Abstract— We discuss the limitations of the concept of ‘normal values’ in Medicine. Nonlinear dynamics and deterministic chaos theory are proper physical frameworks for biomedical applications. Nonlinearity of dose-response behavior (hormesis) and informational interactions with electromagnetic fields illustrate limitations of ‘normality’ in Medicine and risk of using stiff standardized protocols. So, there is no alternative to Personalized Medicine provided by a well trained Medical Specialist.

Keywords— deterministic chaos, hormesis, nonlinear dynamics, norm, normative databases, personalized diagnostics

I. INTRODUCTION

In Physics there exist well defined normal values. Normal values are not independent from one another - normal boiling temperature of water is 100°C but only if the water is pure and under normal atmospheric pressure 760 mm Hg.

In Medicine normal values practically do not exist. The only such value seems to be ‘normal body temperature’ - 36.6°C. It is an erroneous belief that in Medicine normal value equals population average value – so called ‘normative databases’ e.g. of Quantitative EEG, no matter how large do not give a possibility of ‘reliable comparison’ to decide if the given case is ‘normal’ or ‘abnormal’.

Even the concept of a disease is relative and should take into account e.g. genetic differences between local populations. For example, sickle cell anemia is genetically inherited and in USA and Europe it is considered to be a serious blood disorder; but in Africa it gives evolutionary advantage - those with sickle cell anemia are resistant to malaria.

II. PROTOCOLS MAY LEAD TO SERIOUS ERRORS

Human organism (and human brain in particular) is a highly complex nonlinear systems (cf. [1]), and that is why standardized approach based on ‘stiff’ protocols may lead to serious errors of judgement.

There are differences in defining ‘normal’ ranges even between quite reliable sources. For example, in Medline one may read: ‘Normally, the ICP [Intracranial Pressure] ranges from 1 to 15 mm Hg’, but other sources give ranges like 8 to 18 mm Hg; anyway, what for one person is a quite high ICP for another may be quite low (cf. [2]), and if this person was treated according to a protocol that said ‘decrease the patient’s high ICP’ he/she might die.

A. Hormesis

A nonlinear effect called hormesis manifests itself in a nonlinearity in dose-response behaviour, like stimulatory effects caused by low doses of inhibitors (β-curve) or inhibitory effects caused by low doses of stimulators (U-curve). The best-known hormetic-type effects are the stimulatory effects of alcohol, caffeine, or nicotine, all of which are toxic at high concentrations. Hormetic effects concern not only chemicals but physical exposure as well. For example, adaptive and stimulating effects of ionizing radiation occur at near natural doses - this disagrees with linear, no-threshold hypothesis on the dose-effect relationship.

Fig. 1. Hormetic dose-response U-curve (after [3]). Deficit of an agent (doses less than D) causes deficiency symptoms; small doses (between D and T) are vital for good health (shaded area), doses higher than T cause toxic or other harmful effects. Dotted line represents linear no-threshold dose-effect relation that is often implicitly assumed by those researchers who are ‘infected with Human Linearity Virus’ [4].
Commonly used statistical tests are not optimized for use with such data - the assumption of monotonicity is implicit in these tests and results in a reduction of the possibility to identify changes in an unanticipated direction. Ignoring hormetic responses in the analysis of data, in particular using models that cannot accommodate potential effects of hormesis, may lead to biased estimates.

The problem here lies again in impossibility to define norms. What for one person is ‘normal’ i.e. it is a small dose that have positive effect on this person, for another person may be already very large dose, a cause of illness or even of death.

**B. Sensitivity to Electromagnetic Fields**

Electromagnetic fields (EMF) generated by different technical devices in our environment are not without an influence on our health. So called ‘norms of exposure’ to EMF mislead even Medical Doctors [4] since they are based only on thermal interactions as characterized by so called specific absorption rate (SAR) while they completely neglect informational interactions [5]. A living organism is an open system, pumped with free energy from biochemical reactions, similarly like a TV-set is pumped with free energy from electrical outlet. EMF that interact with the antenna of a TV-set bring extremely low energy; what EMF waves bring is information that influence the system and may cause either meaningful or just noisy images to show up on the screen.

There are no norms that assess information effects of EMF on human organism. Identical exposition to EMF of identical intensity may show very different effects in different persons, and even effects in the same person may differ depending on the person’s psycho-physiological state. Living system are highly nonlinear and operate far from thermodynamic equilibrium, that is why methods of Nonlinear Dynamics and Chaos Theory [6] are much better suited for assessment of EMF influence than ‘classical’ linear spectral methods.

Even European Parliament stressed this important fact in a report (cf. [7] pp. 23-24) : ‘Future research sponsored by the EC, should incorporate the following recommendations: (…) That systematic investigation be made of the influence of different kinds of pulsing (of real phones) on the human EEG, and ideally on the MEG, and of whether any observed changes in power spectra are correlated with changes in the level of deterministic chaos’.

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**Fig. 2.** Higuchi’s fractal dimension of 300 sec. long epochs of EEG-signals. 

- **a.** of a person who does not show sensitivity to EMF of the cellular; 
- **b.** of a person who may be (hyper)sensitive to EMF. In the columns, from left to right, respectively: basal – phone at place but not in use; sin – phone in use, without NPD; con – phone in use, with NPD. EEG was registered on 4 channels respectively (upside down): T6-O2; T4-T6; F8-T4; Fp2-F8. For the sensitive person Higuchi’s fractal dimension, $D_f(t)$, shows characteristic ‘saw-teeth’ pattern (cf. Fig. 4.d. in [4]) when cellular phone is in use without NPD (EEG-data thanks to J.L.Bardsano and I.Gutiérrez, Department of Medical Specialties, University of Alcalá, Madrid, Spain, cf. [8]).
The Authors of [8] did claim that using spectral method they had demonstrated that certain NPD (neutralizing protective device) really neutralizes negative influence of EMF generated by cellular phones. When we analyzed the same EEG-data using Higuchi’s fractal dimension one has not only shown that for majority of users (7 out of 8 analyzed cases) the NPD has practically no effect, but one may also point at one person out of 8 who is more sensitive (hypersensitive) to EMF [5] (Fig. 2.). About 12% to 18% of population may belong to a high-risk (hypersensitive) group of cellular phones users, at least of certain phone models, and for those persons NPD may be a matter of choice.

III, CONCLUSION

Markers supplied by Biomedical Physicists, e.g. quantitative descriptors of EEG-signal adapted from Nonlinear Dynamics may help in better assessment of various spontaneous or evoked, normal and pathological functional states of the brain in neuropsychiatric patients [4], and so may be helpful in deciding diagnosis, treatment, and prognosis.

As stated in the above mentioned European Parliament report (cf. [7] p. 14): "Difficulties sometimes experienced in attempts to independently replicate certain frequency-specific non-thermal effects are actually to be expected, in consequence of the highly non-linear, non-equilibrium nature of living systems, whereby even the slightest differences in the physiological state of the biosystems used and in conditions obtaining in a particular experiment can, in consequence of deterministic chaos, assume singular importance.'

And this is exactly the reason why in Medicine any 'norm' is only of very relative importance. In Medicine two plus two not always equals four [9] and that is why there is no alternative to Personalized Medicine provided by a well trained Medical Specialist (cf. [10]).

Is Medicine Art or Science? I think, Medicine is both Science and Art. Both Art and Science are helpful in life potential development directly as well as by their influence on Medicine. Also thanks to possibilities created by contemporary computer science representation of biomedical data now often looks like abstract art.

It is personalized approach to diagnostics and the treatment tailored to each individual’s biological and psychological personal profile that should be the norms in contemporary Medicine, in everyday medical practise.

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