BILATERAL COCHLEAR IMPLANTATION
under the prism of the 'disruptive technology' concept

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Using the business concept of technology disruption helps us to give a different look on bilateral cochlear implantation and the binaural benefits it provides to users. Applying the concept shows for instance how simultaneous or short delay bilateral CI represents a disruptive technology in the treatment of bilateral deafness since it prevents auditory cortex from reorganisation. Long sequential implant can be considered as a form of technology disruption since users accept and appreciate a lower level of fidelity than the market expects they would require to get the level of benefit they derive. Settling happily with this poorer fidelity demonstrates that the criterion “good enough” is relevant to consider in a cost-efficacy analysis.

In 1997, a book called The Innovator's Dilemma, by Clayton M. Christensen, presented a concept called disruptive technology. Basically, a disruptive technology is a technology that creates a new market and may eventually disrupt an existing market, substituting an earlier technology. The term describes products or services improvements that are not expected by the market, first allowing the market to reach a different set of customers and then lowering prices in the existing market. In his model, Christensen distinguishes between low-end disruption aiming at customers who do not need the top performance valued by customers at the high end of the market.

To have a good understanding of the concept, let's use the example of the cameras. A fancy brand will continue to make a certain model better and better in such a way that performance exceeds the needs of the high-end of the market and of course, the low-end of the market. They continue to progress by improving technology. The company wants its high-end constituted market to approve the products, so that the brand markets fancier cameras.
But one day a cellphone manufacturer put a camera on its devices. The pictures were first pixelated and not of high quality and the high-end cameras market customers did not buy the idea. But the technology continued to improve and the market in general has embraced it more than the camera standard technology, thus provoking a market disruption. The market disruption happened in the camera industry in 2011 where more pictures were taken using cellphones than using cameras.

The disruptive technology model fits well to the health care field

The disruptive technology model may be applied to many things in our life and also fits well to a number of issues that we have in the health care field. For instance, we can apply the concept of disruptive technology to binaural benefits of cochlear implant, looking at speech perception and spatial unmasking in children.

With electroencephalography (EEG), Daniel Wong (1) got real time imaging of the brain in children with cochlear implant. This population cannot undergo MRI because of the CI magnet. The information provided with EEG is the similar to that derived with MRI and allows to compare the cortical electrical activity on both side of the head and thus watch the brain activated by CI.

Bilateral input protects the cortex from unilaterally-driven reorganisation in children who are deaf (2). If you implant simultaneously, you have a normal auditory cortex. With a very short delay between implant, you also have a normal auditory cortex in terms of lateralisation. But if there is a long delay between the implants, you get an abnormal organisation of cortex.

The concept of disruptive technology describes a technology that creates a new market and can knock down, eventually, an existent market while substituting a more ancient technology.
"Bilateral cochlear implantation represents a disruptive technology in the treatment of bilateral deafness."

It will never be normally organised. So by stimulating the auditory system with asymmetric sounds the brain responds by developing asymmetrically. Using this technique allowed us for the first time to see how the brain organises itself when exposed to sound. It means that if part of the brain is not being used, the cost of keeping that part of the brain alive is so high that the brain will use it for something else rather than leaving it dormant. So the area where the auditory cortex was not stimulated are presumably working the visual system or the proprioceptive system instead of the auditory system. And it never will be allocated to the auditory system. That’s one of the reasons why bilateral cochlear implantation should be progressively pursued.

Getting back to the philosophy of disruptive technology and based on the work of Daniel Wong, we can say that simultaneous or near-simultaneous implantation providing symmetric auditory brainstem development is a good thing because it protects auditory cortex from reorganisation. On the contrary, sequential bilateral implantation with a long delay between the two sides allows for asymmetric auditory cortex development that compromises the brain’s ability to binaurally process sound. One would think then that long sequential implantation will not provide as much benefit since the underlying processing system has been so altered. Perhaps this is an outcome that can demonstrate technology disruption.

**Speech perception is a non-sensitive measure of binaural benefit**

Let’s now consider speech perception. In our institution in Toronto, when we compare all the data from our users we see that the benefits in speech perception due to bilateral implantation are initially best in the group that has been near simultaneously implanted. This would support the benefit of near simultaneous and simultaneous implantation and supports the brain imaging data mentioned above. To our surprise however, the benefits almost disappeared after 4 years of bilateral use which meant that any superiority we had predicted in speech perception was not measurable after a long period of use. This was an interesting finding. Interestingly, the most binaural benefit was observed when the two ears were symmetric and the least benefit was observed when there was one ear that performed much better than the other. This effect was small but substantiates the fact that the brain likes to process symmetrical data. In fact there was a direct correlation between performance and the degree of symmetry which demonstrates the degree to which the brain likes to process symmetric data. Using our technology model then would show that for speech and language outcomes, the asymmetric inputs one obtains with long sequential cochlear implants would provide a benefit that was not “good enough”.

**Identifying the source of sound in space**

Next our group looked at a number of patients ability to find sound sources in space using an experimental technique called “spatial guidance” and another one called “localisation”. In these two experiments all the subjects showed some benefit. The children with simultaneous or near simultaneous implants demonstrated near normal results. But here was the big finding: even children with long sequential implantation (and presumably asymmetric processing) showed enough benefit to determine which side of the world the sound source was coming from and this was enough to allow them to turn towards it with their good ear and eyes! It was all they needed. So whereas our experiment (the market) predicted they would not benefit, the constituent user (the consumer) found that the result was far better that “good enough”. The technology disruption had occurred.

Interestingly, a few years ago this data would have made me think that the superiority of simultaneous implantation was the only application of the technology that would make it cost-effective. We were all surprised by the benefit accrued by the children with asymmetric inputs after sequential implantation. Clearly they were getting benefit that far exceeded our prediction based on our (the market) expectations. The user was delighted to just identify the general direction the sound source emanated from. Then the listener could direct the better ear and eyes towards the source and get the speech perception benefit they desired. In practice, children have learned to use their sequentially implanted devices and are some of the most successful children in our program. They love their devices. It allows them to find sound sources and to behave more naturally in the three-dimensional auditory world.

So, in summary, bilateral cochlear implantation represents a disruptive technology in the treatment of bilateral deafness and users appreciate a much lower level of fidelity of sound than we predicted. That means that the criteria “good enough” for benefit must be considered now in the cost-efficacy context.