CURRICULUM VITAE

ROMAN R. POZNANSKI *Integrative/Computational Neurobiologist*

Current Position:

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Table of Contents:

Education:

Graduate:

1. Australian National University, Research School of Biological Sciences. Canberra, Australia. 1988 - 1991. Ph.D., November, 1991. Thesis title: "**Quantitative Analysis of a Neuron Model and its Application to Directional Selectivity in the Mammalian Retina**". Supervisor: W R Levick, FRS.

2. Monash University, Department of Mathematics. Melbourne, Australia. 1985-87. M.Sc., December, 1987. Thesis title: "Mathematical Models of Dendritic Neurons". Supervisor: H C Tuckwell.

Undergraduate:

1. Monash University, Department of Mathematics. Melbourne, Australia. 1984. B.Sc. (Hons), March, 1985. Major: Applied Mathematics.

Employment History:

2001- 2002: Visiting Research Scientist, Centre de Recherche en Physiologie Intégrative, Hôpital Tarnier-Cochin, Paris, France.

2001- 2002: Visiting Research Scientist, Laboratory for Dynamics of Emergent Intelligence, Brain Science Institute, RIKEN, Japan.

1998 - 2001: Research Scientist, Advanced Research Lab., Hitachi. Ltd., Japan.

1995 - 1997: Visiting Instructor/ JSPS Researcher, Department of Information Sciences, Toho University, Chiba, Japan.

1991 - 1994: Postdoctoral Fellow, Neurobiology Research Laboratory, Department of Physiology, University of Sydney, Australia.

1987 - 1988: Teaching Assistant, Department of Mathematics, University of Queensland, Australia

Awards and Grant Support:

1. Australian Research Council grant # AC9031997: "Neural Computation in the Hippocampus". $400,000, 1992-1995. PI: M R Bennett, Co-PI's: J Robinson , W G Gibson.

2. Japan Society for the Promotion of Science Fellowship to undertake research in Japan. $185,000. 1995-1998.

Refereed Publications:

1. Poznanski, R.R. (2002) Towards an Integrative Theory of Cognition. ***Journal of Integrative Neuroscience***. **1**, 145-156.

2. Krzyzanski , W. , Bell, J. and Poznanski, R.R. (2002) Neuronal Integrative Analysis of the 'Dumbbell' Model For Passive Neurons. ***Journal of Integrative Neuroscience***. **1**, 217-239.

3. Poznanski, R.R. (2002) Dendritic Integration in a Recurrent Network. ***Journal of Integrative Neuroscience*** **1**, 69-99.

4. Poznanski, R.R. (2002) The Importance of Continuity: A Reply to Chris Eliasmith. ***Minds and Machines*** **12**,435.

5. Poznanski, R.R. (2002) Review of Parkes, Levine and Long's "Fundamentals of Neural Network Modeling: Neuropsychology and Cognitive Neuroscience." ***Neurocomputing*** **43**, 323-324.

6. Poznanski, R.R. (2001) On Recent Cable Models in Neurophysiology. ***The Mathematical Scientist*** **26**, 74-86.

7. Poznanski, R R (2001) Conduction Velocity of Dendritic Potentials in a Cultured Hippocampal Neuron Model. ***Neuroscience Research Communications*** **28**, 141-150.

8. Poznanski, R R (2001) Dendritic Spike-like Potentials in a Neural Network. In, ***Biophysical Neural Networks: Foundations of Integrative Neuroscience*** (R R Poznanski, ed.) Mary Ann Liebert, NY.

9. Poznanski, R R (2001) Introduction to Integrative Neuroscience. In, ***Biophysical Neural Networks: Foundations of Integrative Neuroscience*** (R R Poznanski, ed.) Mary Ann Liebert, NY.

10. Poznanski, R R and Bell, J (2000) Theoretical Analysis of the Amplification of Synaptic Potentials by Small Clusters of Persistent Sodium Channels in Dendrites. ***Mathematical Biosciences*** **166**, 123-147.

11 Poznanski, R R and Bell, J (2000) A Dendritic Cable Model for the Amplification of Synaptic Potentials by an Ensemble Average of Persistent Sodium Channels. ***Mathematical Biosciences*** **166**, 101-121.

12. da F. Costa, L and Poznanski, R R (1999) Review of Koch and Segev's "Methods in Neuronal Modeling, 2nd edition." ***Trends in Neuroscience*** **22**, 329-330.

13. Poznanski, R R and Umino, O (1999) Determination of Cable Parameters for Neurons With Gap-Junctions. In, ***Modeling in the Neurosciences: From Ionic Channels to Neural Networks*** (R R Poznanski, ed.) Gordon & Breach Publishing Group, Amsterdam.

14. Poznanski, R R (1998) Electrophysiology of a Leaky Cable Model for Coupled Neurons. ***Journal of the Australian Mathematical Society*, Series B40**, 59-71.

15. Poznanski, R R and Umino, O (1997) Syncytial Integration by a Network of Coupled Bipolar Cells in the Retina. ***Progress in Neurobiology* 53**, 273-291.

16. Poznanski, R R and Peiris, S M (1996) Subthreshold Response to White-Noise Current Input in a Tapering Cable Model of a Neuron. ***IMA Journal of Mathematics Applied in Medicine and Biology* 13**, 207- 222.

17. Poznanski, R R (1996) Transient Response in a Tapering Cable Model With Somatic Shunt. ***NeuroReport* 7**, 1700-1704.

18. Poznanski, R R, Gibson,W G and Bennett, M R (1995) Electrotonic Coupling Between Two CA3 Hippocampal Pyramidal Neurons: A Distributed Cable Model With Somatic Gap-Junction. ***Bulletin of Mathematical Biology* 57**, 865-881.

19. Poznanski, R R and Glenn, L L (1994) Estimating the Effective Electrotonic Length of Dendritic Neurons With Reduced Equivalent Cable Models. ***Neuroscience Research Communications* 15**, 69- 76.

20. Poznanski, R R (1994) Electrotonic Length Estimates of CA3 Hippocampal Pyramidal Neurons. ***Neuroscience Research Communications* 14**, 93-100.

21. Bennett, M R, Gibson, W G and Poznanski, R R (1993) Extracellular Current Flow and Potential During Quantal Transmission From Varicosities in a Smooth Muscle Syncytium. ***Philosophical Transactions of the Royal Society of London*, *Series B342***, 89-99.

22. Poznanski, R R (1993) Nonlinear Summation of Junction Potentials in a Three Dimensional Syncytium. ***Annals of Biomedical Engineering* 21**, 401-406.

23. Poznanski, R R (1992) Modelling the Electrotonic Structure of Starburst Amacrine Cells in the Rabbit Retina: A Functional Interpretation of Dendritic Morphology. ***Bulletin of Mathematical Biology* 54**, 905-928.

24. Poznanski, R R (1991) A Generalized Tapering Equivalent Cable Model for Dendritic Neurons. ***Bulletin of Mathematical Biology* 53**, 457- 467.

25. Poznanski, R R (1990) Analysis of a Postsynaptic Scheme Based on a Tapering Equivalent Cylinder Model. ***IMA Journal of Mathematics Applied in Medicine and Biology* 7**, 175-197.

26. Poznanski, R R (1988) Membrane Voltage Changes in Passive Dendritic Trees: A Tapering Equivalent Cylinder Model**.** ***IMA Journal of Mathematics Applied in Medicine and Biology* 5**, 113-145.

27. Poznanski, R R (1987) Transient Response in a Somatic Shunt Cable Model for Synaptic Input Activated at the Terminal**.** ***Journal of Theoretical Biology* 127**, 31-50.

28. Poznanski, R R (1987) Techniques for Obtaining Analytical Solutions for the Somatic Shunt Cable Model. ***Mathematical Biosciences* 85**, 13-35.

Papers/Chapters in press:

1. Analytical Solutions of the Frankenhaeuser-Huxley Equations Modified for Backpropagation of a Single Sodium Action Potential. In, "**Modeling in the Neurosciences: An Integrative Approach**." 2nd Edition. With K.A. Lindsay, J.R. Rosenberg and O. Sporns. CRC Press, Baco Raton.

Other Professional Activities:

Papers In Preparation:

1. Analytical Solution Describing the Interactions of Synaptic Potentials, Backpropagating Action Potentials and Dendritic Spikes During Network Activity *in vivo.*

2. Position-Dependent Theta Phase-Precession in Dendritic Networks. With Y. Yamaguchi

3. Bidomain Model for Analysis of Neuromodulatory Effects on Functional Connectivity Patterns in the Cortical Neuropil. With O. Sporns.

4. Extrasynaptically Connected Neural Networks: A Bidomain Model of Ionic Diffusion Through Multiple Core-Conductors Interconnected in a Volume Conductor Representation of the Cell Assembly in the Cortical Neuropil. With P. Bach-y-Rita and G.L. Aiello.

5. Model of a Network of Electrotonically Coupled Mammalian Retinal Ganglion Cells. With S. Hidaka

Books in Preparation:

1. "Neuromathematics. Vol. 1. Electrophysiological Cable Theory." Imperial College Press, London.

2. "Neuromathematics. Vol. 2. Integrative Neuronal Networks." Imperial College Press, London.

Journal:

Associate Editor: "*Journal of Integrative Neuroscience*" - an interdisciplinary journal. Imperial College Press, London. http://www.worldscinet.com/jin/mkt/editorial.shtml

Seminars and Colloquia:

1. Wright State University, Dayton, OH. Program in Applied Biomedical Computing Seminar: "Analytical Description of Backpropagating Sodium Action Potentials in Dendrites", September 29, 2003.

2. RIKEN, Brain Science Institute, Laboratory for Dynamics of Emergent Intelligence Seminar: "Biophysics of Cognition", February 21, 2003.

3. UCLA, Los Angeles, Department of Biomathematics, School of Medicine, Gonda Goldschmidt Neuroscience Seminar: "Networks of Synaptically Connected Ionic Cables", October 18, 2000.

4. UMBC, Baltimore, Department of Mathematics & Statistics, Differential Equations Seminar: "Biophysical Neural Networks", October 17, 2000.
5. RIKEN, Brain Science Institute, Laboratory for Dynamics of Emergent Intelligence Seminar: "Introduction to Integrative Neuroscience", October 9, 2000.

6. Toho University, Department of Information Sciences, Graduate Students Seminar: "Modeling Neurons With Gap Junctions", November 20, 1997.

7. Toho University, Department of Information Sciences, Graduate Students Seminar: "New Insights into the Synaptic Mechanism of Directional Selectivity in the Retina", November 13, 1997.

8. Toho University, Department of Information Sciences, Graduate Students Seminar: "Function of Neuron Structure", October 23, 1997.

9. Queensland University of Technology, Brisbane, School of Mathematics & Statistics Seminar: "Reduced Models of Neurons", November 29, 1994.

10 James Cook University of North Queensland, Townsville, Department of Mathematics & Statistics Seminar: "Electrotonic Coupling Between Two CA3 Hippocampal Pyramidal Neurons", December 6, 1993.

11. Case Western Reserve University, Cleveland, Seminar: "Quantitative Analysis of a Neuron Model and its Applications", June 14, 1991.

12. University of Southern California, LA, Center for Neural Engineering Seminar: "Modeling Directional Selectivity in the Retina", June 14, 1991.

13. N.I.H., Bethesda, Mathematical Research Branch Seminar: "Tapering Equivalent Cable Model: Analytic Solutions and Applications", June 11, 1991.

14. The Salk Institute, San Diego, Seminar: "Information Processing in the Mammalian Retina", June 7, 1991.

15. The Smith-Kettlewell Eye Research Institute, San Francisco, Colloquium: "Modeling the Electrotonic Structure of Starburst Amacrine Cells in the Retina", June 5, 1991.

Abstracts and Conference Proceedings:

1 R.R.Poznanski. "Softer than Soft Computing", IEEE International Workshop on Soft Computing in Industrial Applications. Binghamton, New York, USA, June 23-25, 2003. Invited Chair of Session.

2. R R Poznanski, "Introduction to Integrative Neuroscience", Biomedical Engineering Society Meeting, Seattle, USA, October, 2000. Invited Chair of Session.

3. R R Poznanski, "Dendritic Spikes in Neuromorphic Networks", Biomedical Engineering Society Meeting, Seattle, USA, October, 2000. Invited Chair of Session.

4. R R Poznanski and M Naito, "Synaptic Potentials Amplified by Sparse Distribution of Sodium Channels in Dendrites of CA1 Hippocampal Pyramidal Neurons", The Trans-disciplinary Symposium on the Frontier of Mind-Brain Science and Its Practical Applications (II), Tokyo, Japan, January, 2000.

5. R R Poznanski, "Neural Networks Without Synaptic Weights", The Third International Workshop on Neuronal Coding, Osaka, Japan, October, 1999.

6. R R Poznanski, "Strong Coupling can Reduce the Time-to-Peak of EEPSPs: A Substrate for Neural Synchronization", The Fifth International Conference on Neural Information Processing.

Kitakyushu, Japan, October, 1998.

7. R R Poznanski, W G Gibson and M R Bennett, "Electrotonic Coupling Between Two CA3 Hippocampal Pyramidal Neurons: A Distributed Cable Model With Somatic Gap-Junction", Fourteenth Annual Meeting of the Australian Neurosci. Soc., Sydney, Australia, February, 1994.

8. R R Poznanski, "Electronic Length Measurements of Starburst Amacrine Cells", The Robertson Symposium: Sensory Stratagems, Canberra, Australia, February, 1993.

9. R R Poznanski, W G Gibson and M R Bennett, "Potential Changes in a Three Dimensional Syncytium During Secretion of a Transmitter Quantum", Thirteenth Annual Meeting of the Australian Neuroscience Society, Melbourne, Australia, February, 1993.

10. R R Poznanski and I G Morgan, "Modeling the Electrotonic Structure of Starburst Amacrine Cells in the Rabbit Retina", Eleventh Annual Meeting of the Australian Neuroscience Society, Dunedin, New Zealand, January, 1991.

11. R R Poznanski, "Analysis of a Postsynaptic Scheme for Directional Selectivity", Tenth Annual Meeting of Australian Neuroscience Society, Brisbane, Australia, April,1990.

Teaching Experience:

My early training in teaching mathematics at the University of Sydney in Australia (and also as a predoctoral fellow at the University of Queensland) involved practical classes using interactive software for symbolic, numerical and graphical visualization of doing mathematics by computer (e.g., Mathematica®), and tutorial classes in mathematics to undergraduate students enrolled in science and engineering courses (e.g., *Mathematical Methods*). During my later years (in Japan) I taught classes in neuroscience, specifically on information processing in the vertebrate retina to information science students taking a postgraduate course in "*Scientific English*" at Toho University as part of my electrophysiological training in retinal research with Prof. Osamu Umino and Dr. Soh Hidaka during my postdoctoral training. I have given 15 seminars to various academic groups (see above) and advised a student thesis: Hiroshi Yamamoto 1996 M.S. "**Computer Simulation of Bipolar Cell Coupling in the Teleost Retina**," Department of Information Sciences, Toho University, Japan.

Proposal for New Graduate/Advanced Undergraduate Course: Neuronal Networks & Neurobiology

This course will provide the student with an interdisciplinary survey of a variety of contemporary topics in integrative/computational neuroscience. The presentation will draw from my own background in mathematics and neurobiology as well as from recent and some classical literature. The course content, presentations, and assignments will be designed to be flexible according to student background and time limitations. The subject may be of interest to many different student populations (e.g., neurobiology, engineering, computer science, psychology, neurology, mathematics).

The teaching of a graduate course in neuronal networks and neurobiology : integrative/computational approaches is usually set up in an interdisciplinary environment reflecting my training in both mathematics and neuroscience. I have the ability to effectively communicate interdisciplinary thinking and scholarship through a course on integrative neurobiology. The course would vary year to year depending on interest and background of students.

Course Outline: Introduction to mathematical and numerical techniques for modeling single neurons and networks of neurons: integral transform methods, separation of variables, bifurcation theory, Green's function methods, applied functional analysis, reaction-diffusion systems, stochastic processes, diffusion processes and nonlinear phenomena; cable theory; Rall's model; compartmental models; introduction to available software for simulating neurons and networks of neurons; modeling of action potentials, dendritic spikes, Hodgkin-Huxley equations, FitzHugh-Nagumo equations, Poznanski-Bell equations, synaptic conductances, and voltage-dependent conductances; stochastic processes associated with the spontaneous activity of neuronal systems; the role of calcium, calcium currents, diffusion and electrodiffusion, buffering, calcium waves; field theory and volume conduction, bidomain modeling; Additional neuroscience including spreading depression phenomena, neural Darwinism and epileptiform activity in the hippocampus; Hebbian synapses, associative learning and memory, role of backpropagating spikes in learning; synaptic modification rules; quantal analysis; basic anatomy and cellular morphology; neuronal physiology: limbic, sensory, and motor systems and their integrative function. The neurobiology of semantics (the association of cognitive representations to neuronal constructs); grandmother cell theories of how the brain represents information in neuronal networks. Functional brain imaging and the relationship between human brain electrical activity and cognitive function; the dynamics of brain organization associated with cognitive processes (attention, motivation, categorization, planning, altruism, memory). Mathematical aspects of integrative brain function; principles of neuronal network modeling; the neurobiological basis of integrative network models; integrative approach to higher brain functions; chaotic dynamics in mood disorders, schizophrenia and other psychopathologies; neuronal models of associative learning; functional connectivity and learning rules for synapses in neuronal networks; neuromodulation of cortical dynamics; representative neuroethological case studies.

Reference texts:

"Modeling in the Neurosciences: From Ionic Channels to Neural Networks." Harwood Academic Publishers, Amsterdam, 1999.

"Biophysical Neural Networks: Foundations of Integrative Neuroscience." Mary Ann Liebert, Inc. Publishers, New York, 2001. http://www.liebertpub.com/bio/defaultstatic.asp

Student Facilities:

I will be available as my schedule permits and would make every effort to help students outside of formal class periods. I am enthusiastic about helping students.

Career Ambitions

1. To advance integrative/computational approaches in neuroscience research. In particular, to develop new models based on an integrative approach to higher brain function which can be experimentally verified through a collaborative research effort;

2. To continue growth as an independent researcher and develop a strong research program through competitive grants and as a 'theoretician' in collaborative team-efforts for grant projects with experimentalists and other colleagues;

3. To serve as a role model for younger researchers;

4. To promote and maintain world class recognition in research through the publication of books and the editing of an international journal.

Administrative Abilities

I have an ability to manage, evaluate, and monitor policy development and implementation with respect to academic and administrative programs within University environment. I have capacity to effectively identify key policy and program issues, and apply conceptual and analytical thinking to problem solving. I can effectively lead, motivate and develop teams of staff to provide a high standard of academic service. My abilities include highly developed communication skills, interpersonal and liaison skills, and demonstrated ability to consult and negotiate with senior personnel at all levels of academia and industry. I manage deadlines effectively and show care in making a decision. I enjoy working as a team player and I am sensitive to my responsibilities to colleagues. I have a willingness to do my share whatever is required of Faculty service, such as committees, organization of seminars, student supervision (undergraduate, graduate, post-graduate, advising, etc.) For example, at Sydney University in Australia and at Toho University in Japan I was often consulted with respect to academic administration. I was in attendance at Faculty meetings concerning curriculum development and co-ordination. I administrated a regular seminar series and acted as a consultant on several occasions on matters relating to my professional expertise.

Pedagogical vision

I would promote the development and professional training of students enrolled in undergraduate and graduate studies. I believe a true interdisciplinary outlook is needed for students pursuing a career in integrative neuroscience. I would encourage the blending of both experimental and theoretical work. The challenge is to bring about the interaction early at the undergraduate level. I believe it is at this level that a true interdisciplinary outlook can be harnessed to yield the greatest success. I would promote integration of mathematics into neuroscience curricula. I believe a broader undergraduate training through an interdisciplinary study would give the student self- motivation and freedom to maximize their true potential by crossing boundaries, especially if students cannot be categorized through a traditional program. In retrospect, by giving the student a sense of self-fulfillment and an active role in designing his/her own course, the educational process becomes a partnership where students can define his/her own destiny and their own niche in an ever-changing world. In my opinion, the undergraduate courses need to cater for cross-disciplinary mixing, so that a bastion for creativity and advancement of the students' true potential can be harnessed. With only a few places in the world having invested in interdisciplinary training in integrative neuroscience I believe it should be promoted with zeal and hindsight in order to advance the students skills and give them a competitive edge for further studies and employment opportunities in academic research, teaching etc.

Research Interests:

The goal of my research is through model-based analysis to (a) help interpretation of experimental results, and (b) to reveal emergent properties of brain function at local and systems levels. My research interests can be broadly categorized under the following general themes: (1) integrative neuroscience and neuroinformatics (e.g., large-scale realistic neural networks for understanding cognition and sensorimotor control; large databases for understanding the large-scale functional organization of the brain); (2) mathematical modeling techniques (e.g., bidomain modeling, theory of complexity, bifurcation theory, ionic cable theory, electrodiffusion theory, n-field theory, adaptive resonance theory, Nernst-Planck theory); (3) theoretical cognitive neuroscience (e.g., analytical and dynamical foundations of neuroscience; schema theory, and theories of mind); (4) vision (e.g., motion perception, role of gap junctions in the spread of noise, syncytial integration).

Currently I have an ongoing interest in the following projects:

1. Inverse problems associated with infinite dimensional nonlinear dynamical systems

An important problem in neuromathematics is to determine the Hopf bifurcations of neurons with continuous membrane and ionic channels. The classical Hopf-bifurcation analysis can be used to determine if neurons undergo through the same bifurcation points as the spaced-clamped systems. Working in Banach space, use of functional analysis methods can be utilized to determine if co-dimension-2 bifurcations are ubiquitous in neuronal cables. Do voltage-dependent ionic channels serve as bifurcation parameters? Given a neuronal cable representation of a dendrite invested with ion channels, in clusters and distributed nonuniformly, and extra measurements of membrane potential at distal and proximal ends of the cable can the distribution of ion channels between the recording sites be recovered? This amounts to an inverse problem of finding a space-dependent coefficient in a reaction-diffusion equation by over-specifying time-dependent boundary conditions. It remains to be seen how the inverse problem for recovering spatially discrete and nonuniform distribution of voltage-dependent ion channels can be solved.

2. Biophysically plausible associative learning rules for small-scale neuronal networks

In order to model biologically realistic neuronal networks, a new approach is necessary, incorporating the spatial structure of single neurons essential for Hebbian principles of learning in the brain, and a "learning rule" that is independent of synaptic weights. The inclusion of a biophysically plausible learning rule in such biologically realistic neural networks is a new and challenging research direction, since neither the error correction rules used in perceptron models nor the steepest descent rules used in back-propagating neural networks are biologically plausible. An estimated large number of different equations used to describe learning rules, so far, clearly advocates the non-uniqueness of a "generic" learning rule as applicable to any neuronal system. A new type of learning rule(s) that considers the relationship between patterns of output activity (back propagating spikes) and patterns of dendritic activity (NMDA receptors, Ca^{+2} influx, Na^{+}- Ca^{+2} exchange, persistent Na^{+}, and A-type K^{+} channels) has not been developed. At the molecular level biochemical reactions involving calcium binding to calmodulin and calmodulin trapping by CaM-kinase are required. At the cellular level , calcium influx through NMDA receptor channels involving diffusion modeling of the synaptic cleft and the effects of ambient glutamate and the time course of glutamate release on NMDA conductance are required. In short, this would entail modeling a small network of biological neurons, with structure in the synaptic dynamics that will allow the network to recognize and learn a pattern.

3. On the neural circuit underlying directional selectivity in the rabbit retina:

In order to construct an underlying neural circuit of the motion perceptive neurons in the rabbit retina, it is necessary to take into consideration the network connectivity leading to directionally selective responses in ganglion cells that could be the result of transmitter modulation from the pre-synaptic circuitry yet to be determined with precision. In the inner and outer plexiform layers highly specific patterns of connectivity are not random, and depend on non-impulsive signal transmission. The exploration of topological arrangements of excitatory and inhibitory synapses onto cholinergic amacrines and the transfer of synaptic action onto bistratified ganglion cells will need to be examined with a biophysical model with the aim of showing how the synaptic circuitry of the amacrine cells relates to the global organization of the overall network of neurons in the generation of direction selectivity. The analysis of dendro-dendritic interactions in more realistic network models is of importance in constructing retinal circuitry for motion perception. The ultimate goal is to re-construct the neural circuitry that relates to the functional organization of complex information processing governing the *Barlow-Levick* mechanism of directional selectivity. The need for modeling as an inaugural component in the future development and in the construction of neural circuits for this particular retinal function cannot be underestimated. The application and extension of the Poznanski-Bell model to dendrites with sparse density distribution of fast TTX-sensitive Na^{+} channels will be investigated. Of recent interest have been the directionally selective starburst amacrine cells in the rabbit retina are known to produce fast Na^{+}-based spikes. It is still unclear how Na^{+}-based backpropagating action potentials in starburst amacrines produce the directionally selective Ca^{+2} influxes observed in recent experiments.

4. Mathematical modeling of volume transmission (VT) following transcranial magnetic stimulation (TMS) of Wernicke's area as recorded with high-resolution electroencephalography (EEG)

Today it has become popular to integrate large databases (i.e., neuroinformatics) in the hope of better understanding brain function. However, this becomes inconceivable, when faced with the possibility that "meaning" of data rather than the individual data is represented non-locally in the brain. For example, when there is synchronous firing of a large number of local neurons, ionic currents from large numbers of neighboring cells tend to coalesce into particularly large and coordinated extracellular (macroscopic) effects, or brain waves, observed in EEG signals, such as alpha, gamma, or theta rhythms. Such synchronized neural activity reveals cortical reactivity, but not necessarily connectivity. This is because when two spatially distinct neuronal systems are activated synchronously (temporal) in response to a stimulus, this is not an indication that the neuronal systems are functionally connected, but simply are dynamically coherent. Therefore, in order to understand integrative brain functions, it is vital to incorporate all modes of neurotransmission found in animal and human brains, especially non-synaptic diffusion neurotransmission, or VT, known to be a dynamic phenomena or adaptive pressure responsible for neuromodulatory effects, including dynamic changes to functional connectivity.

Repetitive transcranial magnetic stimulation (rTMS) is a new and non-invasive method of magnetic neuromodulation by which the stimulating coil is held close to the scalp so that the field is focused and can pass through the skull. The magnetic field created by a stimulating coil produces local electrical currents in brain tissue. The magnetic field can be repeated over small intervals of time, thus allowing the stimulation of neurons during their refractory period. Electrical brain activity resulting from the brief electromagnetic pulse can be recorded with high resolution EEG.

It is known that rTMS may be used to temporarily facilitate savant-like skills in normal people by disrupting part of the left fronto-temporal lobe. The possible (disinhibiting) neural mechanisms that underlie rTMS induced access to information that is normally inaccessible remains unknown. The hypothesis is that VT facilitates in this process of semantic representation by modulating the neural tissue, and disrupting the functional connectivity surrounding Wernicke's area. As neuroimaging technologies *per se* are of little help in determining cortico-cortical connections, in order to test this hypothesis, a symbiosis of integrative modeling (e.g., when simulating macroscopic brain dynamics in a volume conductor) and magnetic neuromodulation is required to gain insight into how the brain integrates semantic information.

Neuronal responses to magnetic stimulation recorded with high-resolution electroencephalography (EEG), referred to as event-related potentials (ERPs) at the macroscopic level, can be related to cellular activity (e.g., extrasynaptic signals or local field potentials) at the single neuron or network levels. This will hasten the formation of a dynamical theory of semantic processing based upon functional integration of biophysical neural networks. The methodology involves a macroscopic neuronal model to represent semantic processing based on more biologically plausible neural networks. A population network model consisting of biophysically realistic neurons represented by spatially distributed units (or dendritic cables) with ionic channels, functionally connected in groups of excitatory and inhibitory neural assemblies. The initial goal is to obtain analytical solutions using Green's function matrices for a large-scale simulation of approximately 10,000 neurons arranged as an array of column units. The integrated membrane potentials arising from spiking activity in the dendrites of such simulated cortical neurons are the sum of depolarizing potentials of pyramidal neurons and hyperpolarizing potentials of GABAergic interneurons in the left temporal area of the neocortex.

The work is expected to help to achieve better awareness of the symptoms and treatment of people who develop fronto-temporal lobe dementia and aphasia.

Referees:

1. Gilbert A. Chauvet, M.D., Ph.D.
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