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Physics and Mathematics of Brain Death Visualized through Group Structure of the Covariant-Enhanced-Coupling Model

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Brain is a very intricate and a complex structure containing around the order of 10^{11} neurons with approximately 10^{15} synaptic connections. This topic has long been of interest for neurobiologists, neuromathematicians and neurophysicists. Modeling of global-electrocortical activity is emerging as a most significant field of modern times. When the speaker took up this challenge in 1987, taking the linear model of Wright and Kydd as the starting point, and constructing a covariant model by writing the state-transition matrix of the signal equations, transformed in the laboratory frame from the comoving frame, the complexity appeared from the fact that this matrix was of the order of $10^{16} \times 10^{16}$ (for each synaptic connection, the generalized-electromagnetic potential had 4 components — one for the electrical potential and 3 for the magnetic-vector potential), hence 10^{32} parameters had to be dealt with. One must realize that in 1987, the world's fastest supercomputer (Cray XL 3 in the Los-Alamos Laboratories) could not even enter this matrix (these days, it is possible using memory sharing and cloud computing). The speaker is proud to state that the problem was worked out in Department of Physics, University of Karachi employing group-theoretical techniques. All these models were reviewed by the speaker during 9th ANC (Fig. 1). The signal equations, in the segment of the dendritic tree, were written in the comoving frame of the signal in the covariant model. Upon transformation into the lab frame, magnetic-vector potential exhibited along with the electrostatic potential. The electrical potentials depended on the neighboring potentials as well as their first-time derivatives in the generalized-coupling model, from which the covariant-generalized-coupling model was formulated. In the enhanced-coupling model, signal equations were re-written to include enhanced coupling, which depended on potentials as well as their first- and the second-time derivatives. This was used to set up the covariant-enhanced-coupling model. Effects of weak electromagnetic fields have been studied. To study the group structure, one notices that the covariant-enhanced-coupling-state-transition matrix is a linear transformation. The set of these matrices forms a group under the binary operation of matrix multiplication. The state-transition matrix is neither symmetric nor hermitian. However, the set of these matrices satisfies closure property, associativity, existence of identity and existence of inverse. Hence, this set forms a group. The identity is obtained by making the damping coefficients as well as the coupling constants vanish and setting value of the parameter representing eigenvalues of square of natural frequencies as –1. The first condition states that there is no damping present. The second condition states that there is no interaction among the neighboring neurons, *i. e.*, the neurons are decoupled. The condition on natural frequencies gives the eigenvalues (N_i) as $\pm i$. The expression $\exp(iN_i t)$ with the eigenvalue $-i$ does not represent a physiological situation (a rising exponential resulting in an unbounded state). However, the eigenvalue $+i$ represents a decaying exponential. On the electroencephalogram, this should correspond to the physiological state of *brain death*, representing a biological state manifested by absolute unresponsiveness to stimuli, absence of all spontaneous muscle activity and an isoelectric electroencephalogram for 30 *minutes*, all in the absence of hyperthermia or intoxication by the central-nervous-system depressants. This lecture is dedicated to the loving memory of **Prof. Dr. K. (Khawaja) Zaki Hasan** (1928, Panipat, District Karnal, British India – December 15, 2007, Karachi, Pakistan), who was a Pakistani neuropsychiatrist, physician and human-right activist. He got his early education in Hyderabad Daccan and graduated from the Osmania University Medical College prior to migrating to Pakistan (Fig. 2). He headed the neuropsychiatry department of the Jinnah Postgraduate Medical Center, also known as JPMC (1967-1987). He, also, remained Dean of the Jinnah Medical College and Vice Chancellor of the Baqai Medical University. He played a pivotal role in shaping the history and in contributing to the evolution of psychiatry in Pakistan. An office-bearer of the Pakistan Institute of Labor Education Research (PILER), of which Professor Hasan remained President, said about him: "We saw him as an activist of civil society working for a progressive change. He played a leading role both as an intellectual and a leader. He, not only, identified the physical and (the) social ills, but also, suggested practicable remedies." (words in parentheses added by the author). Apart from his valuable services to the medical profession, especially psychiatry, his active role in a long struggle for human rights of the working class and other segments of society had widely been recognized and commended. He was regarded as "father of psychiatry in Pakistan" by his students, who had complete knowledge of, not only, each and every aspect of his profession, but also, numerous other problems faced by the humanity — role model, competent, highly professional and expert in his field. As a professor of neuropsychiatry at JPMC, he was particularly focused on the health and the social aspects of children. He remained member of UNICEF executive board (1972-1981) and headed the agency during 1979-1980. The speaker had the honor that Professor Hasan was the external examiner in his PhD defense on May 23, 1990 — speaker's 34th birthday (Fig. 3); internal examiner was Professor S. A. Husain. The speaker met the Professor many times later — once during guest lecture on July 3, 1993 at the Baqai Medical College, Nazimabad, Karachi and later in his clinic in Saddar, Karachi.

1984	Linear Model of Wright and Kydd
1989	The Covariant Model
1992	The Generalized-Coupling Model
1997	The Covariant-Generalized-Coupling Model
2021	The Enhanced-Coupling Model
2021	The Covariant-Enhanced-Coupling Model

Fig. 1. Timeline of modeling of the global-electrocortical activity

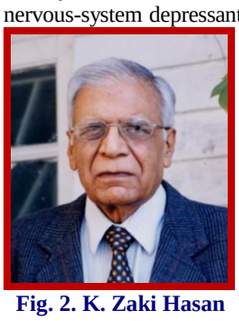
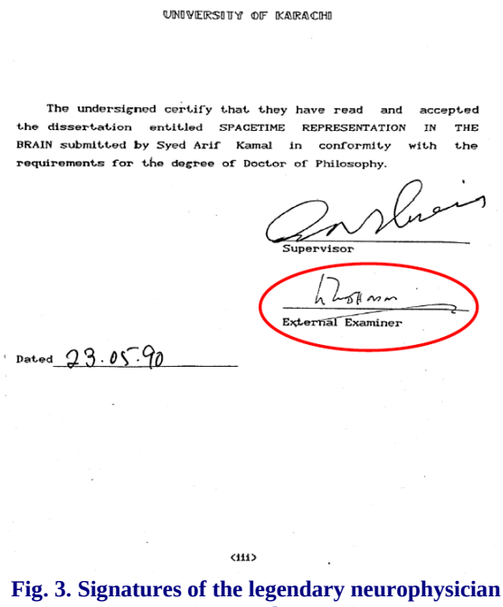


Fig. 2. K. Zaki Hasan



UNIVERSITY OF KARACHI

The undersigned certify that they have read and accepted the dissertation entitled SPACETIME REPRESENTATION IN THE BRAIN submitted by Syed Arif Kamal in conformity with the requirements for the degree of Doctor of Philosophy.

Supervisor

External Examiner

Dated 23.05.90

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Fig. 3. Signatures of the legendary neurophysician accepting my dissertation

Keywords: Covariant model • Electro-magnetobiology • Enhanced-coupling model • Generalized-coupling model • Linear model of Wright and Kydd • Magnetoencephalography • Neuromagnetic response

Video-Recorded Presentation

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