The role of the environment in the realization of cognitive systems : The example of the immune system

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From a systems perspective we presuppose that living systems and, moreover, cognitive systems, share certain dynamical rules regarding their relationship with themselves and with the world. This is nowhere better expressed then in the theory of Autopoesis and in Varela's later work on cognition. I wish to present a refinement of this theory and suggest how this effects our view of the immune system' relationship to its environment and this relationship in cognitive systems in general.

We have previously suggested a minimal criterion of cognitive systems [1]. This criterion is that the capabilities of a cognitive system are not preordained by the plan of the system, but require interaction with the environment for the system's capabilities to form. As examples, we presented the visual system, the adaptive immune system and the use and acquisition of language in infants[1]. In doing so, we have placed an emphasis on the role of the environment in cognition, which is radical even compared to Varela's' definition of cognition [2].

Varela's definition of cognition revolves around functional closure. He defined such systems as being capable of action and perception, the coupling of which is such that:

1) The system exhibits operational closure.
2) The emergent behavior of the system in the environment satisfies meaningful constraints. By this he meant that it is only through interaction with the environment that the meaning of the actions is defined. Thus, a brain with no world to perceive and act in would not be cognitive [2, 3].

This definition of cognitive systems is a system science one, as Varela has shown that it applies not only to cognitive systems based on neurons. In fact, the above definition leads directly to his model of the cognitive immune system [3, 4]. This implies that in order to construct an artificial cognitive system, we need not worry about neuronal architecture as such, but rather on the dynamics of its interaction with the environment that would satisfy the above criteria [2].

I have followed Varela's footsteps in this regard, but have suggested the following: a proper interpretation of the way closure is achieved by cognitive systems places the environment in an even more central position. To use the above phraseology, I would place the environment already in point one, namely: operational closure is not innately exhibited; rather, it is learned, and requires interaction with the environment to be formed.

This change in the definition of cognitive systems, and the emphasis on the relationship to their environments, has implications regarding the way cognitive system develops and the form of the environment in which it is expected to do so [5]. Both

Varela and I have treated the immune system as cognitive, but we suggest different conclusions that stem from our differing view of cognition.

The immune system is built of a diverse population of cells that express receptors of varied affinity. With the help of this varied repertoire, the immune system can identify practically every chemical substance, most particularly the various chemical patterns (known as antigens) created by pathogens invading our body.

A major problem in explaining how this repertoire functions lies in the question how the repertoire of immune receptors, which are both varied and crossreactive, react only to the foreign antigens and refrain from reacting to self antigens. Varela's solution, based on network definition of the relationship of the different receptors and their affinities [3], was that the self reactive receptors exist in a cross reactive network. Using a model simulation, he showed that such a network would ultimately self-stabilize, leading to an active but stable repertoire of receptors. When a non-self antigen was encountered, the receptors that reacted to it where those which did not belong to the cognitive network. Thus the reaction was cognitive only when regarding self antigens. As regards non self antigens the reaction could only be termed cognitive by omission, as the receptors reacting to these antigens could be defined by their lack of relationship to the cognitive network [3]. The problem with Varela's model was that self reactive network, following several interactions, would expand and cover the whole shape space of receptors, leaving no room for the non-self antigen to react 'non cognitively' (i.e. without perturbing the network [3, 4]).

This problem disappears under our definition of cognition. Although we agree that the environment of the immune system is our self, it need not be defined as being only that which was there in the original developmental phase of our bodies. In order to fully understand the function of a cognitive system and the form of its closure within the environment, we should look at the distribution and relationship of examples it interacts with. In doing so, we notice that the filling up of the entire shape space by the network is not a fault of the system, but an asset. The body has co-evolved with its invaders and those essential imprints that define our cells and their stress are similar in our invaders [6]. We have built a model that demonstrates the known dynamics of immune cells. In this simulation the entire shape space is covered by the immune receptors. Foreign antigens cause the immune system to behave differently because their dynamics and the specific regions of the shape space they stimulate differ from those of the self antigens [7].

References

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