LEARNING TO LISTEN WITH COCHLEAR IMPLANTS

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I work at the Medical Research Council Institute of Hearing Research (IHR), in Nottingham, which is a government funded organisation where the entire programme of research is based on a theme which we call "the auditory brain" (see Figure 1). This is a somewhat simplified representation of the

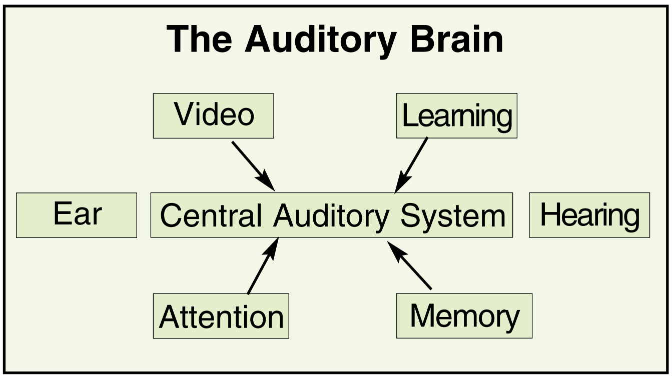

Figure 1

different parts of hearing in which there are four main supporting functions to the primary function of converting sound impulses into nerve signals which are perceived by the brain and which we understand as hearing. First is vision, which for people who are hard of hearing needs little introduction. Obviously, we use lip-reading or speech reading. We have learning, and that is really the basis of what I am going to talk to you about today. We believe that, in addition to our biological and genetic endowment, we learn to listen and we can harness that learning in order to help improve outcomes for cochlear implantation. Attention is terribly important. I'm sure everyone has had the experience of really focusing their attention on one task, such as reading a book, and suddenly losing all contact with the rest of the auditory world. I have put memory down because we know that that also interacts with hearing and of course as we learn words, for example, in our native language, we can access those words from parts of the brain in which they are stored and to do that of course we need our hearing. Now there are other examples of interaction with parts of the brain and at IHR our focus is on trying to understand all these mechanisms.

You will be only too well aware, I am sure, that different people have very different outcomes as a result of cochlear implantation. The question is: Why should that be? I'm going to describe 3 different sets of experiments and research efforts which are trying to understand why we have different outcomes and to hopefully make a difference in the outcomes that we do get from cochlear implantation. The first of these I am going to telling you a little about is our research into language. We are interested in comparing the language capabilities of children who have cochlear implants with those of normal hearing children without and with language difficulties. The second point I'm going to be talking about is spatial hearing, which is much more important than we had previously thought, both in normally hearing as well as hard of hearing people. Spatial hearing is our ability to know whereabouts in space a sound is coming from. But the true gift of spatial hearing is not so much being able to put your finger on where a sound is coming from, but in using the mechanisms we have for spatial hearing to target sounds in an otherwise noisy environment. If you ask anyone, whether they have good or poor hearing, what is the single aspect of hearing that they have most difficulty with, they will tell you it is hearing sounds against noisy backgrounds. Then finally, I am going to have a bit to say about auditory training. This is what I meant when I was introducing the auditory brain concept of learning. We know that if you listen to sounds repeatedly, you get better at hearing those sounds. I think everyone is aware of the benefit that practice can bring to physical activities. What people are less aware of is the benefit that practice can bring to purely sensory activities, like seeing and hearing.

What we are doing at IHR is trying to figure out how we can optimise auditory learning by using different types of training techniques. W are very focused on implementing the results of our research into applications that are useful in the real world.

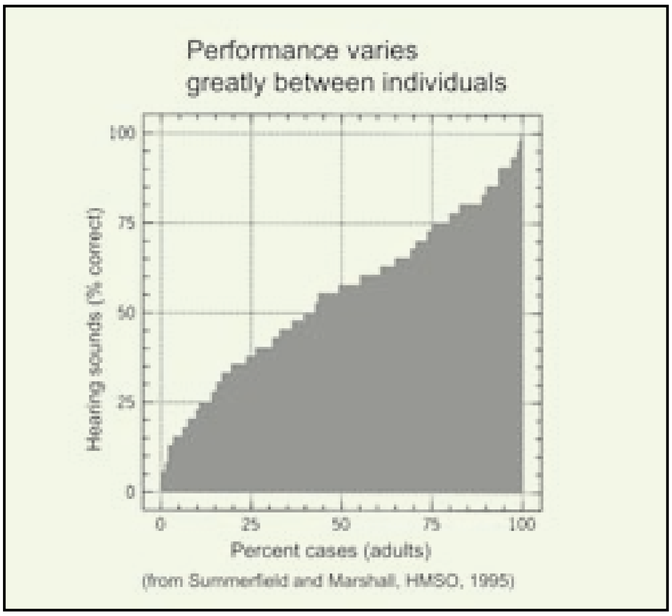

Figure 2

Back to the question of why people have varying outcomes from cochlear implantation, despite advances in surgery and implant design and knowledge about implants. Figure 2 is a graph showing the relationship between hearing and the percentage of cases of implanted people who can hear at each of these different levels. You can see that it is not far off being a straight line, which means that basically half of the people are getting better than 50% correct on this measure of hearing sounds, but half of the people who had cochlear implants were scoring less than 50% correct. There is, in other words, a large proportion of people who are getting rather little benefit from their cochlear implants. What I want to talk about now is some of the limitations and some of the opportunities we have for trying to move these people higher up this curve.

The first subject is **language learning**. By language, here, I mean learning to speak in your native language. Of course, people who are born with profound hearing loss have great difficulties learning to speak. When they receive a cochlear implant, the expectation is that the hearing they receive from their cochlear implant will assist them greatly in learning to speak and this is what we generally find. Of course, in order to learn to speak, you need to be able to hear language or, certainly, it helps a great deal if you do hear language. About 2 years ago, Sue Archbold, working at the Ear Foundation in Nottingham, told me an anecdote that some of the professionals working with the cochlear implant children in the Ear Foundation were reporting that a significant proportion of those children seemed to be having difficulty with language, despite the fact that they seemed to be able to hear alright through the cochlear implant. So we started a study about 18 months ago using two groups of children, a control group, and a group that are called DLI (Disproportionate Language Impairment). This is a term which was coined by our collaborator, Dorothy Bishop (Oxford University), who is probably the leading authority in the UK on language impairments in normally hearing children. What we find is that the implant users who are doing quite well (the 'Control' group) are actually operating at about the level of children with normal hearing who are regarded as specific language impaired (SLI). They are not at the same level as normally hearing children. But the children who are using implants, and who are thought to have a language problem (DLI), are performing much worse again. For each of 4 language tests reviewed, there was a highly significant difference between the performance of the Control and the DLI groups. Why are these data important for us? It had been assumed until we did this study that children who were having difficulties learning language after implantation did so because of some aspect of the implant itself. Either it wasn't working properly, or the surgery hadn't gone well, or the children couldn't learn to use their implants or whatever. What the data suggest, and particularly the comparison between their core performance on the language tests and the good performance on audiograms, is that these children had a predisposition to have poor language, just as some normally hearing children do, and it was only after the cochlear implant was turned on that that problem became apparent.

Bishop and others have done a great deal of research on language impairment in normally hearing children, and that research in the last few years has focused around the genetic basis of SLI. It is now quite clear that, for a variety of language impairments, including SLI that I have mentioned, and dyslexia, which is very well known as difficulties with learning to read, there is a highly significant genetic component. What we would suggest is that the DLI children, who are having difficulty specifically with language following implantation, may well have a genetic predisposition to poor language, just the same as normally hearing children do. So, as we learn more about the genetics of language impairment in normally hearing, SLI and dyslexic children, so we hope we can apply some of the therapeutic techniques that might come out of that research to children who receive cochlear implants and have poor outcomes.

The next subject I want to turn to is **spatial hearing**. This ability is measured by the minimum audible angle (MAA) between two successively presented sources of sound that can be identified as coming from different directions. For a young, normal hearing adult, this can be less than 5 degrees. In the study groups of children researched by Ruth Litovsky and colleagues at the University of Wisconsin (USA), the best group had bilateral implants and achieved a minimum audible angle 15 - 20 degrees. The same children, when they had a single implant, started at a very poor 50 degrees, but improved to 25 degrees a year after implantation. Now it is interesting here, and I think we should bear this in mind when we look at the claims that have been made for bilateral cochlear implantation, that although the scores are poorer than those of the children with bilateral implants, they are not that much worse. More research is needed and is being done, for example, by Litovsky, Quentin Summerfield (York University) and ourselves at IHR. This additional research is focusing more on speech perception against noisy backgrounds. But, based on these interim MAA results, one of the tough decisions that may have to be made is whether the benefits of bilateral implants are worth the cost against a background of NHS economics.

The final thing I want to talk about is **auditory training**, which I have been working on for a number of years now, mostly in the context of trying to understand how it might help normally hearing children improve their language ability. One of the key tasks in this is what is called 'frequency discrimination' where 2 tones, a high pitched one and a lower pitched one, are sounded successively and the listener has to identify which is the high pitch note. The difference in pitch is then varied and reduced until the listener makes mistakes. This is all computer controlled and recorded. Some listeners can perform this task very well and are able to hear about 0.3 % difference between the 2 tones, so if the standard tone is 1000 Hz the target tone would be 1003 Hz. In contrast, a very poor listener might only be able to perform at something like 20%, so the high-pitched tone has to be made 1200 Hz for them to be able to hear the difference. These are results for normal hearing people.

The remarkable thing is that, as these tasks are repeated, there is a training effect and listeners' performance improves over time. Examples show how there can be a 10 fold improvement in just one hour of training. So there is a case for using these sorts of training exercises in the early days after implantation as part of the speech and hearing therapy. A company called MindWeavers, with which I'm associated, has produced a CD of a training game called Phenomena which is proving very popular with children. In this task, the listener has to discriminate phonemes (the building blocks of language) rather than tones. Studies in a primary school in Oxford showed that, over a four week period, the trained group of children improved their age equivalent level on a composite language and literacy test by 2 years compared with an untrained group. This benefit was still apparent when the trained group was retested five weeks after the end of training. What is not known is whether such training benefit is permanent and what would have to be done to make it so if that were possible.

Professor Moore summarised his talk as below in figure 3.

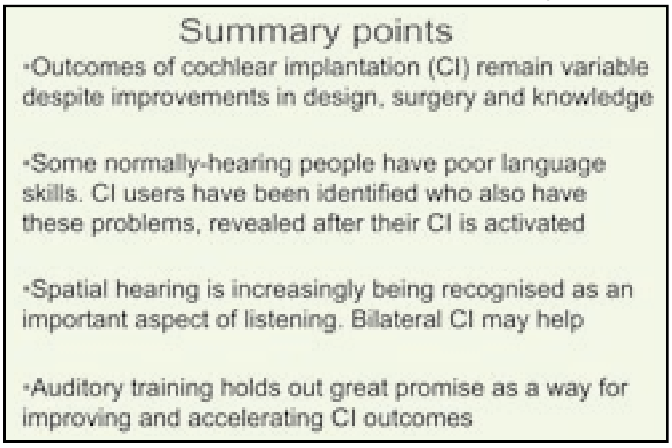

Figure 3