The Revival of Vision

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The Human Eye: How Do We See?

Light passes through many layers during the transmission of an image to the brain for visualization (Fig. 1). The cornea is a thin layer on the surface of the eye that protects the pupil and iris, the iris uses two muscles to regulate the size of the pupil, and the pupil controls how much light passes (1). The lens behind the pupil focuses light into a narrow beam onto the back of the eye, the retina. The retina is composed of ten distinct layers of cells, including photoreceptors (rods and cones), ganglion cells, bipolar cells, and nerve fibers. Cones, primarily found in the center of the retina (the “fovea”), are essential for color vision and high resolution vision, while rods, distributed along a much wider range in the retina, are essential for scotopic (dark-adapted) vision and peripheral vision (2). At the very back of the eye is the optic nerve, which connects the retina to the brain via a series of electrical impulses.

Some Causes of Vision Impairment

Cataracts

The lens of the eye often becomes cloudier with age. Because the lens is essential for focusing light, one will perceive a blurry image as a result. This condition, known as a cataract, not only results from aging but also from other eye problems, injuries, radiation, or may even exist from birth (3).

Artificial Eyes

In some severe cases, an eye must be removed because of either a retinoblastoma—cancerous tumor in the eye—or other significant damages. In the past, an artificial eye could be put in place of the enucleated eye, but this would simply be a non-functional placeholder. This practice evolved during the 16th and 17th centuries, and eyes needing to be removed were replaced with glass. In more recent times, prosthetics have governed proper replacements. These are commonly made with either acrylic or cryolite glass; care is given to make the product look similar to the existing eye, specifically with regard to the iris pigment (9). While this is indeed a solution as far as aesthetics are concerned, the more beneficial procedure is not just an optical prosthesis but also a visual prosthesis, both replacing an eye and restoring vision. Retinal stimulation by electrodes helps restore partial vision in cases where photoreceptors or other parts of the retina are damaged, as will be explored in the next section.

Optoelectronics

Electrical stimulation of the retina and other technological approaches have become increasingly researched areas of restoring vision. It is possible to use a series of energized electrodes that can transmit information to the brain through neurons in the eye. These multielectrode devices target the retina, which communicates with the visual cortex; arrays ranging from only 16 electrodes to over 1000 electrodes have been studied, and in these cases the retina perceives not an image but rather a series of dots (10, 11). As shown in Fig. 2, the micro-electrode array is routed to a video
Two different varieties of retinal implants are currently in the stage of clinical trials to determine their safety and effectiveness: subretinal implants and epiretinal implants (12-15). Both cases rely on the fact that—even during degeneration of cells in ARMD or RP—the neural network of the retina stays intact. In other words, the light sensing photoreceptors do not function, but the rest of the visual system still can function (16). For the first type of retinal prosthesis, subretinal, the implant is placed beneath the retina to essentially “replace” photoreceptors (13). In the second type, the implant is placed on the surface of the retina and functions with healthy nerve (ganglion and bipolar) cells. A small video camera captures a light signal and converts the data into an electric signal through a microprocessor, which is transduced across these nerve cells, through the optic nerve, and ultimately to the brain for the creation of an image (14-15, 17). At the same time, this device must be engineered in such a way that it must not disturb the rest of the tissue in the eye, and exist stably in the saline environment of the vitreous (18). The US Food and Drug Administration has not yet approved these devices and methods, but clinical trials still continue to test how well they will potentially function.

Fig. 3, adapted from an article in the Journal of Vision, shows a simulation of the creation of an electron-array image. In short, the electrodes tap enough nerve cells in the eye such that certain fig.s can be outlined, and the clarity of the image reflects how optimum of a device it is. The device worn by the subject is connected to a computer, which processes the image; each phosphore, or spot of light, produced by electrical stimulation, is rendered into the software (7).

People who have tried using this technology find it extremely useful. Though there are only a small number of electrodes compared to the millions of photoreceptors, people can make out a general sense of their surroundings. “They can differentiate a cup from a plate, they know where the door is in their home, and they can tell where the tables are,” according to Dr. Mark Humayun of the Doheny Eye Institute at the University of Southern California (18). Furthermore, the brain can take over and fill in some of the missing pieces of information especially when memory is taken into consideration (19).

Conclusion

Vision, an essential element in the quality of life, brings color to the world and adds multiple dimensions to everything that surrounds us. We have many different surgical procedures for curing different ocular diseases, including cataracts, glaucoma, and myopia (nearsightedness), so why not have ways of restoring the retina? Only further research and clinical trials will determine, with a greater certainty, whether these methods prove effective.

References

11. E. Zrenner, “Restoring neuroretinal function by subretinal microphotodiode arrays” (2007), Speech delivered at ARVO, Fort Lauderdale, USA.