Emergent Oscillations and Cyclicity: Physical Aspects of Frustrated Cognitive Systems

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This talk will attempt to answer the question "Where does syntax come from?". This is, of course, a restatement of a very old question; that is, "what is the core type of operation or processes that underlies our cognitive experience?" However, we contend that it is timely to revisit this thorny problem. Recent developments in Mathematics, Physics and Cybernetics have provided a number of sophisticated tools and techniques relevant to answering this question. They are not often brought together largely because they range across a wide landscape of questions and methodologies. Here we will provide a fusion of relevant notions and present what we hope is a kind of answer. We will argue that the ground state of cognitive systems is (a very rich) uncertainty and that an essential part of the dynamics of such uncertain systems necessarily leads to transient simplifications. These simplifications are the stuff of syntax and without them we could not exploit the information embedded in cognitive systems. The approach assumes that physical principles apply not only to the physiological systems that support cognition but also to the content of cognitive space these systems determine. Here we will not focus on the physiology but the principles we appeal to apply equally to physiological phenomena. Our story depends upon the core notion of dynamic frustration and a further tension between ultrametric and metric spaces. We show that dynamically frustrated systems, as in the case of spin glass, instantiates an ultrametric space (Stein and Newman, 2011; Ramal et al., 1986). As such, they allow for very rich associative fields or manifolds but lack mechanisms that can categorize. However, a general property of dynamical systems is that fields or manifolds can/will interact. The consequences of such interactions are captured in the Center Manifold Theorem (CMT henceforth) which tells us that the intersection of manifolds leads to the creation of a new manifold that is of lower dimensionality and which combines the core dynamics of the intersecting higher dimensional manifolds (Carr, 2006). This is the first core observation, a dynamically frustrated system under conditions found in biologically instantiated systems, will necessarily manifest oscillations between higher and lower dimensionalities and hence between higher and lower entropies. The second core observation is that, while a dynamically frustrated system expresses an ultrametric space, the consequence of the intersection of manifolds in that space, following from the center manifold theorem, is to impose metrical structure onto the lower dimensional, lower entropy offspring. Thus in a dynamically frustrated system we have an engine that necessarily delivers oscillatory behaviour, a very good thing from the neurophysiological point of view (see, e.g., Poeppel et al., 2015), and also moves between ultrametric and metric spaces, quite useful from the information processing point of view (due to the fact that the oscillations provide a built in mechanism that can update the associative manifolds).