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LUX ET VERITAS

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Recommendation letter on behalf of Dr. Alireza Soltani

I am writing this letter in enthusiastic support of Alireza (Ali) Soltani who applied to a faculty position at your Institution. On the outset, I will be clear: Ali is the brightest student among a number of excellent students I have had the good fortune to train over the last two decades. The breadth and depth of his accomplishments are already impressive, and his proposed research will bring him to another level in his career.

Ali obtained his B. S. in Physics at Sharif University of Technology, Iran, which is well-known for its rigorous education in physics and mathematics. He came to the States in 2001, first in a graduate program at Northeastern, and transferred to Brandeis one year later. At the time he joined my lab in early 2003, several monkey labs (Paul Glimcher, Bill Newsome, Daeyeol Lee) were starting to report at meetings their new physiological experiments that revealed neural correlates at the single-cell level of reward valuation and stochastic choice behavior. The eventual publications of these findings (Sugrue et al 2004, Barraclough et a 2004, Dorris and Glimcher 2004) would mark the beginning of a new era for neurobiological studies of economical decision-making in the primate brain.

In 2002, I published a paper in Neuron showing that a neural circuit model previously developed for working memory is also capable of decision-making computations. It was thus natural that we wondered whether such a model could be extended to describe adaptive choice behavior. Therefore, when Ali joined my lab, I asked him to embark on incorporating reward-dependent synaptic plasticity in our decision-making model, so we could investigate the cellular basis of expected reward/utility and the origin of randomness in choice behavior. In the next few years Ali has built such a model. Briefly, in our decision circuit model, different neural pools are selective for choice options (say A and B). Spiking neurons in each neural pool are endowed with strong recurrent excitation underlying 'slow reverberation' in a decision process. The two neural pools compete against each other via inhibitory neurons, and the winner produces an action choice (A or B). Due to irregular spiking neural dynamics, this decision process is stochastic, the probability of choosing A is a sigmoid ('softmax') function of the difference in the inputs to the two neural pools (g_A–g_B). Ali incorporated a stochastic Hebbian learning rule, initially proposed by Amit and Fusi, at synapses g_A and g_B. He added reward-dependence to this learning rule, based on the evidence for dopamine modulation of synaptic plasticity, so that if the circuit chooses A, g_A would be potentiated only if A is rewarded, but depressed if A is not rewarded. This is a fairly general model, not designed specifically for any particular task. Interestingly, Ali showed that the model could be applied to several monkey experiments.

First, Ali showed that this neural circuit model can reproduce the monkey's behavior as well as physiological data from LIP neurons in a dynamic foraging task (Sugrue et al 2004) where rewards are delivered stochastically. In the model, the synapses onto a pool of decision neurons turned out to compute the return on that choice option (the amount of reward per choice), rather than income (the amount of reward per trial) which has been the basis of previous models (Surgue et al. 2004). Ali's model not only captures Herrnstein's 'matching law' (that a subject's choice allocation matches in proportion the relative reinforcement obtained on these choices), but also provides an explanation for the suboptimal 'undermatching phenomenon' observed widely in the monkey (and human) experiments. This work was published in the *Journal of Neuroscience*. Next, in collaboration with Dr. Daeyeol Lee, Ali applied his model to an interactive game task, in which monkeys play matching pennies with a computer and the best strategy is to play completely randomly. Ali showed that this model is able to account for the monkey's behavioral data on a trial-to-trial basis. Moreover, with the addition of a slow learning ('meta-learning') component, the model also captures the very gradual changes (over many days) in monkey's behavior as the computer opponent switches strategies. These results are interesting, because the same model was used here, as in the foraging task, except now the choice outcome depends on the decisions of both the 'stimulated monkey' and another agent. The model provided insights into the roles of synaptic plasticity as well as the feedback by the interacting agent in producing random choice behavior. This work appeared in *Neural Network*.

Ali proceeded to apply his model to other tasks that combine sensory information with reward contingencies. For instance, in a two-alternative forced choice version of the random-dot motion direction discrimination task, either the prior probabilities or the amounts of reward (associated with choice options) have been manipulated, in Shadlen's lab and Newsome's lab respectively, in order to investigate how monkeys combine sensory evidence with reward magnitude or likelihood in their choice behavior. In another, 'weather prediction', task, different visual stimuli are assigned different 'weights of evidence' (WOE) for rewarding choices, and it was found that monkeys made decisions based on integrated WOEs of several visual stimuli (Yang and Shadlen). Impressively, Ali showed in his thesis that the same model can be applied to all these tasks and can reproduce single-cell physiological data as well as monkeys' behavioral data. As it turns out, following the same learning rule but depending on the task design, the plastic synapses compute different quantities: the prior probability in the motion direction discrimination task or log posterior probability ratio in the weather forecasting task. Taken together, these findings point to a unifying neural circuit model for a diversity of reward-dependent choice behaviors. This work was published in *Nature Neuroscience* in 2010, and has received wide attention. I also invited Ali to co-write a *Current Opinion in Neurobiology* piece. Remarkably, he completed all these, and finished his PhD thesis, in a little more than 3 years.

Since Ali left my lab, he was a postdoctoral fellow with Christof Koch at Caltech, when he built a large-scale model of spiking neurons for visual information processing and selective attention. This work appeared in *Journal of Neuroscience*. He then moved to Baylor College of Medicine and is currently working with Read Montague, learning human fMRI and pursuing computational modeling of decision-making processes. After Read moved to Virginia, Ali went to Stanford with Tirin Moore. Christof, Read and Tirin will be able to tell you about Ali's growth and accomplishments after he left my lab.

Ali discussed with me his proposed research for this K25 award. The plan is to use mutli-unit electrodes (U-probes) to record from two sites in V4 and FEF, simultaneously. In addition, he also plans to use FEF inactivation (using an GABAa agonist Muscimol) to see whether the effects of reward on attentional processes rely on FEF activity or not. So overall, he will have psychophysical data, neural recording, and inactivation to investigate the influence of reward on attentional processes. His plan addresses a conceptually important issue (how attention and reward relate to each other) using advanced experimental tools. Data thus obtained will no doubt lead him to develop a new computational model for the attentional brain circuitry.

In my view, Ali stands out in several respects. First, Ali is well versed in neurobiology (thinking in terms of neurons and circuits) as well as psychology (being sophisticated about behavioral tasks). Second, Ali is equally skilled in mathematical techniques, model simulations, and statistical analysis of experimental data. Third, Ali is very good at collaborating with experimentalists. He has interacted extensively with monkey physiologist Daeyeol Lee, and human cognitive neuroscientists at Caltech and Baylor. Fourth, I want to stress that Ali has worked quite independently. Fifth, it would be hard to find someone like Ali in our field who has the experience in modeling decision-making, large-scale network of the visual system, and human fMRI. As a theorist with a degree in Physics, he is brave enough to now propose to learn monkey physiology in the lab of Tirin Moore, with the goal to test interesting ideas about the role of reward in selective attention. Thus, he is now well positioned to take a faculty position and start his own research group. I have no doubt he'll have a successful career in Computational Neuroscience; he has my highest recommendations.

Yours sincerely,

Xiao-Jing Wang

Professor of Neurobiology, Physics and Psychology
Director, Swartz Initiative in Theoretical Neurobiology