Title: Neural bases of accumulator models

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Reaction times in human and animal decision process, such as initiation of eye saccade, are surprisingly long. In saccade, eye movement starts not immediately but several hundred milliseconds after stimulus onset. This longevity cannot be accounted for only by neuronal conduction delays but is considered to represent some higher levels of brain process, referred to as procrastination.

Reaction times can also be characterised by their variability. The length of reaction time largely fluctuates from one trial to another trial even if experimental parameters are held constant in each trial.

One class of cognitive models, accumulator models, can well describe the longevity and variability of reaction time in decision process. In accumulator models (Fig. 1A), decision signal, which represents some internal activation level, is postulated. When a stimulus is onset, decision signal, say S, starts to rise linearly form an initial level S_0 at a rate r. When S reaches a pre-specified threshold level S_T, the reaction (eye movement, for example) is triggered. In the framework of accumulator models, there are two possible sources of the variability of reaction times. One is the fluctuation of the threshold level S_T across trials (variable-threshold model), and the other is the fluctuation of the rate r across trials (variable-rate model, Fig. 1B). These models give different experimental predictions, and recent psychological experimental studies support the variable-rate models.

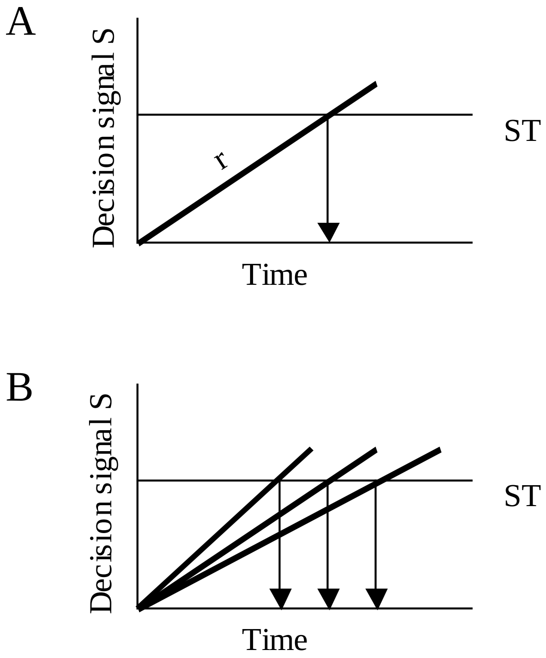

Fig.1

Thus, accumulator models are a powerful scheme to explain observed properties of reaction times in decision process at a behavioural level. However, little is known about neural bases of accumulator model: What is neural substrate of the decision signal, and what is the neural origin of the fluctuation of the growth rate of the decision signal?

The present study is devoted to examine possible neural mechanism of accumulator models. We have considered a recurrent network of bistable spiking neurons. Spike generation dynamics is given by a leaky-integrate-fire model, and the membrane potential bistability is achieved by adopting after-depolarization current.

We have performed computer simulation study of stochastic dynamics of the network and found that the neuronal activity, defined by the number of spikes/s averaged over 10 trials for a given neuron, grows linearly with time (Fig. 2). The rate of growth changes if the amplitude of constant external input, which is input to each neuron in addition to the recurrent input, is varied (Fig. 2).

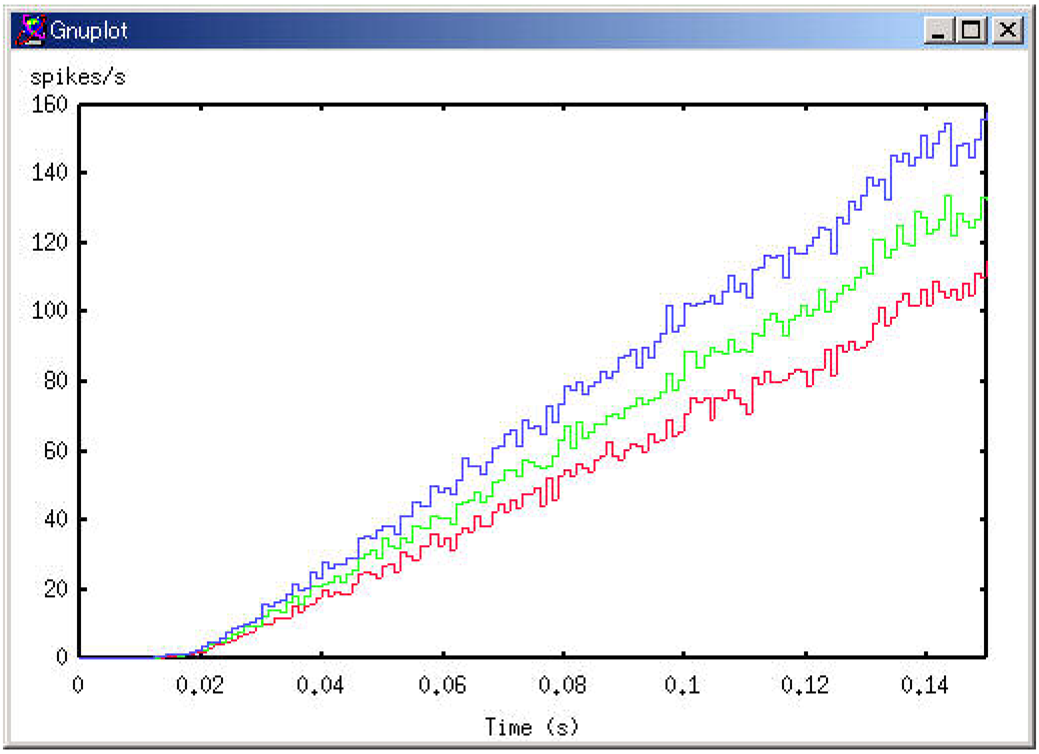

Fig. 2: Each line represents the results for different amplitude of external input

The results obtained above show that the linear growth of decision signal postulated in accumulator models can be realised by stochastic dynamics of a recurrent network of bistable neurons; decision signal itself can be represented by the averaged firing rate. Furthermore, the rate of the growth of the firing rate can be changed if the amplitude of constant external input is varied. Indeed, fluctuation of the amplitude external input is possible: It probably represents the target stimulus, but it might be modified by 'attention' that can be easily varied from one trial to another trial. Finally, it is notable that the firing rate that grows over time, seemingly linearly, has experimentally been observed in the frontal eye field, the activity of which controls initiation of saccade eye movement.

Thus, the present study provides a proposition to explain behavioural function in terms of neural mechanisms.