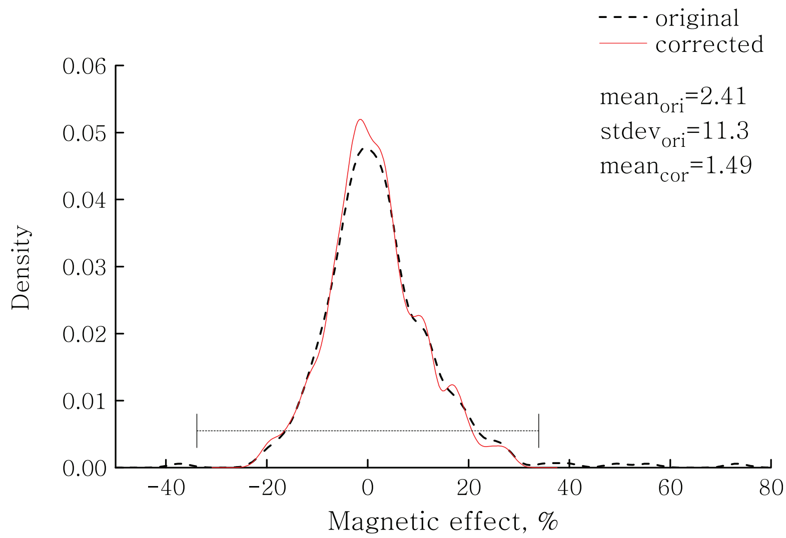

Figure 1. Original and corrected empirical distributions of the magnetic effects in all the people and all the tests.

Figure 1 shows that a set of reading of the original array fall out of the interval $(-3\sigma, 3\sigma)$. In view of a small probability of such deviations, they are often associated with the influence of some unrecorded factors of a pulsed origin, such as voltage jumps at the switching of powerful units. Therefore, they are sometimes eliminated from the data subject to further treatment. In our case, most of the out-of-order readings fall to the right of the distribution center. It can contribute to the mean magnetic effect and thereby lower down the reliability of the conclusion. It was reasonable to eliminate those readings.

Six sessions were detected, three for Sham and three for ZMF, in which magnetic effects fell out of the main group of effects. These sessions were eliminated from the initial data of 80 sessions. In as much as all these sessions were associated with different people, we had to remove another six sessions that were paired to the first six sessions by the exposure conditions. Indeed, magnetic effects in those sessions could not be determined. In fact, from the group of 40 people, removed were 6 people revealing great magnetic effects, improbable according to the "three sigma" principle. The corrected array of readings was processed in the same way as the original one. Empirical distribution of the magnetic effects in the corrected array is shown in Figure 1 by a solid line. Note that at the level $p = 0.05$, the distributions of the magnetic effects do not differ from the Gaussian distribution neither before nor after the correction. As is seen, all the overshot data have disappeared.

The distributions built after correction on the blocks Sham and ZMF, i.e., for S and Z readings, are plotted in Figure 2. The distributions show that the magnetic effect decreases the number of cases, in which the people displayed accelerated reactions and reduced number of errors. In opposite, in ZMF the number of cases grows in which the tested people demonstrated worsening of cognitive functions. According to the two-sample Student t-test, the mean over ZMF is greater than that of Sham at the level of statistical significance $p = 0.004$. The elimination of 12 from 80 sessions of testing does not change the conclusion on the existence of ZMF effect in cognitive processes in the tested people.

The distributions of magnetic effects (values S and Z, averaged over all the people) in the corrected array of readings in different tests are shown in Figure 3. It is

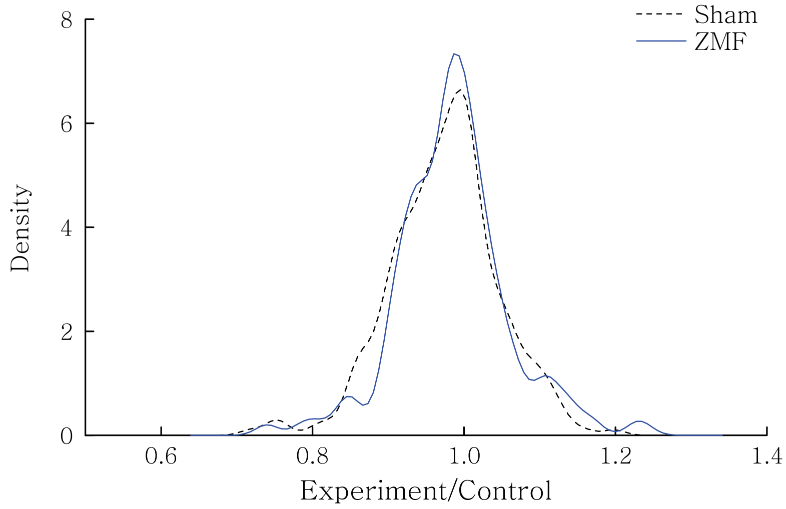

Figure 2. Empirical distributions of *S* and *Z* readings (Experiment/Control) for the different magnetic exposure conditions.

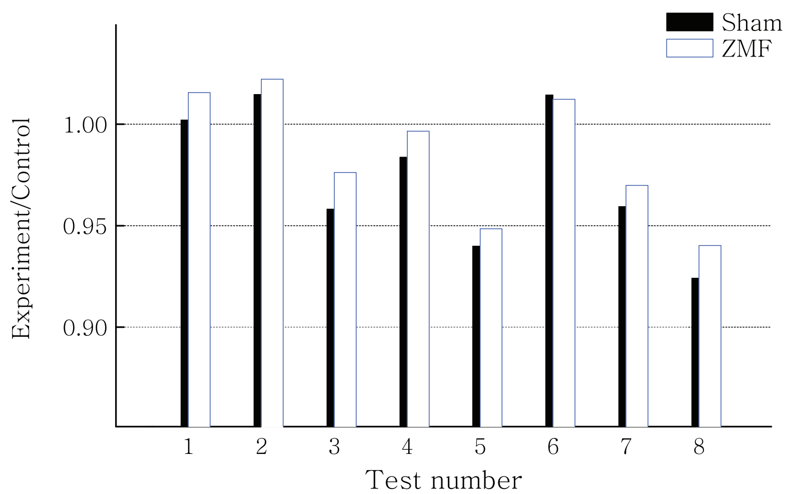

Figure 3. Mean values of *S* (Sham) and *Z* (ZMF) over all people in different cognitive tests. Statistically significant ($p = 0.05$) changes are in tests No. 3, 4, 7, and 8.

seen that ZMF does change parameters of almost all the tests. As before, maximal changes take place in test No. 8 "number of errors at recognition of rotated letters." Magnetic effects in seven of eight tests demonstrate cognitive function impairment—a growth of task processing time and an increase of the number of errors.

Then, the magnetic effects, which a person demonstrated in average all over the tests, were calculated. The distributions of these values over 40 people in the original set and over 34 people in the corrected set are shown in Figure 4. The distribution of the corrected set is centered at 1.5%. It is this value that is a "global" mean magnetic effect for the given group of people. As is seen, the mean magnetic effect is not a consequence of the presence of a small group, within the 34 people, that possess a particularly great sensitivity. In opposite, practically all the people have demonstrated sensitivity to ZMF. However, nearly equal parts of the whole group had an inverse response to ZMF, which has resulted in a rather small averaged effect. Although it was small, it has proved to be statistically significant. At the

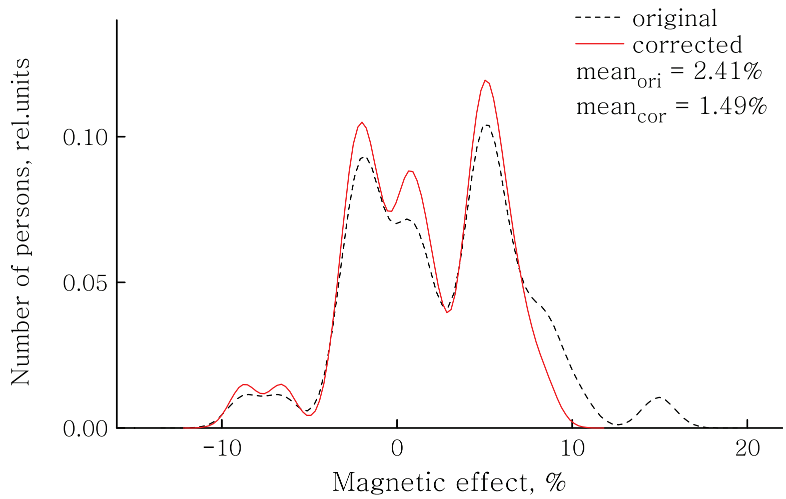

Figure 4. Empirical distributions of the test-averaged magnetic effects over people.

same time, individual magnetic effects in ZMF were significant just in about half of the group.

As compared to the original uncorrected curve, the corrected one has lost a small peak at the right edge. It originates from the contribution of the eliminated people. In some tests, mainly in the test No. 8, these 6 people revealed magnetic effects up to 30–80%. It would be interesting to associate these observations with the so-called "electromagnetic hypersensitivity syndrome" repeatedly reported in literature (Levallois et al., 2002; Schuz et al., 2006). There are indications that a few percent of the human population can markedly react even to relatively weak electromagnetic radiations that are incapable of appreciable tissue heating; the nature of such non-thermal biological effects from weak electromagnetic fields remains a physical problem (Binhi, 2002). The size of the lost peak in Figure 4 does not contradict to the hypothesis of few-percent hypersensitivity. However, a small number of people in the present study do not allow discussing this question in detail.

Conclusions

(1) The correction of the data on ZMF effect on human cognitive processes, i.e., the elimination of the data falling out of the "three-sigma" range, has no influence on the conclusion that the magnetic effect exists in the group of tested people. The magnitude of the effect in average is 1.49% at the level of significance $p = 0.004$.
(2) Magnetic effect is evident in seven of eight cognitive tests used. Statistically significant changes were observed in the tests on colored words recognition (tests No. 3 and 4) and in the tests on recognition of rotated letters (tests No. 7 and 8).
(3) The distribution of mean magnetic effects over people, after correction, proved to have no bright particularities. No people possessing a particularly great sensitivity to ZMF have been found within the group of 34 people.
(4) We suggest that the magnetic effect observed in the group of tested people is actually a general effect that takes place in the human population as the effect of changes in the parameters of cognitive processes under the variations of the static magnetic field at the level of the geomagnetic field.

Declaration of Interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

References

Binhi, V. N. (2002). *Magnetobiology: Underlying Physical Problems*. San Diego: Academic Press.

Binhi, V. N., Milyaev, V. A., Sarimov, R. M., Zarutsky, A. A. (2006). Influence of electrostatic and "zero" magnetic fields on psychophysiological state of human. *Biomed. Technol. Radioelectr*. 9:48–58.

Binhi, V. N., Zarutsky, A. A., Kaparanov, S. V., et al. (2005). The method of studying of the "magnetic vacuum" effect on the psychophysiological state of the human. *Radiatsionnaya Biologiya Radioekologiya* 45:451–456.

Levallois, P., Neutra, R., Lee, G., Hristova, L. (2002). Study of self-reported hypersensitivity to electromagnetic fields in California. *Environ. Health Perspect*. 110(Suppl 4):619–623.

Sarimov, R., Binhi, V. N., Milyaev, V. A. (2008). Influence of the compensation of the geomagnetic field on human cognitive processes. *Biophysics* 53:433–441.

Schuz, J., Petters, C., Egle, U. T., et al. (2006). The "Mainzer EMF-Wachhund": Results from a watchdog project on self-reported health complaints attributed to exposure to electromagnetic fields. *Bioelectromagnetics* 27:280–287.

Wand, M. P., Jones, M. C. (1995). *Kernel Smoothing*. London: Chapman and Hall.