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GUEST EDITORIAL

Bionic eyes: where are we and what does the future hold?

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Restoring sight to the blind is perhaps the greatest dream in the field of sensory physiology. Vision scientists have watched with wonder as the bionic ear has gone from an idea to a functioning device that not only allows people to hear simple sounds but provides high-quality speech perception.[1] Among the vision community, there has been and continues to be in some quarters a rather pessimistic attitude toward the possibility that a similar 'bionic' approach could be feasible for vision. The reasons for this self-doubt are many and are far from unreasonable. The visual system codes a very large array of variables from the visual scene, and the thought that anything more than rudimentary flashes of light could be evoked through electrical stimulation of the retina has been regarded by many as somewhat fanciful. Add to this the problems of dealing with a degenerate retina and the relatively fragile anatomy of the eye and there is little wonder that sceptics abound.

In the last decade, enormous advances have been made in the field of visual bionics. The review article found in this edition by members of Erica Fletcher's research group at The University of Melbourne[2] is a thorough and timely summary of progress to date. The review summarises the patient trials that have been attempted around the world and discusses the highlights and limitations of those studies. The review makes it very clear that while implants have been placed into human patients, the existing devices are still a long way from providing functional vision at a high level. Nonetheless, this pioneering work and the selfless commitment of the first human recipients have done much to push back the boundaries of technology.

The question most often posed to me about the bionic eye is when will it really start working? Given this common question, it is useful to compare progress against other well-known engineering successes. Aviation is perhaps the easiest comparison. The first aeroplane, the Wright flyer, flew a few short metres along a beach in 1903. This achievement is widely toted as a major leap forward, yet in truth the flight was shorter than the flight deck of a modern airliner. Similarly, the first human implants of a bionic eye did not offer the visual equivalent of intercontinental flight—they simply offered the first proof of concept that restoration of sight through electrical stimulation was possible. In the realms of bionic vision, humanity has achieved its first flight.

For a decade after the Wright flyer, the development of aviation was pitifully slow and most often driven by individuals, until a human calamity led to the injection of vast amounts of government research funds. That calamity was World War I and within four short years aircraft went from crude contraptions to sophisticated machines that could reach dizzying heights, manoeuvre like nothing before and bring the pilot home almost every time. The bionic eye is currently sitting on the verge of its great leap forward, much as aviation was prior to WWI. Efforts around the world have seen small groups of scientists trying to raise sufficient research dollars to progress the field. Several companies have been formed and some have already fallen. The Australian effort to build bionic visual technology was substantially boosted by an injection in 2009 of AUD50M from the Federal government, internationally the largest single government contribution. Such initiatives are very welcome and just what the field needs before industry and private venture can take the financial risks involved in developing such a complex device.

Of course, funding targeted at end products limits the basic research that can be done. It goes without saying that the decades of basic research that have led to our current understanding of the eye and visual system is the foundation of the entire bionic eye concept. Unfortunately, what is left to discover still outweighs the progress that has been made, particularly with respect to the discovery of the causes of retinal degeneration.[3] Despite the recent money invested in bionic eye research, it is imperative that basic research in vision continues, not least to inform the continued development of a bionic eye.

What is left to do in bionic eye research? As outlined in this issue by O'Brien and colleagues,[2] there is a great deal that needs to occur. It is an interesting reality that despite nearly a hundred years of 'modern' research on the visual system, we know surprisingly little about what electrical stimulation does to retinal and other visual tissue. Many have used microcurrents to activate parts of the visual system but this has been largely for research-specific purposes, such as establishing the latencies of neural responses.[4] Rarely has the influence of long-term stimulation of the retina in the intact eye been considered. This research is essential to establish the safety of bionic eye devices and the ability for them to remain viable for the lifetime of the patient.

How many electrodes does a bionic eye need to provide functional vision? Currently most devices have relatively few electrodes and those that have many have found it necessary to gang groups of electrodes together to obtain robust signals, thus limiting the number of useful inputs across the retina. The current efforts aim to provide sufficient power to drive many electrodes within safe limits. The development of new materials and fabrication techniques will be key to meeting these challenges.[5] This necessity highlights the multi-disciplinary nature of the research effort required for the bionic eye: for example, materials scientists are just as important as electrical engineers and vision researchers.

What signals should a bionic eye deliver to the retina? This might sound like an odd question to pose. Of course, the visual signals are those available from the world in front of the wearer; however, it is more complex than that. From its earliest stages in the retina, the natural visual system makes complex comparisons between different regions of visual space and constantly adapts to the visual environment to maximise the information content, discarding redundant information and using only those signals useful for visual perception, as for example was shown by Crowder and colleagues.[6] Therefore, we need to understand how to pre-process signals from the visual environment to throw away useless information. This in itself is a huge area of research in the vision field and another area where a range of scientists is getting together to effectively encode the visual signals for a bionic eye. The hope is that with useless information stripped away, the remaining visual system will better adapt to the artificial signals it receives. A good example would be to throw away all the detailed information about the texture of a path and only encode more relevant information such as the boundaries of the path and any obstructions. The development of these encoding strategies is critical for the success of a bionic eye.

In summary, today bionic eyes are a reality;[7,8] however, just as the Wright flyer was the first step toward the sophisticated aircraft of today, the bionic eye devices available today reflect only the initial steps toward a bionic future. A decade from now, bionic eyes will deliver high-fidelity functional vision. As with all areas of technology, development is unlikely to slow for many years to come, particularly once the first highly functional devices start to make money. It will be the norm within just a few decades to be 'bionically assisted'. With aging populations, the need for bionic eyes, ears, arms, legs and numerous other microelectronic prostheses will become commonplace. Indeed, I find it impossible to imagine that bionic devices will not eventually become yet another cosmetic necessity.

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