Cortical neurons viewed as binary random number generators: Practical considerations for a PK experiment

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Abstract: An analogy of cortical neurons to binary random number generators was utilized to tentatively estimate the action of the mind on a cortical neuron [1]. The condition derived for a significant psychokinetic effect on the probability of firing an action potential appears to be nearly but not fully met. In the present note the condition is shown to hold only in the vicinity of a particular *z*-score. However, monitoring a sequence of action potentials of the same neuron may in many circumstances produce a significant cumulative result.

Binary random number generators (RNGs) are today the preferred tool for studying the psychokinetic (PK) effect, i.e. the influence of mental intention on otherwise random events. The experiments are like automatized coin flipping. The outcome of a flip may be characterized by one of two numbers, either (0,1) or (-1,+1). Many investigators have done PK experiments on RNGs. Let me mention H. Schmidt, the ground-breaking pioneer [2], and R. Jahn and B. Dunne who founded and conducted for many years Princeton Engineering Anomalies Research (PEAR), well known as the most productive laboratory [3].

The question of whether or not the mind can act on matter without any physical means has, of course, far-reaching philosophical implications. An affirmative answer proves dualism of mind and matter, while a negation supports the idea of a mind being nothing but a function of the material brain.

A special subject is mind-brain interaction, i.e. the question of whether or not the mind acts on brains. It is also timely because of the rapid progress of modern brain science. If dualism holds, mind-brain interaction may be expected not to fall below a certain level because we feel in control of ourselves. On the other hand, if the mind acts on its own brain it may act also on the brains of others. This should not allow controlling their brains, which calls for an upper limit to mind-brain interaction. There need be no conflict between the two requirements because intrapersonal mind-brain interaction may be supported by normal neuronal activity.

Interestingly, all the ingredients needed for an investigation of mind-brain interaction have become available in the last decades. They are:

1) Quantum physics - the evolution with time of physical systems seems to have been definitively clarified by modern quantum experiments [4].
2) Brain research - much more is known about synapses; the action potentials of a single cortical neuron can be monitored [5].
3) PK experiments on RNGs - large number and a great variety of studies, pulse numbers per experiment ranging from 20 to $2{\cdot}10^{11}$, meta-analyses [3.6].
4) There is an analogy between neuron and RNG.

In an article now in press by the Journal of Scientific Exploration I point out the analogy and utilize RNG data to estimate PK-induced mind-neuron interaction [1]. The result suggests that the effect of the mind on firing an action potential is substantial but may be up to an order of magnitude below the limit of significance. After summarizing the earlier work, I will discuss additional factors that impair the sensitivity of the neuron to a PK effect. It will then be shown that monitoring a sequence of action potentials can help to approach significance.

The credibility of the PK effect on RNGs has been established in a convincing manner by the meta-analyses of Radin and Nelson [6,7]. Based on originally $\Omega = 597$ experiments collected from the English-language literature, they found a mean shift $\langle z \rangle = 0.6$ and a widening by the factor $\alpha = 3/2$ of the Gaussian standard distribution that was realized in the absence of directional intention. Using Stouffer's formula, $z_{\mathrm{cum}} = \langle z \rangle \Omega^{1/2}$, to calculate the cumulative z-score of the shifts, they derived a chance probability of the approximate order of 10^{-50}. (Remember that the z-score of a quantity is its deviation from the mean value divided by the standard deviation.) This probability reduced further to roughly 10^{-100} when the widening was taken into account [1]. Two recent attempts to explain the shift in terms of selective reporting and publishing [8,10] were contradicted [9,11]. A funnel plot of $\log N$ versus e_{PK} [8] appears to show that the arguments against PK are inconsistent [1].

The experimental data of the RNG PK effect employed to estimate mind-neuron interaction may be divided into two categories:

1) Quantitative data

The shift of the Gaussian standard distribution by $\langle z\rangle = 0.6$ holds only for the "isolated" experiments predominating in the meta-analyses. As in the original standard distribution, the frequency of z seems to be independent of N in the range $20 < N < 3\cdot10^8$.

In the "crowded" experiments of the PEAR group and others it was the effect size e_{PK} defining the effect per bit that was nearly independent of N . Accordingly, with (-1,+1) counting, one has

$$\langle(N_+ - N_-)\rangle = e_{\mathrm{PK}}\, N$$

and thus

$$\langle z \rangle = \langle(N_+ - N_-)\rangle/\sqrt{N} = e_{\mathrm{PK}} \sqrt{N} \, .$$

In most experiments at a given N in the range $20 < N < 200000$ the effect size was found to be $e_{\mathrm{PK}} \approx 3\cdot10^{-4}$ or, more appropriately, $1\cdot10^{-4} < e_{\mathrm{PK}} < 1\cdot10^{-3}$.

2)Qualitative data

The z-scores turned out to be to be insensitive to the type of RNG, the distance between test person and RNG, and a time shift between mental intention and operation of the RNG. The random numbers were produced by radioactivity, electron tunneling, or resistor noise, the distances varied between a few feet and thousands of miles, and the positive and negative time shifts were several hours or days. This indifference to basic physical parameters is, perhaps, the biggest stumbling block for an experimental physicist in accepting the PK effect. At the same time, it suggests to apply the data obtained on RNGs to other systems such as neurons.

In order to discuss the analogy between RNG and cortical neuron, we first draw a clear distinction between the generator of binary random numbers and the pulse counter. In the case of the neuron the cell body with its firing site takes the place of the counter. The pulse generator is replaced by the ensemble of 10^4 synapses contributing to the postsynaptic potential of a cell body [5]. This number may increase to 10^6 when the neurons are arranged in minicolums of about 100 neurons operating in synchrony. The latter is thought to be brought about by electrically conducting gap junctions. The presynaptic sides of the synapses are connected to axons, each axon transporting the action potentials of a neuron. A synapse either transmits or does not transmit an electric signal when it is hit by an action potential. The probabilistic transmission is accomplished by chemical means and the postsynaptic signals are collected and integrated by the branches, called dendrites, of a tree-like structure, In modeling, one may assume a 50% chance of transmission and simple summation of the signals. The two analogous systems differ in one respect: The RNG pulses arrive sequentially, while the synapses deliver their signals more or less simultaneously. The insensitivity of the PK effect on RNGs to time shifts may be taken as an excuse to ignore the difference.

The limit of significance in statistical experiments is usually set at $z = 2$, the criterion $z \geq 2$ amounting to a chance probability of 2.5%. In technical language, a z-score satisfying this criterion is above noise. Applying it to the conjectured PK effect on the firing probability of a neuron requires some discussion. For a cortical neuron, the potential U of the interior of the cell body relative to the surroundings has two characteristic values. They are the resting potential $U_{\text{rest}} \approx -65\text{mV}$ and the threshold voltage of firing an action potential, $U_{\text{th}} \approx -55\text{mV}$, their difference being 10mV or a little more. Below threshold the potential of the cell body is $U = U_{\text{rest}} + U_{\text{ps}}$, where U_{ps} is the sum (or integral) of the postsynaptic potentials originating from 10^4 synapses. In a simplistic model imitating a correlation time of 10ms, U is assumed to be newly created in one step every 10ms. Whenever U surpasses U_{th} from below, an action potential is fired which lasts about 1ms in the cell but travels along the axon.

The potential U_{ps} fluctuates because of the probabilistic nature of synaptic transmission. The fluctuations are a precondition for a PK effect on firing. The r.m.s. fluctuation of the cell potential, σ, can be obtained from $\sigma^2 = \langle(U_{\text{ps}} - \langle U_{\text{ps}} \rangle)^2 \rangle$, where $\langle U_{\text{ps}}\rangle$, the mean value of U_{ps}, is commonly assumed to be positive. The z-score as a function of U is given by $z = (U - U_{\text{rest}} - \langle U_{\text{ps}} \rangle) / \sigma$. If the PK effect leads to $z = 2$ and the threshold potential happens to be

$$U_{\text{th}} = U_{\text{rest}} + \langle U_{\text{ps}}\rangle + 2\sigma,$$

the probability of firing is increased by a factor of more than ten above its value in the absence of PK. This ideal realization of of a significant response breaks down for both $z_{\text{th}} > 2$ and $z_{\text{th}} < 2$. As z_{th} rises above 2, firings rapidly become rarer, while the ratio of the probabilities at U and $U + 2\sigma$ gets larger. As z_{th} drops below 2, which may be due to an increase of σ, the ratio of the firing rates with and without PK effect decreases rapidly.

At this point, it is interesting to estimate σ by means of

$$\sigma^2 = (1/4)\, N \langle(\delta U_{\text{ps}})^2\rangle$$

where δU_{ps} represents the contribution of a single transmitting synapse to the postsynaptic potential. This formula presupposes positive and negative contributions to be equal in magnitude and a 50% probability of synaptic transmission. Inserting $N = 10^4$ and $\delta U_{ps} = \pm$ 0.2 to 0.4 mV [5] leads to $\sigma =$ 10 to 20 mV, which when halved to take into account an absence of phase correlation between the synapses is still (½ to 1)($U_{th} - U_{rest}$). Fluctuations of that size would imply $z_{th} = 2$ to1, while $z_{th} > 2$ becomes possible with a sufficiently negative $\langle U_{ps} \rangle = (N/2)\langle \delta U_{ps} \rangle$.

In most RNG experiments z remains on average well below 2. In the case of neurons we may at best expect $\langle z \rangle = 1$ if they are part of a minicolumn. Several or many experiments may have to be done until the cumulative z-score as given by Stouffer's formula attains values ≥ 2. In the case of a neuron, repetition should be particularly convenient. Neurons tend to fire action protentials spontaneously. (To convey quantitative information, they emit rather regular trains of impulses typically in a frequency range of 50 to 500 Hz.) With each action potential being a separate experiment in the model used, one could try to influence by mental intention the number per second of spontaneous firings of a neuron and thus raise z_{cum}. There may be problems such as a decline effect or the increase of the threshold of a new firing in the refractory period of a few ms after firing, but any elaboration seems premature.

To scientists, in particular theoretical physicists, it is abhorrent that there seem to be no theories of the psychokinetic effect, at least not yet. This makes experimental checks a requirement in every new situation, such as the application of RNG data to the question of mind-brain interaction. If generalizations are possible, we can formulate rules, but are not closer to physical explanations.

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