Considering the reconfiguration process of subjective temporal order by using recurrent neural networks

Kohei Nakajima and Takashi Ikegami

Department of General Systems Sciences, The Graduate School of Arts and Sciences, University of Tokyo
nakajima@bio.c.u-tokyo.ac.jp

Starting from the famous conception of B. Libet, how the brain orders successive events has been a matter of intense debate in neuroscience. S. Yamamoto and S. Kitazawa (S. Yamamoto et al., 2001, Nature Neuroscience, 4, p.759) revealed that subjective temporal order of successive taps to hands, or to the tips of sticks held in each hand, are easily reversed just by crossing the arms. What is astonishing is that, especially in the crossing case, when the tapping interval was less than 0.3 second, the mistake rate grew to 100%. This result could be taken as general functionality of the real brain's time-space reconfiguration process. In this session, we try to explain these phenomena and to characterize the real brain reconfiguration process of subjective temporal order, from dynamical systems perspectives. To construct the computational model, we adopted the following settings. We prepared an agent containing two arms and corresponding pairs of input nodes, consisting of proprioceptive and exteroceptive inputs, and output nodes to make the agent answer which hand had received the stimuli first. Proprioceptive nodes detect the location of the arms and exteroceptive nodes detect the stimulus applied to the hand. For the agent's internal architectures, we adopted discrete time recurrent neural networks with plasticity and trained the network by using a genetic algorithm depending on the tasks. To prepare the same settings as S. Yamamoto and S. Kitazawa's experiment, one calculation of internal networks was defined as 0.01 second, and one experiment takes 3 minutes by iterating 60 cycles of time period consisting of "a stimulus application interval", "an agent responding interval" and "a resting interval". Each interval was defined as 2 seconds, 2 seconds and 1 second, respectively. The agent receives the stimuli in "a stimulus application interval", has to respond to the stimuli in "an agent responding interval", and rests in "a resting interval". Other actions are not allowed for the agent. Stimuli are designed to create alternative time delay between both hands. For the agent's task, we set two: Task1 involved changing the locations of both arms for the entire parameterized region, and applying the stimuli to only one hand, after which the agent had to answer which hand had received the stimuli. Task2 involved changing the locations of both arms for a limited parameterized region, non-hand-crossing region, and applying the stimuli to both hands, after which the agent had to answer which hand had received the stimuli. For the experiment, we crossed the agent's arms, applied the stimuli to both hands and then analyzed the response and the agent's internal dynamics. Finally, determining the result, we discuss the implications of this model to real brain reconfiguration processes of empirical time and space.