What Japanese gardens teach us about neural dynamics

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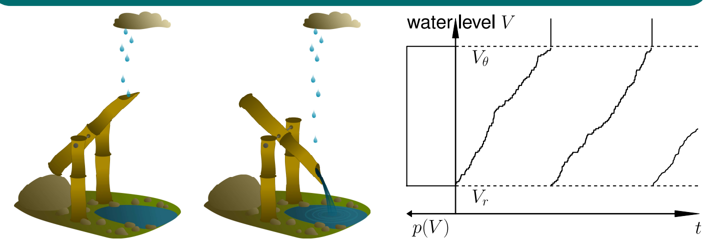
Summary

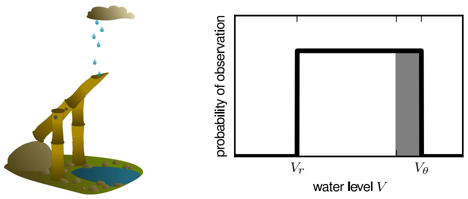
- nerve cells (neurons) **respond fast**
- neurons **perform non-linear operations**
- uncoordinated synaptic inputs **cooperate**

A neuron works like a shishi odoshi

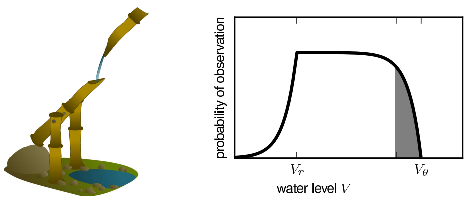


- a neuron receives inputs from thousands of other nerve cells
- these inputs are short impulses, like rain drops
- the nerve cell accumulates these impulses, like a shishi odoshi collects water
- at a certain water level the shishi odoshi tilts, analogously the nerve cell generates an output pulse

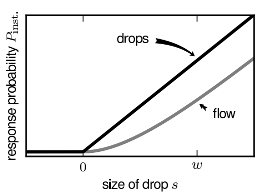
Distribution of water determines response



- random rain: only the probability to observe a water level is known
- our new theory [1,2] takes into account impulses like rain drops



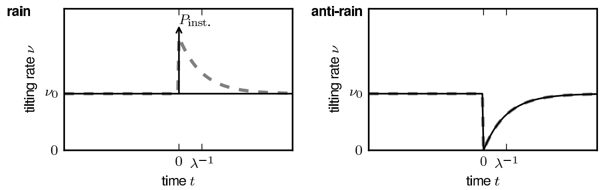
- the old approximative theory replaces drops by water flow
- causes artifactual decrease of probability near threshold
- researchers overlooked fast response



- new theory exposed fast response
- the water level is closer to tilting for drops
- background rain promotes response to additional drop

New theory explains the existence of a fast response

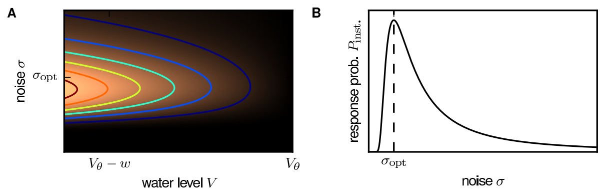
Rain and anti-rain act asymmetrically



- neurons also receive inhibitory impulses
- inhibitory pulses are like anti-rain: rain drops escaping from the tube
- an additional rain drop can cause a threshold crossing immediately (left, black arrow)
- an anti-rain drop delays the point of next turning for a period of time, decreasing the rate of tilting (right)
- the old theory falsely predicted a symmetric response (underlying dashed gray curve)

Excitatory pulses convey precise temporal information

Rain drops cooperate



- a single rain drop cannot tilt an empty shishi odoshi
- in heavy rain, the shishi odoshi has a probability to be close to threshold (**A**), so that a single drop can cause the tilt ⇒ rain drops cooperate
- an optimal amount σ_{opt} of rain and anti-rain causes the strongest cooperation (**B**)
- neurons receive thousands of inputs, like a heavy rain
- these inputs, though unrelated, cooperatively promote the neuron's firing

Neurons like to carry out many processes simultaneously

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References

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2 M. Helias, M. Deger, S. Rotter, and M. Diesmann. PLoS Comput Biol (2010), 6(9): e1000929