Human Neurophysiology to clinical neuroscience and back again

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Abstract

Psychophysics investigates the relationship between sensory input and behaviour. The sensory input studied is often visual, because humans rely heavily on this sense. Eye movements lend themselves to study as a behavioural read-out because of the ease with which they are measured and, the relationship between vision and eye movements remains a pillar of psychophysical investigation. A central structure in the brain involved in visual processing and eye movement control is the superior colliculus (SC). The SC is a structure in the midbrain that has been the focus of studies in psychophysics and neuroscience for over 40 y. Based on this work; we know that the SC plays a crucial role in converting sensory signals, particularly visual signals, into commands to orient toward those sensory signals. In lower mammals, orienting takes the form of whole-body movements toward the stimulus. In monkeys, as in humans, it is often just the eyes that move to realign the fovea—the high-acuity portion of the retina—on the visual object of interest Our visual sense can be decomposed into many domains and subsystems. One broad domain is colour vision. The retina of humans and monkeys contains three types of cone receptors providing us with our daylight and colour vision; they are the S-, M-, and L-cones, defined by the short-, medium-, and long-wavelength stimuli that activate them maximally. The S-cone system exists in nearly all mammals and is evolutionarily older than the M- and L-cone systems. Interestingly, the S-cone system remains segregated from the L- and M-cone systems from the retina to visual cortex. Human studies indicate that the S-cone system contributes to colour perception and not very strongly to luminance perception. It has low spatial frequency sensitivity so it is not useful for fine visual discriminations. The segregated and special nature of the S-cone system has made it an area of active investigation, with an entire recent issue of Visual Neuroscience devoted to the topic. This accepted view, that SC lacks S-cone input, led to the clever idea of using S-cone–specific stimuli to activate the cerebral cortical visual system independently of the subcortical visual system. This approach was pioneered by Sumner et al, who developed a psychophysical method in humans to define stimuli that activate only S-cones. Sumner and his colleagues used these calibrated S-cone stimuli in human behavioural experiments with the expectation that S-cones would not activate subcortical visual structures, but only activate cerebral cortical structures. They reasoned that this stimulus specificity would allow them to tease apart the roles of cerebral cortical and subcortical areas in perception and higher mental processing. The ability to isolate specific neuronal pathways using targeted physical stimuli is important because it would allow non-invasive interrogation of the functioning of sites of damage in patients with visual deficits. A broad range of phenomena have been tested for dependence on the SC using this kind of approach, including the neural mechanisms of blind sight and interhemispheric transfer of information in patients without a corpus callosum. This influential technique is currently being used in studies of face perception and visual development. Indeed, a full review article promoting this research strategy in humans recently appeared in the literature