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Emergence of sensory selection mechanisms in Artificial Life simulations

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Background

The evolutionary advantages of selective attention are unclear. Since the study of selective attention began, it has been suggested that the nervous system only processes the most relevant stimuli because of its limited capacity [1]. An alternative proposal is that action planning requires the inhibition of irrelevant stimuli, which forces the nervous system to limit its processing [2]. An evolutionary approach might provide additional clues to clarify the role of selective attention.

Methods

We developed Artificial Life simulations wherein animals were repeatedly presented two objects, "left" and "right", each of which could be "food" or "non-food." The animals' neural networks (multilayer perceptrons) had two input nodes, one for each object, and two output nodes to determine if the animal ate each of the objects. The neural networks also had a variable number of hidden nodes, which determined whether or not it had enough capacity to process both stimuli (Table 1). The evolutionary relevance of the left and the right food objects could also vary depending on how much the animal's fitness was increased when ingesting them (Table 1). We compared sensory processing in animals with or without limited capacity, which evolved in simulations in which the objects had the same or different relevances.

The evolution of neural networks was simulated by a simple genetic algorithm. Fitness was a function of the number of food and non-food objects each animal ate and the chromosomes determined the node biases and synaptic weights. During each simulation, 10 populations of 20 individuals each evolved in parallel for 20,000 generations, then the relevance of food objects was swapped and the simulation was run again for another 20,000 generations. The neural networks were evaluated by their ability to identify the two objects correctly. The detectability (d') for the left and the right objects was calculated using Signal Detection Theory [3].

Table 1: Nine sets of simulations were performed, varying the values of food objects and the number of hidden nodes in the neural networks. The values of left and right food were swapped during the second half of the simulations. Non-food objects were always worth -3.

Variables	Simulation Sets								
	2-6-6	4-6-6	8-6-6	2-9-3	4-9-3	8-9-3	2-11-1	4-11-1	8-11-1
Number of hidden nodes	2	4	8	2	4	8	2	4	8
Initial value of left food	6	6	6	9	9	9	11	11	11
Initial value of right food	6	6	6	3	3	3	1	1	1

Results and conclusion

When both stimuli were equally relevant, networks with two hidden nodes only processed one stimulus and ignored the other. With four or eight hidden nodes, they could correctly identify both stimuli. When the stimuli had different relevances, the *d*' for the most relevant stimulus was higher than the *d*' for the least relevant stimulus, even when the networks had four or eight hidden nodes. We conclude that selection mechanisms arose in our simulations depending not only on the size of the neuron networks but also on the stimuli's relevance for action.

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