UC Merced

Proceedings of the Annual Meeting of the Cognitive Science Society

Neural Substrates and Temporal Characteristics for Consciousness, Brief Sensory Memory, and Short-Term Memory (STM) Systems

Charles Q. Wu (charles@cogpsy.org)
Vision and Cognition Research Institute
Shanghai 201203, CHINA

Neural Substrates for Consciousness

Human visual consciousness certainly consists of many levels. For instance, when one views Leon Harmon's painting of Lincoln, three levels of consciousness may occur: the awareness of the colors and patterns in the painting, the awareness of a face in the drawing, and the awareness that the face is Lincoln's. The visual consciousness at the first level (i.e., the vivid visual consciousness of patterns and colors) may occur without any sense of object recognition. Counterintuitive or not, vivid visual consciousness in human is monocular! This idea has its root in the "suppression theory" of perception proposed by some early students of binocular rivalry (BR) such as Porta (1593) and Dutour (1760). BR is a striking phenomenon where a viewer experiences alternating periods of different percepts when the two eyes receive disparate stimuli. Logically, the suppression of the consciousness of a monocular image must happen at a monocular site – this is because that once the two images are mixed at a binocular site there is no possibility to retrieve the identity of either of them. The suppression stage in BR is the neural substrate for vivid visual consciousness. The suppression theory maintains that despite having two eyes we normally see with only one eye at a time. In reality, however, both suppression and binocular superimposition may occur in normal viewing. Binocular superimposition is the maintenance of two monocular images in consciousness – this also implies the monocularity of vivid visual consciousness in humans.

Mapping onto the neuroanatomy of the primate visual system, Wu (1997) suggested that the neural substrate for vivid visual consciousness is the principal thalamic recipient layer (i.e., layer 4C) in the primary visual cortex (V1). Layer 4C has been traditionally viewed as the very first stage of cortical visual processing; however, in terms of the dynamics of conscious visual perception, this layer is also the very last processing stage for each and every episode of visual conscious perception. I believe that the vivid visual consciousness involved in various visual appearance (spreading, filling-in) and disappearance phenomena (e.g., binocular rivalry, monocular rivalry, Troxler effect, fading of retinally-stabilized images, the ebbs in the ebb-and-flow cycles of afterimages, motion-induced blindness) all occurs in layer 4C. Of course, it is important to note that all such phenomena may in fact involve many levels of neural processing, but the final cortical processing stage for vivid visual consciousness appearance/disappearance is layer 4C in cortical visual area V1.

Neural Temporal Characteristics for STMs

Wu (1997) suggested that the neural substrates (layer 4s in various cortical areas) revealed in BR are the substrates for brief sensory memory and STM systems implicated in every perceptual or cognitive task. BR indicates that human visual perception is discrete in time. It is well established that the switching rate between percepts in BR is about $1/T$ (T=2~3 seconds) and that percept durations in BR follow the gamma distribution. This fact indicates that each percept episode in BR further consists of some discrete events (sub-episodes):

$$T = n_1 T_1$$

I suggest that the T and n_1 manifested in BR are the two parameters for visual STM: its temporal span and its capacity; and T_1 is the temporal span of STM at a sub-level. This equation can be generalized to multiple neural levels. Following the tradition of "perceptual or cognitive time quantum" theory, I postulate the following equation between various levels of sensory memory & STM systems involved in a perceptual or cognitive task:

$$T = (\prod_{i=1}^{k} n_i)t$$

where k is the number of neural levels involved in conscious processing for the task, n_i is the STM capacity at level i, t (=12.5ms, according to Kristofferson, 1967) is the time quantum in the brain's conscious processing, and T is the STM temporal span.

The above equation immediately offers an explanation for the inverse relation between STM capacity and memory search rate (Cavanagh, 1972): The temporal span for STM in various perceptual and cognitive tasks is basically constant: T=2~3 seconds; therefore there is an inverse relation between STM capacity n_1 and the processing rate $(\prod_{i=2}^{k} n_i)t$ for each STM element.

References

Cavanagh, J.P. (1972). Relation between the immediate memory span and the memory search rate. *Psychological Review, 79*, 525-53

Kristofferson, A.B. (1967). Attention and psychophysical time. *Acta Psychologica, 27*, 93-100

Wu, C.Q. (1997). From perceptual consciousness to cognitive architectures. *Proceedings of the 11th Annual Conference of the Cognitive Science Society* (p.1092). Hillsdale, NJ: Erlbaum.