Towards the Artificial Vision – the retina implanting and visual Perception

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Abstract— Artificial vision for the blind was once the stuff of science fiction. But now, a limited form of artificial vision is a reality .Now we are at the beginning of the end of blindness with this type of technology. In an effort to illuminate the perpetually dark world of the blind, researchers are turning to technology. They are investigating several electronic-based strategies designed to bypass various defects or missing links along the brain's image processing pathway and provide some form of artificial sight.

I. INTRODUCTION

Bionic eye,' also called a Bio Electronic eye, is the electronic device that replaces functionality of a part or whole of the eye. It is still at a very early stage in its development, but if successful, it could restore vision to people who have lost sight during their lifetime. A bionic eye work by stimulating nerves, which are activated by electrical impulses. In this case the patient has a small device implanted into the body that can receive radio signals and transmit those signals to nerves.

II. HOW RETINA WORKS

The eye is one of the most amazing organs in the body. To understand how artificial vision is created, it's important to know about the important role that the retina plays in how you see Here is a simple explanation of what happens when you look at an object:

- Scattered light from the object enters through the cornea.
- The light is projected onto the retina.
- The retina sends messages to the brain through the optic nerve.
- The brain interprets what the object is.

In a healthy eye, the rods and cones on the retina convert light into tiny electrochemical impulses that are sent through the optic nerve and into the brain, where they're decoded into images.

The retina is complex in itself. This thin membrane at the back of the eye is a vital part of your ability to see. Its main function is to receive and transmit images to the brain. These are the three main types of cells in the eye that help perform this function:

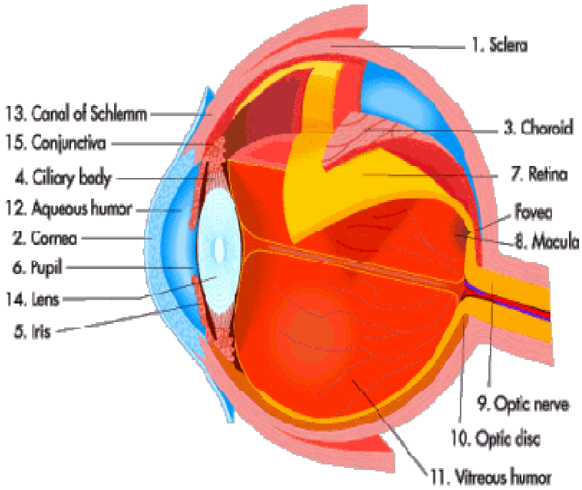

Fig 1. the anatomy of the eye

- Rods
- Cones
- Ganglion Cells

There are about 125 million rods and cones within the retina that act as the eye's photoreceptors. Rods are the most numerous of the two photoreceptors, outnumbering cones 18 to 1. Rods are able to function in low light (they can detect a single photon) and can create black and white images without much light. Once enough light is available (for example, daylight or artificial light in a room), cones give us the ability to see color and detail of objects. Cones are responsible for allowing you to read this report, because they allow us to see at a high resolution.

The information received by the rods and cones are then transmitted to the nearly 1 million ganglion cells in the retina. These ganglion cells interpret the messages from the rods and cones and send the information on to the brain by way of the optic nerve.

III. BLINDNESS

Blindness is more feared by the public than any ailment with the exception of cancer and AIDS.

Blindness is the condition of lacking visual perception due to physiological or neurological factors.

Various scales have been developed to describe the extent of vision loss and define blindness. Total blindness is the complete lack of form and visual light perception and is clinically recorded as NLP, an abbreviation for "no light perception." Blindness is frequently used to describe severe visual impairment with residual vision. Those described as having only light perception have no more sight than the ability to tell light from dark and the general direction of a light source.

A. Causes Of Blindness

There are a number of retinal diseases that attack these cells, which can lead to blindness.

The most notable of these diseases are

- Retinitis Pigmentosa
- Macular Degeneration

Retinitis Pigmentosa

Retinitis Pigmentosa (RP) is the name given to a group of hereditary diseases of the retina of the eye. RP may be caused by a breakdown in the function of the rods or the cones in some part of the retina. The retina is so complex that breakdowns may occur in a variety of ways and so RP is not a single disorder but a great number of disorders. The breakdown of cone function may be called Macular Degeneration.

Macular Degeneration

Macular is a sensitive area in the centre of the retina which provides us with sight in the centre of our field of vision. It allows us to see the fine details when we look directly at something. In macular degeneration, a layer beneath the retina, called the retinal pigment epithelium (RPE), gradually wears out from its lifelong duties of disposing of retinal waste products. A large proportion of macular degeneration cases are age- related.

B. Engineering Of The Bionic Eye

First, for visually impaired people to derive the greatest benefit from an enhanced-vision system, the image must be adapted to their particular blind areas and areas of poor acuity or contrast sensitivity.

The thrust of all prosthetic vision devices is to use an electrode array to give the user perceptions of points of light (phosphenes) that are correlated with the outside world.

Thus, to achieve the expected shift of the image across the stimulating electrode array, the camera capturing the image must follow the wearer's eye or pupil movements by monitoring the front of the eye under infrared (IR) illumination.

The eye-position monitor controls the image camera's orientation. If the main imageacquisition camera is not mounted on the head, compensation for head movement will be needed, as well.

Finally, if a retinal prosthesis is to receive power and signal input from outside the eye via an IR beam entering the pupil, the transmitter must be aligned with the intraocular chip. The beam has two roles: it sends power, and it is pulse-or amplitude modulated to transmit image data. Under the control of eye movement.

C. Bionic Eye Implants

There are two approaches by which we can implant a bionic eye:

- Artificial Silicon Retina – ASR
- Multi-unit Artificial Retina Chipset - MARC

Artificial Silicon Retina(Asr)

The ASR is a silicon chip 2 mm in diameter and 1/1000 inch in thickness. It contains approximately 3,500 microscopic solar cells called "micro photodiodes," each having its own stimulating electrode.

These micro photodiodes are designed to convert the light energy from images into thousands of tiny electrical impulses to stimulate the remaining functional cells of the retina in patients suffering with AMD and RP types of conditions.

Multiple Unit Artificial Retinachipset (Marc)

The other revolutionary bio electronic eye is the MARC; this uses a ccd camera input and a laser beam or rf to transmit the image into the chip present in the retina. Using this, a resolution of 100 pixels is achieved by using a 10x10 array. It consists of a platinum or rubber silicon electrode array placed inside the eye to stimulate the cells.

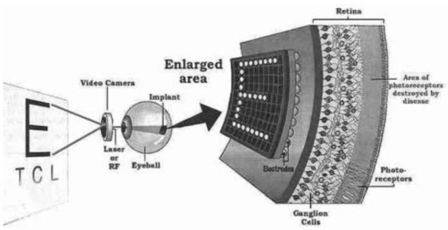

Fig 2 Multi-unit Artificial Retina Chipset

The schematic of the components of the MARC to be implanted consists of a secondary receiving coil mounted in close proximity to the cornea, a power and signal transceiver and processing chip, a stimulation-current driver, and a proposed electrode array fabricated on a material such as silicone rubber thin silicon or polyimide with ribbon cables connecting the devices.

The stimulating electrode array, an example of which is given in the figure below, is mounted on the retina while the power and signal transceiver is mounted in close proximity to the cornea.

An external miniature low-power CMOS camera worn in an eyeglass frame will capture an image and transfer the visual information and power to the intraocular components via RF telemetry.

The intraocular prosthesis will decode the signal and electrically stimulate the retinal neurons through the electrodes in a manner that corresponds to the image acquired by the CMOS Camera.

D. Working Of Bionic Eye

It uses a small video camera-equipped device to capture images, encode them and send them into the eye implant (a silicon chip inserted into the eyeball) via a laser beam that also powers the chip's solar cell.

Photo sensors convert the light and images into electrical impulses,which charge a plate that stimulates the nerves and transmits visual information to the brain. The laser and camera can easily be mounted on eyeglasses without having to wear bulky headgear.

The patient would wear goggles mounted with a small video camera. Light enters the camera, which then sends the image to a wireless wallet-sized computer for processing. The computer transmits this information to an infrared LED screen on the goggles.

The goggles reflect an infrared image into the eye and on to the retinal chip, stimulating photodiodes on the chip. The photodiodes mimic the retinal cells by

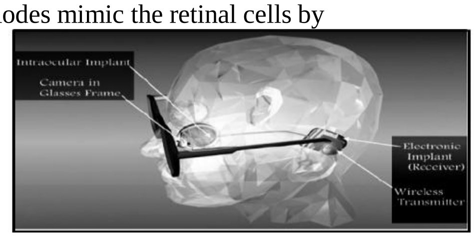

Fig 3. Working of Bionic Eye

converting light into electrical signals, which are then transmitted by cells in the inner retina via nerve pulses to the brain.

The goggles are transparent so if the user still has some vision, they can match that with the new information - the device would cover about 10° of the wearer's field of vision. The device involves a miniature video camera fitted to a pair of glasses.

The camera sends compressed digital images to a bionic implant on the back of the eye. Thousands of tiny electrodes in the bionic chip then stimulate the optic nerve, sending a signal to the visual centre at the back of the brain, where it is translated into an image.

Normal vision begins when light enters and moves through the eye to strike specialized photoreceptor (light-receiving)cells in the retina called rods and cones. These cells convert light signals to electric impulses that are sent to the optic nerve and the brain.

Retinal diseases like age-related macular degeneration and retinitis pigmentosa destroy vision by annihilating these cells. With the artificial retina device, a miniature camera mounted in eyeglasses captures images and wirelessly sends the information to a microprocessor (worn on a belt) that converts the data to an electronic signal and transmits it to a receiver on the eye. The receiver sends the signals through a tiny, thin cable to the microelectrode array, stimulating it to emit pulses.

The artificial retina device thus bypasses defunct photoreceptor cells and transmits electrical signals directly to the retina's remaining viable cells. The pulses travel to the optic nerve and, ultimately, to the brain, which perceives patterns of light and dark spots corresponding to the electrodes stimulated. Patients learn to interpret these visual patterns.

It takes some training for subjects to actually see a tree. At first, they see mostly light and dark spots. But after a while, they learn to interpret what the brain is showing them, and they eventually perceive that pattern of light and dark as a tree. Researchers are already planning a third version that has 1000 electrodes on the retinal implant, which they believe could allow for reading, facial recognition capabilities etc.

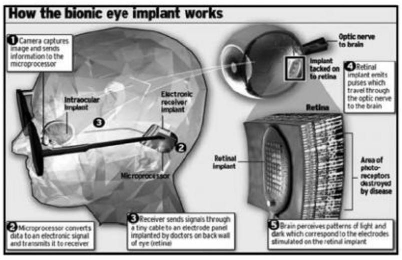

Fig. 4. Implantation of Bionic Eye

E. References

[1] Dowling, J. "Current and Future Prospects for Optoelectronic Retinal Prostheses." Eye 23.10 (2008): 1999-2005. Academic Search Premier.

[2] "Breakthrough Eye Implant Helps 3 Blind Patients See." The Vancouver Providence [British Columbia] 3 Nov. 2010, Final ed. LexisNexis Academic. Web. 27 Jan. 2011

[3] Park, Robert I. "The Bionic Eye: Retinal Prostheses." International Ophthalmology Clinics 44.4 (2004): 139-54. Wolters Kluwer Health. OvidSP, Fall 2004. Web. 26 Jan. 2011. <http://ovidsp.tx.ovid.com>.

[4] Victor Shnayder, Bor-rong Chen, Konrad Lorincz, Thaddeus R. F. Fulford-Jones, and Matt Welsh. "Sensor Networks for Medical Care", Harvard University Technical Report TR-08-05, April 2005.

[5] Anthony's textbook of Anatomy and Physiology -Gary A Thibodeau, Kevin T Patton
Image processing for a high-resolution optoelectronic retinal prosthesis. Asher, A; Segal, WA; Baccus, SA; Yaroslavsky, LP; Palanker, DV; IEEE Transactions on Biomedical Engineering, 54(6): 993-1004 (2007).

[6] Optoelectronic retinal prosthesis: system design and performance. J.D. Loudin, D.M. Simanovskii, K. Vijayraghavan, C.K. Sramek, A.F. Butterwick, P. Huie, G.Y. McLean, and D.V. Palanker. Journal of Neural Engineering, 4: S72–S84 (2007).

[7] High-Resolution Electronic Retinal Prosthesis: Physical Limitations and Design. D. Palanker, A. Vankov, P. Huie, A. Butterwick, I. Chan, M.F. Marmor and M.S. Blumenkranz; Chapter 14 in ARTIFICIAL SIGHT: BASIC RESEARCH,BIOMEDICAL ENGINEERING, AND CLINICAL ADVANCES; M.S. Humayun, J.D. Weiland, G. Chader, E. Greenbaum (Eds.), Springer Series: Biological and Medical Physics, Biomedical Engineering, New York, 2007.

[8] Effect of shape and coating of a subretinal prosthesis on its integration with the retina. A. Butterwick, P. Huie, B.W. Jones, R.E. Marc, M. Marmor, D. Palanker. Experimental Eye Research