A Roadmap to Visual Restoration

Stephen Macknik, PhD

Recent imaging advances and scientific discoveries about circuit maps in the visual cortex have opened new pathways to neuroprosthetics that restore foveal vision. Using precisely targeted optogenetic activation, an optical prosthetic can now focally stimulate spatially localized lateral geniculate nucleus (LGN) synaptic boutons within the primary visual cortex (V1). If we localize a cluster of boutons encoding the same point in visual space, and then transduce photreceptor genes into these neurons so that their synaptic projections within V1 are now sensitive to light, we can stimulate these neurons to create a pattern that mimics naturalistic synaptically-precise every possible visual percept in that single point of visual space. We posit that by creating patterns across the cortical map, we can restore vision at the highest attainable acuity and contrast sensitivity. Optogenetic targeting of these inputs is free from unwanted co-activation of inhibitory neurons (a common problem in electrode-based prosthetic devices, which cannot isolate excitatory from inhibitory activation and thus result in diminished contrast perception). Because prosthetic devices only succeed in driving naturalistic stimulation when they account for rapidly changing cortical activity and response conditions, our system will integrate a real-time cortical read-out mechanism to continually assess and provide feedback to modify stimulation levels, just as the natural visual system does. By tracking eye movements in the patient, we will account for oculomotor effects by adjusting the contemporaneous stimulation of the LGN boutons in real-time to mimic the effects of eye movements on real inputs into V1 in natural vision. This system, called the Optogenetic Brain System (OBServ), is designed to function by optimally activating visual responses in V1 from a fully-implantable coplanar emitter array coupled with a video camera bioluminescent read-out system. As such, the system holds the promise of restoring vision in the blind at the highest attainable acuity, with maximal contrast sensitivity, using an integrated nanophotonic implantable device that receives eye-tracked video input from a head-mounted video camera, using relatively non-invasive prosthetic technology that does not cross the pia mater of the brain.