Mathematical Modeling of Neurotransmitters Release for Independent Synaptic Currents.

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ABSTRACT

Networks of neurons and synapse play a key role of communication in the brain. Presynaptic terminals release neurotransmitters either in response to action potential or spontaneously independent of presynaptic activity. Spontaneous neurotransmission has an independent role in neuronal communication that is distinct from that of evoked release. However, the process of spontaneous neurotransmitter release is still unclear. We develop a mathematical model in 3-D to emulate spontaneous and evoked neurotransmissions resulted from glutamate release within a single synapse. We propose numerical methods for solving piecewise continuous heat diffusion equation, estimate and verify its errors of second order accuracy. In order to identify the spatial relation between spontaneous and evoked glutamate releases, we consider quantitative factors, such as the size of synapses, inhomogeneity of diffusion coefficients, the geometry of synaptic cleft, and the release rate of neurotransmitter, that will affect postsynaptic currents. We conclude quantitatively when a synaptic size is larger, the cleft space is less diffusive in the central area than the edge area, if the geometry synaptic cleft has a narrower gap in the center and if glutamate release is slower, then there is a better chance for independence of two modes of currents from spontaneous and evoked release. The computed results match well with existing experimental findings and provide a quantitative map of boundaries of physical constraints for having independent synaptic fusion events.