and that noncommunicating processes (like *c[push_coffee-button,ready_tea-button]* are abstracted away, we obtain:

$$H\|M = accept\_coin.(pour\_tea + pour\_coffee).(H\|M)$$

This is indeed the outlook on the world from the point of view of such a vending machine (we left out considerations that the machines need to be refilled, and that water and energy are available in unlimited quantities). We see the difference with ordinary algorithmic programming, which is directed towards termination. Programming a process is often directed in an interactive environment to unlimited continuation.

The theory of communicating systems carefully describes processes with a global control, versus ones with a local distributed control without global knowledge.

Context rules

Steven L. Bressler

Center for Complex Systems and Brain Sciences, Florida Atlantic University, Boca Raton, FL 33431. **bressler@fau.edu**
http://www.ccs.fau.edu/~bressler

Abstract: It is proposed that cortical activity is normally coordinated across synaptically connected areas and that this coordination supports cognitive coherence relations. This view is consistent with the NMDA-hypoactivity hypothesis of the target article in regarding disorganization symptoms in schizophrenia as arising from disruption of normal interareal coordination. This disruption may produce abnormal contextual effects in the cortex that lead to anomalous cognitive coherence relations.

The human brain is an engineering marvel. Its range of capabilities far surpasses that of any animal or machine. Understanding the factors that give the human brain its unique cognitive abilities is of central importance to numerous human endeavors. Awareness has been growing in recent years that a major factor determining the brain's computational power is its connectional complexity (Stone & Kotter 2002). While it is commonly agreed that cortical areas are specialized for processing different types of information, relatively little attention has been given to the dependence of this specialization on the connectional architecture of the cortex. A major determinant for an area's ability to process a certain type of information is the inputs that it receives. Yet, the connections between areas appear to be overwhelmingly supported by bidirectional pathways, implying that, through recursive interactions, an area's inputs from other areas will be affected by the output signals that it sends to them. Therefore, it would seem that the unique processing that is characteristic of each cortical area must be defined in terms of its interactions with other areas. It is therefore necessary, in seeking to determine the function of a cortical area, to consider the collection of areas with which it is connected, and with which it may jointly process information. This collection has been called an area's "connection set" (Bressler 2002) or "connectional fingerprint" (Passingham et al. 2002).

The anatomical pathways linking the areas of a connection set are undoubtedly crucial for defining what inter-areal interactions are possible, but the specific interactions that occur will ultimately depend on the dynamics of inter-areal coordination (Bressler & Kelso 2001). Phillips & Silverstein (P&S) are amply justified in addressing the basic question of how specialized cortical processes are coordinated (Varela et al. 2001). They rightly stress the importance of dynamic coordination in visual perception (Bressler 1996) and its possible disruption as a determinant of schizophrenia (Bressler 2003). Moreover, they correctly assess the importance of coordination for the issue of local contextual effects within cortical areas (Bressler 1999; 2002).

P&S are on weaker ground, however, when they attempt to formulate a general principle of cortical function from the distinction between primary and contextual influences. To define the "primary input" to cortical neurons as arising from their receptive fields, as P&S do, is a decision fraught with difficulties. The concept of receptive field cannot serve as a sound basis for deriving a universal computational property of cortical neurons. Neurons in non-sensory cortical areas do not have unambiguous receptive fields, and neurons in higher-level sensory areas have large receptive fields that derive from multiple converging inputs rather than clearly defined primary inputs. In short, cortical areas with a clearly defined primary input pathway are the exception rather than the rule.

The overall lack of primary inputs should not, however, be taken to denigrate the role of local context in cortical processing. In a broad sense, all inputs to a cortical area may be considered as contextual – even those primary inputs that can obviously be defined as directly originating in the periphery. Therefore, contextual influence may be seen as a common outcome of cortical function, a property that emerges from the coordinating interactions in which a cortical area engages with the other areas of its connection set. Included within the various types of coordinating interactions may be top-down effects from high-level areas (connectionally far from the periphery), as well as bottom-up effects from low-level areas (connectionally near the periphery).

From this perspective, the interactions that a cortical area undergoes in conjunction with the members of its connection set, automatically provide context for that area's local processing (Bressler & Kelso 2001). An understanding of the rules that govern the contextual influences exerted by cortical areas on one another may come from the study of cognitive coherence (Thagard 2000). If we assume that cognitive domains are spatially mapped in the cortex, then the dynamic coordination of cortical areas, constrained by the cortical connectional architecture, may instantiate cognitive coherence relations. In this interpretation, cognitive state depends on interacting cortical areas, which normally reach a consensus that resolves cognitive coherence and incoherence relations among participating cognitive domains. Large-scale networks of coordinated cortical areas that emerge during cognitive processing consequently reflect the recruitment and exclusion of areas according to the satisfaction of these relations. Areas that are able to express mutually consistent information are included in these networks, thereby satisfying coherence relations (positive constraint). Conversely, areas that would express information that is inconsistent with any of the included areas are excluded from participation, thereby satisfying incoherence relations (negative constraint). This viewpoint is consistent with that of P&S when they assign a functional role to cognitive coordination in schemata conflict resolution.

A prediction from this perspective is that cognitive dysfunction of the type presented by the disorganization syndrome in schizophrenia reflects an underlying discoordination of cortical areas (Bressler 2003). This interpretation is consistent with the NMDA-hypoactivity hypothesis proposed by P&S if one assumes, as they do, that inter-areal constraints are mediated by NMDA synapses. In neural terms, inter-areal discoordination would mean that cortical areas were unable to maintain a proper balance between engagement in and disengagement from large-scale coordinated networks (Bressler & Kelso 2001). In terms of cognitive coherence, discoordination would be expected to result in cognitive states marked by a breakdown of coherent relations and the manifestation of incoherent ones. The disruption of coordination between areas that normally would be coordinated might appear phenomenologically as a failure to make correct associations among sensory fragments, percepts, events, or concepts, depending on the areas involved. The coordination of areas expressing inconsistent information could result in erroneous associations among those same entities. Therefore, discoordination could produce both degradative and illusory symptoms in schizophrenia. These predicted effects would not involve a malfunction of the activity within any cortical area, so they could not be detected by recording the activity of any single neuron or single area. Rather, they would have to be detected as departures from normal patterns of coordination, reflecting violations of the normal rules of context.