

2015

Model-based prediction of maximum pool size in the ribbon synapse

Caitlyn M. Parmelee

University of Nebraska-Lincoln

Matthew Van Hook

University of Nebraska Medical Center

Wallace B. Thoreson

University of Nebraska Medical Center

Carina Curto

The Pennsylvania State University

Follow this and additional works at: <http://digitalcommons.unl.edu/mathfacpub>

Parmelee, Caitlyn M.; Van Hook, Matthew; Thoreson, Wallace B.; and Curto, Carina, "Model-based prediction of maximum pool size in the ribbon synapse" (2015). *Faculty Publications, Department of Mathematics*. 91.
<http://digitalcommons.unl.edu/mathfacpub/91>

This Article is brought to you for free and open access by the Mathematics, Department of at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Faculty Publications, Department of Mathematics by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

POSTER PRESENTATION

Open Access

Model-based prediction of maximum pool size in the ribbon synapse

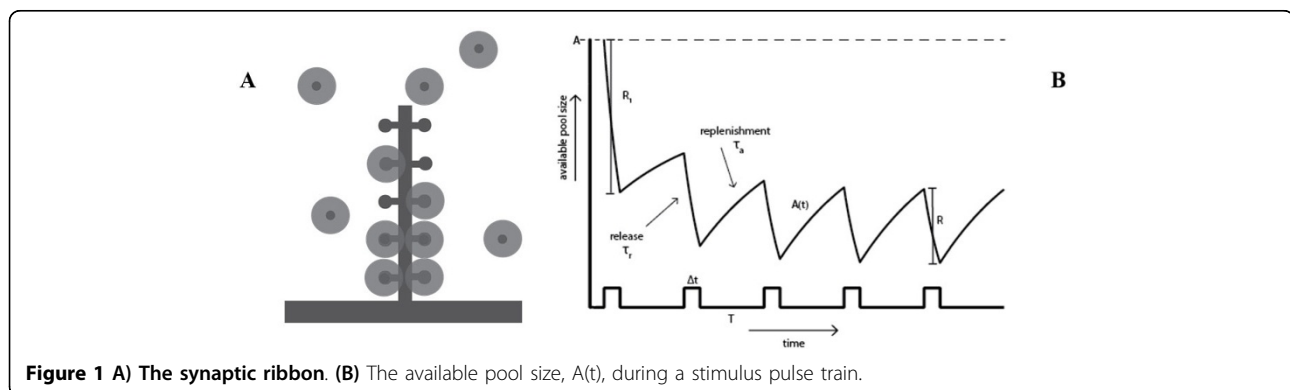
Caitlyn M Parmelee^{1*}, Matthew Van Hook², Wallace B Thoreson^{2,3}, Carina Curto⁴

From 24th Annual Computational Neuroscience Meeting: CNS*2015
Prague, Czech Republic. 18-23 July 2015

The synaptic ribbon is a specialized structure in photoreceptor neurons that tethers vesicles prior to release (Figure 1A). When a cell is stimulated, vesicles are released from the ribbon and later replenished from the population of mobile vesicles in the synaptic terminal. A train of depolarizing pulses causes the ribbon to alternate between periods of release (lasting $\Delta t = 25$ ms) and replenishment (lasting $T = 50$ ms), which occur on estimated timescales of $\tau_r = 5$ ms (for release) and $\tau_a = 815$ ms (for replenishment). After the first few pulses, the system approaches a limit cycle, and the amount of vesicles released on each pulse converges to a limiting value, R (Figure 1B). This can be used to determine the maximum available pool size on the ribbon, A . The standard method for estimating A is to measure the rate of replenishment in the limit, and then back-extrapolate from the cumulative release plot to obtain the available pool size at the start of the pulse train [1]. When comparing pulse trains of

different strengths, this method yields substantially different values for A , a somewhat paradoxical result. Back-extrapolation assumes, however, that the replenishment rate is constant, even though it is thought to be proportional to the available space on the ribbon [2].

We developed a model-based approach to estimate A from the limiting release R . We modeled the rate of release (resp. replenishment) to simply be proportional to the number of vesicles on the ribbon (resp. vacant ribbon sites), and using the measured timescale τ_r (resp. τ_a). By solving the alternating differential equations, we derived a recurrence relation for the release during each pulse, R_i , which we then solved to obtain a closed form expression for R_i and the limiting release R . Specifically, we found that $A = cR$, where c is a function of $\tau_r, \tau_a, \Delta t, T$, and p , with p a release constant that captures the stimulus dependence of release probabilities, and can be estimated from the first release, R_1 . In contrast to the



* Correspondence: s-cparmel1@math.unl.edu

¹Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588, USA

Full list of author information is available at the end of the article

Table 1 Maximum pool size predictions from pulse train data

Stimulus	Estimate for A, from back-extrapolation	Estimate for A, from the model
-10 mV (stronger)	-136.8794 pA	-131.6858 pA
-30 mV (weaker)	-75.1020 pA	-133.6100 pA

back-extrapolation method, our model-based estimate for A was similar across stimulus types (Table 1), while p was much smaller for the weaker stimulus. This suggests that available pool size does not change with stimulus strength; instead, differences in release result from changes in release probability.

Authors' details

¹Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588, USA. ²Department of Ophthalmology and Visual Sciences, University of Nebraska Medical Center, Omaha, NE 68198, USA. ³Department of Pharmacology and Experimental Neuroscience, University of Nebraska Medical Center, Omaha, NE 68198, USA. ⁴Department of Mathematics, The Pennsylvania State University, University Park, PA, 16802, USA.

Published: 18 December 2015

References

1. Sakaba T, Schneggenburger R, Neher E: **Estimation of quantal parameters at the calyx of Held synapse.** *Neurosci Res* 2002, **44**(4):343-356.
2. Van Hook MJ, Parmelee CM, Chen M, Cork KM, Curto C, Thoreson WB: **Calmodulin enhances ribbon replenishment and shapes filtering of synaptic transmission by cone photoreceptors.** *J Gen Physiol* 2014, **144**(5):357-378.

doi:10.1186/1471-2202-16-S1-P41

Cite this article as: Parmelee *et al.*: Model-based prediction of maximum pool size in the ribbon synapse. *BMC Neuroscience* 2015 **16**(Suppl 1):P41.

Submit your next manuscript to BioMed Central and take full advantage of:

- Convenient online submission
- Thorough peer review
- No space constraints or color figure charges
- Immediate publication on acceptance
- Inclusion in PubMed, CAS, Scopus and Google Scholar
- Research which is freely available for redistribution

Submit your manuscript at
www.biomedcentral.com/submit

