**Chapter 5**

**Dimensional-Systems Model (DSM)**

The cortical column has been proposed as the binary digit (bit) for all cerebral cortical processing (Moss, 2006). This simply means that each cortical column represents specific and discrete information. Based on the assumption that circuits of columns are the manner that all higher cortical functions occur, then the role of all other involved brain structures outside the cerebral cortices is to facilitate columnar circuitry. Recent high-resolution fMRI with humans has shown columnar-like structures in V1, V2, V3, hMT, and ventral temporal cortex showing differential representations of categories and domains. Of particular relevance is the recent study in which high resolution fMRI provided proof that in the human middle temporal visual complex, columnar clusters meet the criteria of content-specific neural correlates of consciousness (NCC). NCC refers to the minimal set of neuronal mechanisms jointly sufficient for any one conscious percept.

To assist in understanding cortical processing, two points will be helpful. First, everything works in circuits. Second, the components in the circuit determine what functions occur. For example, a simple electrical circuit involves a power supply, a component or device (e.g., light bulb, buzzer), and the wires connecting these. Usually there is a switch that serves to activate and deactivate the circuit. If a light bulb is in the circuit, it glows when the switch is in the on position. If there is a separate circuit with a buzzer, the buzzer does not activate when the light bulb circuit’s switch is on because it is not connected to that switch. If both the buzzer and light bulb are in the same circuit (i.e., in “series” or serial processing) then both light and sound result with switch activation. Similarly, if the separate light bulb and buzzer circuits are connected to the same switch (in “parallel” or parallel processing), both light and sound occur when switched on. If components or devices are not connected to a given circuit then there is no expectation they will activate. Within the context of the DSM, circuits of columns that do not interconnect lack a means to access one another even though each circuit may have the capability of processing incoming information and initiating a response.

Subcortical enhancement of memory occurs as a function of the activation of the cortical circuit which in turn strengthens the synaptic connections of the involved columns. Thus, when significant emotional sensory memories activate at the cortical level, there is increased activation in associated subcortical structures, such as the amgdalae, that receive cortical projections.

A physiological definition of memory involves the strengthening of synaptic connections in any given circuit of cortical columns that are used in information processing. Forgetting is the result of weakened synaptic connections which means the downstream columns in the circuit fail to activate. In this case, the column’s activation by one or more other columns fails to be maintained.

It is important to consider two different levels related to the column; one is the manner in which the column is formed, with the other being the circuits of columns involved in any given higher cortical function leading to the desired response. Just as a machine has its component parts that interconnect in specific ways, a column has its component neurons and interneurons that connect in specific ways. As I explain columnar cells, I discussed how it potentially relates to several neuropsychiatric disorders to enhance understanding.

To understand how the DSM relates to schizophrenia, autism, and Alzheimer’s disease, it is necessary to consider both the dynamic formation of cortical columns as well as the associated circuits. If cortical columns fail to form or a cortical circuit is disrupted, then cognitive and memory problems result. In relation to cortical circuits and association memories, there is a cortical-hippocampal-thalamus-cortical circuit. The recurrent activity provides the cortical columns involved in a given memory with reactivation leading to the strengthening of synaptic connections among the columns. If a disease affects the hippocampus and the recurrent activity fails to occur, the synaptic connections among the columns fail to strengthen and the association memory is lost.

A different problem can occur if the dynamic formation of columns is disrupted at the cortical level. Even if the hippocampus is intact and supplies the recurrent signal, local factors can prevent the consolidation for one or more of the columns in the circuit. If the integrity of the new column fails, the memory circuit is disrupted. Obviously, failure to form each component in a given columnar circuit results in deficits in cognitive functions that depend upon those components.

*Dimensions of the cortical system.* The dimensions of cortical column processing are described in Table 5-2 and these explain the both the modes and locations of cortical processing.

|  |  |
| --- | --- |
| Dimension Name | Description of Dimension |
| Internal-external  Proximal-distal | The medial cortical columns code stimulus information that is internal and self-referential while the lateral cortex codes for external stimuli. Intermediate or transitional zones code for combinations of both.  In relation to proximal versus distal to the body stimulus coding, the central sulcus is considered the most proximal cortical location. The post-central sulcus parietal cortical area would code for somatosensory (i.e., body sensation) stimuli. Both vision (occipital lobe) and audition (temporal lobe) involve distal sensory information. The pre-central sulcus primary motor strip involves the body directly while anterior prefrontal processing involves information manipulation largely independent of the body. |
| Simultaneous-sequential | Ventral cortex processes in a sequential manner and dorsal cortex in a simultaneous manner, with intermediate areas using both modes of processing. |
| Reception-action | The parietal, temporal, and occipital lobes contain all receptive, or sensory, information while the frontal lobes code for all action-related information. |
| Unorganized-organized | Receptive information progresses from less-organized, or lower-order, information to more-organized, or higher-order, information (i.e., coding) as the stream moves away from the primary sensory receiving areas (i.e., bottom-up processing). On the other hand, the frontal action columns progress in a rostral to caudal more-organized, or higher-order information to less-organized, or lower order information (i.e., decoding) as the stream goes toward the premotor and primary motor areas. The frontal action columns’ control of posterior lobe receptive columns is also present (i.e., top-down processing). |
| Analytical-Global | Each cortical hemisphere acts as a separate, albeit interconnected, processing unit which means that each of the aforementioned dimensions is contained within each hemisphere. However, there are fewer columns from the time of sensory input to the response level in the right hemisphere. This means that the right cortex can process information faster, but with fewer details (i.e., global processing). The greater number of interconnected columns in the left hemisphere allows more detailed processing and memory storage (i.e., analytical processing) |

There must be a way that “automatic” or “habit” behaviors controlled by cortical circuits can occur independent of frontal attention mechanisms. These functions are considered to be the result of basal ganglia and cerebellar involvement, respectively. The basal ganglia are theorized to provide inhibition for each cortical column. There are both motor and non-motor loops of the basal ganglia involved with body movement, oculomotor control, prefrontal cognitive functions, and the limbic system. The loops involve the same basic design with input from the cortex to the striatum which then projects to the pallidal structures which in turn project to the thalamus. The thalamus projects back to the cortex. The loops most relevant to psychological treatments are the prefrontal and limbic ones. The STN is proposed to be the structure involved in activation of the cerebellum.

Based on the DSM, the cerebellum assumes control of the action columns involved in overlearned behavioral responses, freeing the PFC from using attentional resources for those actions. It has been proposed that there is a Universal Cerebellar Transform (UCT), such that there is a basic neurological process in cerebellar design regardless of the functions involved. An interesting idea is that there may be a hallmark cerebellar circuit involving the SN (as opposed to GP), putamen, thalamus, and sensorimotor cortex for all automatic behaviors, including those viewed as cognitive and emotional. Habitual behavior is automatic which simply means it occurs independent of PFC columns involved with attention and verbal awareness. The only way to overcome unhealthy automatic behaviors (e.g., poor body mechanics) controlled by the cerebellum is to overlearn a competing healthy behavior. Thus, repeated practice is necessary. The same can be true in any actions controlled by the cerebellum, including pain behaviors and other behavioral responses (e.g., teeth clenching leading to facial and headache pain) that may be dysfunctional. Similarly, all overlearned non-motor cortical functions associated with actions can theoretically become automatic. These can include language (e.g., syntax, repeated lectures) and emotional (e.g., personality behaviors) actions.