Neurophilosophy

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Deep brain stimulation could restore vision to the blind

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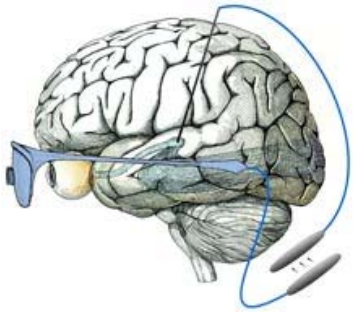
In an advance online publication in the *Proceedings of the National Academy of Sciences*, researchers from Harvard Medical School's Department of Neurobiology show that the perception of single spots of light can be elicited in monkeys by electrical stimulation of a part of the brain called the lateral geniculate nucleus (LGN). Because the new technique completely bypasses the retina, it suggests the possibility of developing neural prostheses that can restore vision to patients with extensive retinal damage due to conditions such as glaucoma, macular degeneration and retinitis pigmentosa. In such patients, conventional retinal implants, which are already in the clinical phase of development, are of little or no use, because they require at least some properly functioning retinal cells.

The LGN is a structure found deep in the brain with the thalamus. It can be thought of as a "relay station" in the visual pathway, because it receives electrical signals about visual stimuli from the eye, via the optic nerve, and then relays them to the primary visual cortex in the occipital lobe of the brain. In the LGN, the visual fields from both eyes are represented somatotopically; that is, the visual scene impinging on the retina is mapped in a straightforward manner onto the LGN tissue, such that adjacent points in the visual field stimulate adjacent LGN neurons. The receptive fields of LGN neurons are similar to those of retinal cells; they are simple and well characterized. Structurally and functionally, the LGN is subdivided into a number of "streams" - the parvocellular and magnocellular pathways. Cells in the former pathway have small cell bodies, and process colour information slowly, while cells in the latter have large cell bodies, process information slowly and do not carry colour information.

Because previous studies have shown that electrical stimulation of the visual cortex in blind people can elicit visual sensations, and because the structure of the LGN is so well characterized, John Pezaris and R. Clay Reid sought to determine whether or not similar sensations could be elicited by stimulation of the LGN. They first trained two adult macaque monkeys to quickly direct their gaze towards points of light presented to them on a computer screen. Individual microelectrodes were then embedded into the LGN through small craniotomies. In response to electrical stimulation applied to specific regions of the LGN, the animals shifted their gaze to the corresponding part of the computer screen. This suggested that the monkeys' visual systems registered spots of light, despite the absence of any external visual stimuli. The researchers then implanted two electrodes in different parts of the LGN, and stimulating one and then the other in quick succession; in response to this, the monkeys quickly turned their heads from one direction to the other. Thus, the electrodes were successfully used to generate artificial visual percepts; from the observed responses of the monkeys, these percepts were indistinguishable from spots of light entering the eye.



The researchers now aim to build a visual prosthetic device consisting of two small digital cameras mounted in the lenses of a special pair of glasses (left). The cameras would gather images and send them to an external signal processor, which would translate the images into electrical impulses and then send them wirelessly to a device that stimulates an electrode array embedded in the LGN. However, the research is still in the early stages, and much work remains to be done before such a device can be developed.

One obstacle is the location of the LGN - it is found deep within the brain and is, compared to the retina, highly inaccessible. Furthermore, in the current study, just two microelectrodes were used to generate activity in the LGN corresponding to two spots of light. This is the equivalent of two pixels on a computer screen. Pezaris and Reid now aim to simultaneously stimulate LGN cells with an array of eight electrodes; this would enable them to elicit the perception of straight lines and other simple shapes. Any such implantable device would, however, require at least a 100-fold increase in the number of electrodes before it would be beneficial. This would enable patients to register patterns in their visual field, but even then the resolution of the image produced by such an array would be very low. Other problems to developing a useful implant are the proximity of neurons in the LGN, the spread of electrical current as it comes out of the tip of the electrode, and the upper limit on the number of electrodes that can be fitted

onto an implant, which is dictated by the size of the electrodes. All of these factors may make it difficult to electrically stimulate individual cells.

Improvements in technologies used for manufacturing microelectrodes will eventually decrease the size of the electrodes; as a result, the maximum number of electrodes that can fit on an implant of a given size will increase. Improvements in neurosurgical techniques will eventually enable the implantation of electrode arrays into the LGN, which could be achieved in humans with only minor modifications to the existing techniques. In recent years, advances have been made in the use of deep brain stimulation for the treatment of conditions such as Parkinson's Disease. This technique, which has proved to be highly successful, involves implanting electrode arrays into a structure called the globus pallidus, or in the thalamus. Both of these targets are very close to the LGN, suggesting that it could be possible to develop devices for implanting into the LGN. This would have at least two advantages over devices designed to be implanted into the visual cortex, which is another avenue being pursued by researchers. Firstly, the structure of the LGN is simpler than that of the visual cortex, so that implantation of an electrode array into the former would be less troublesome than in the latter. Secondly, the representation of visual stimuli in the visual cortex is far more complex than it is in the LGN, such that simulation of the neural activity corresponding to a given visual stimulus would be easier in the LGN than in the visual cortex. So, in principle at least, deep brain stimulation of the LGN seems like a feasible option for the development of a "bionic eye".

Reference:

Pezaris, J. S. & Reid, R. C. (2007). Demonstration of artificial visual percepts generated through thalamic microstimulation. *PNAS* doi: 10:1073/pnas/0608563104. [Abstract]

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