SUPER EARS

Prof. Deniz Başkent

15 April 2014

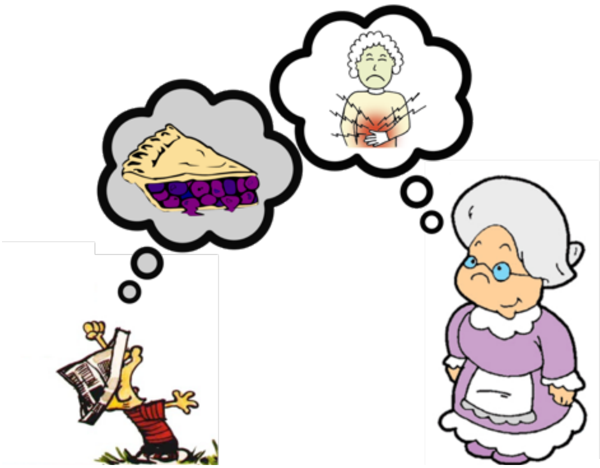
Rede uitgesproken door prof. dr. D. Başkent bij de aanvaarding van het ambt van hoogleraar Auditieve Perceptie bij de afdeling Keel-, Neus en Oorheelkunde van het Universitair Medisch Centrum Groningen, Faculteit Medische Wetenschappen, Rijksuniversiteit Groningen, op 15 april 2014.

INAUGURAL LECTURE

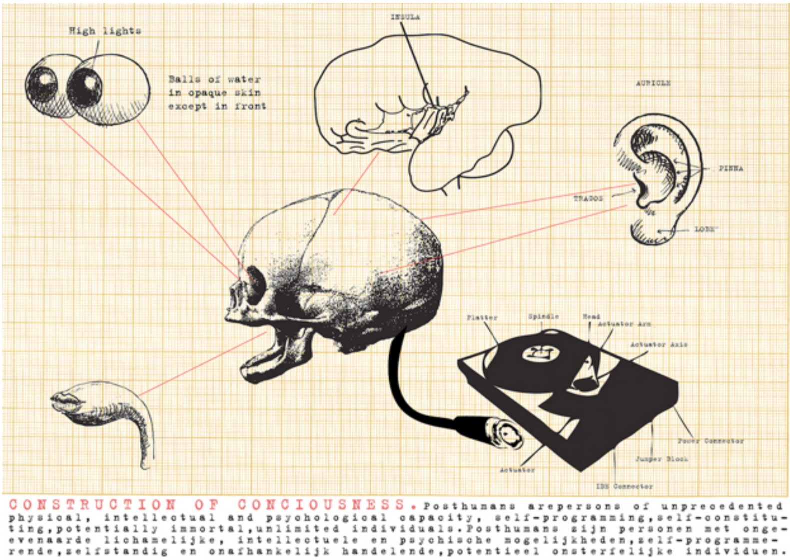
SUPER EARS

Leden van het College van Bestuur,
Geachte aanwezigen,
Αγαπητοί καλεσμένοι,
Değerli konuklar,
Dear guests,

A grandchild asks her grandmother (Slide 1): "Do you want a berry cake?" The grandmother answers: "No, I do not have a belly ache." This misunderstanding could be harmless by itself, and may even be perceived as funny, producing chuckles in a warm family environment. However, when we think about it, there is nothing much funny about hearing impairment. I would like to emphasize here today that hearing impairment can really have serious consequences. And I would also like to present to you what my dream and what my vision is about what I want to do about that.

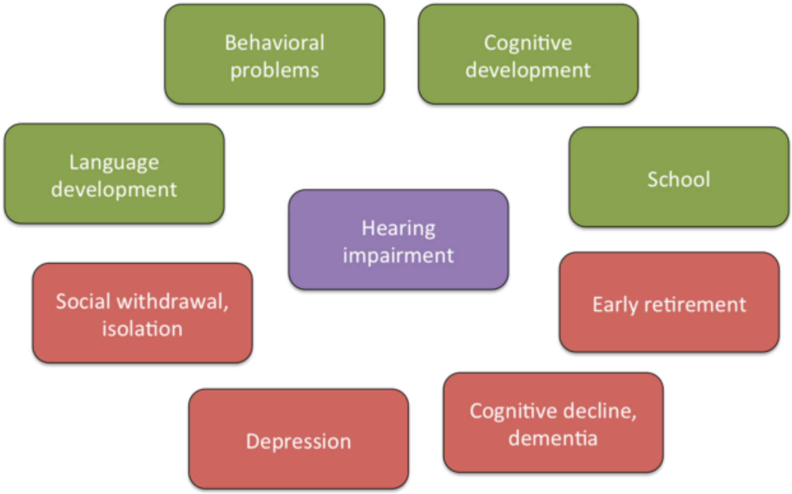


Slide 1



Slide 2: Construction of consciousness, by Jan Vossen.
Creative Commons License.

Hearing is very important for us; hearing is our connection to the outside world, it shapes our consciousness (Slide 2). As a result, hearing impairment is not a simple health problem of sensory deprivation only. Hearing impairment can disrupt oral communication, the very tool that keeps humans connected to each other. Hearing impairment can eventually lead to other negative psychological, mental, social, or societal consequences, affecting the overall quality of life (Slide 3). For adults and older people, for example, if they often find themselves in situations where they misunderstand what they are told to, they may not want to actively communicate anymore (Monzani et al, 2008). They may withdraw from active participation in communication, and in the long term, this social withdrawal may lead to isolation, and perhaps even depression (Kwam et al, 2007). Reduced sensory stimulation can lead to a decline in cognitive functioning, for example, increased possibility of dementia (Lin et al, 2013).



Slide 3: Consequences of hearing impairment can be severe and show in various domains for both hearing-impaired children (upper part, in green), and hearing-impaired adults and older people (lower part, in red).

In addition to negative personal effects, there could also be socio-economic societal effects. Hearing impairment can lead to reduced participation and productivity at work place, for example, due to increased unemployment or early retirement due to disability (Kramer, 2008). In children, language development is largely dependent on interaction with other people, and hearing impairment can delay language development. A child who cannot communicate well can be overly frustrated, which can lead to challenges, for example, which can be perceived as behavioral problems (Theunissen et al, 2014). The lack of sensory stimulation and reduced social interactions can also delay cognitive and social development. A child may present low performance at school, not because of the lack of academic skills, but due to challenges related to hearing impairment. And all of these collectively can affect the opportunities for this child to grow into a healthy and successful young adult.

What I want to do with my research is that I want to increase the quality of life of hearing-impaired individuals. And I want to offer good solutions to hearing impairment. And while at it, why not even create *super ears?*

Slide 4 shows one way of making super ears. Indeed, large pinnae, as shown in the picture, can greatly amplify sounds, and also moving the ears can enhance directional sound perception. In fact, these observations had inspired the idea of implementing this sort of super ear, and led to earlier versions of hearing aids (Slide 5). But what I have in mind is little bit different, more like the one shown in Slide 6. A very sophisticated device that allows you hear very well, to the degree that you feel like a super hero.

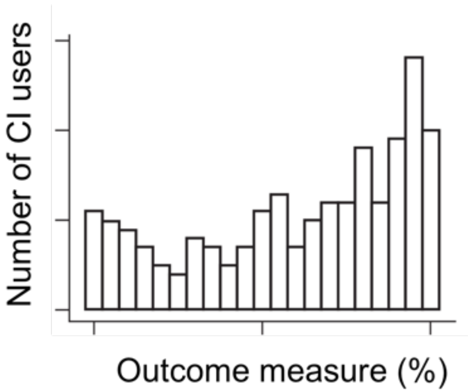
Slide 4: Young kudu with big ears, Lewa Game Park, Kenya. By Kevin Walsh.

Slide 5: A Chase silver ear trumpet, an early version of hearing aids. This device (or a similar version) is rumored to be used by Queen Victoria, who suffered from hearing loss, and used her device to be able to listen to conversations and music performances.
Photo by Ron Case/Keystone/Getty Images.

Slide 6: The Blue Ear comic strip created by Marvel Comics to encourage Anthony Smith, a cochlear-implanted child, to encourage him to wear his device more often.
See the full story here:
https://www.marvel.com/articles/comics/iron-man-introduces-blue-ear

In fact, we do have a device that provides super hearing: cochlear implant. This prosthetic hearing device works well in providing hearing to entirely deaf individuals, by directly stimulating the auditory nerve with electric signals. This is nothing short of a miracle, and I would definitely call it super hearing.

However, the implants do not yet work perfectly. In this talk, I would like to emphasize two main challenges. The first is, the device does not work with equal success for each individual implant user. Slide 7 shows implantation outcome for a large number of implant users, taken from a multicenter cohort study that we also had participated in (Blamey et al, 2013). This figure shows that while a good proportion of users have good speech perception ability with their devices, as measured with speech audiometry (right side), there are still many individual users who show poor speech perception (left side). What causes such large variability in implantation outcome? Why does the device work well for some users, and not so well for others? While some predictive factors are known through similar cohort studies (Blamey et al, 2013), such as the duration of deafness before implantation, there is still a large portion of variability that cannot be easily explained.



Slide 7: Implantation outcome is shown for 2251 cochlear-implant users. There are users with lower (left side) and higher (right side) outcomes. The data were collected in a multicenter cohort study. In addition to UMCG, clinics participated from Netherlands, Australia, France, Canada, England, Switzerland, Belgium, and Poland.
Figure from Blamey et al, 2013.

The second challenge is the sound quality. While the device achieves its most important function, namely providing sound to a deaf person who could not hear otherwise, this sound is far from being perfect. The sounds transmitted to the brain through a cochlear implant are degraded, missing spectral and temporal fine details -- for example, listening to music via a cochlear implant is not a great pleasure for many users, as was reported by our own patients (Fuller et al., 2012). A visual analogue for such degraded auditory signal is shown in Slide 8, a famous example that my PhD advisor prof. dr. Bob Shannon uses in his talks. It will be familiar to some of our guests here. The auditory degradations can be likened to a heavily pixelated image, which is missing a lot of the rich cues. Sound perception through a cochlear implant can be visualized like this. See the figure on the left. If one is deaf and this is the only sound input available, one can still appreciate it. Further, the picture is still recognizable, despite the heavy pixilation. However, only after all rich details are available, one gets the full picture and the high quality. See the figure on the right.

Slide 8: An example of pixilation as a visual analogue of degraded sound quality of electric hearing. From left to right, almost all images are recognizable, yet only the original image on the right provides the rich cues with highest quality.
Image credit: Prof. dr. Bob Shannon.

Now, I not only want to increase the resolution, but I also want to introduce color and movement (Slide 9). This is my dream.

Slide 9: Pixilation example, Calvin and Hobbes. And now with color and dancing the quality is even better.
Image credit:
http://www.fanpop.com/clubs/calvin-and-hobbes/images/318448/title/dancing-photo.

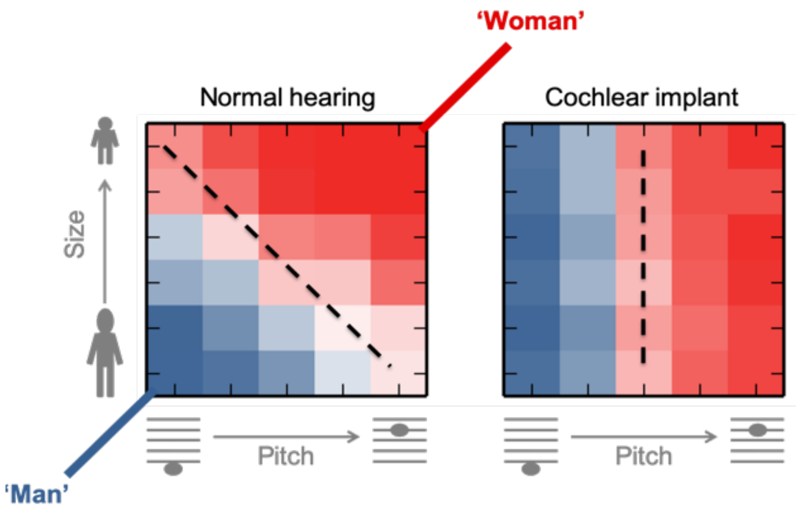
How do I achieve this dream? The world around us, it is very rich in sounds (Slide 10). Hearing is not only picking up the sound from the ear and transmitting it into the brain. It is a more complex process. The brain and the ear have to continually work together to make sense of all these sounds. Which sounds are important (attending), which are relevant (selecting), what is their meaning (interpreting), what response needs to be given (reacting)? As a first step to achieving my dream, we need to start from acknowledging that hearing is a complex process. This complexity requires a sophisticated approach to developing solutions for hearing related problems.

Slide 10: Hearing, from Perception Series. By Didi Wang.
Creative Commons Attribution 3.0 License.
Source: https://www.deviantart.com/ironland/art/perception-hearing-311019486

To achieve that, we have to put all of our forces together and work together. The very first such connection I would suggest is between clinicians and researchers. At many places a clinic and a research lab co-exist. But, sometimes, they simply co-exist. Here, with the clinical team we have been trying to have a strong communication. The reason is that if we do not communicate with the clinic the research we do has the danger of staying as an intellectual exercise only. This may be fine with some research fields. But here we do clinical research. We would really like to keep it relevant. We would like to put our efforts into research questions that are clinically relevant for our patients.

Then, a next suggestion is to talk to the patients themselves. Here our clinical team had the idea of bringing researchers together with the clinic's patients. We organized a great event. During this event, when we were talking with our implant users, they told us about one specific problem they have. They said, even if they can understand what someone is saying, they cannot always say if the person who says it is a man or woman, and this can bother them. When we heard anecdotes like these, we decided to look into it and in a systematic manner too, and this led to a great project (Fuller et al., 2014). We wanted to understand what the underlying problem was causing the difficulties for the implant users understanding the gender of a talker. To do so, we took recorded spoken materials. Using sophisticated tools, we morphed the voice in these spoken words to make it change from a woman (shown with red in Slide 11) to a man (shown with blue in Slide 11). This can be done in two dimensions. You can either change the size of the simulated talker. Men are usually larger than women. When a speaker is large their voice is usually perceived as male and when small as female. Or we can change the voice pitch. A low pitch is usually associated with a man and a high pitch with a woman. The sophistication of the tool comes in this: we can make these changes in one or the other dimension, or both together, while the original utterance remains the same and only the voice changes, producing a large voice map of conditions (Slide 11).

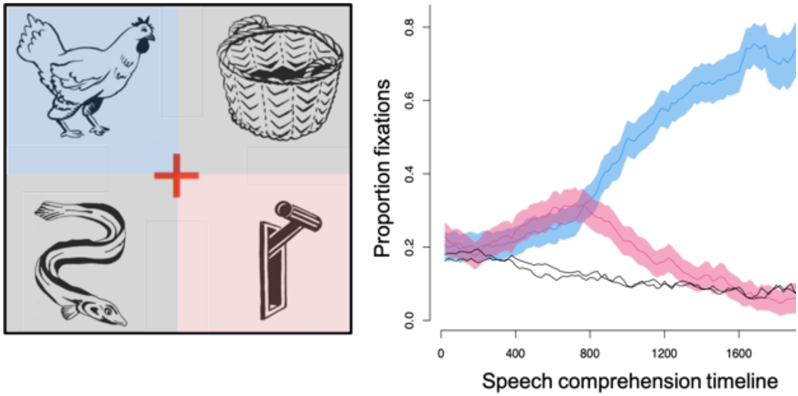
When we did these manipulations, with normal-hearing individuals, we found out that these individuals can use both dimensions of size and pitch easily to make a judgement on the speaker's gender (left panel). There is a clear transition of perceived female voice to a perceived male voice along the diagonal (shown with broken lines). However, when we repeated the experiment with cochlear-implant users, an entirely different pattern emerged (right panel). The transition of perceived voice gender did not happen along the diagonal, but instead it was a vertical line (broken line). What this means is that implant users rely only on one dimension, to make their judgement on the speaker's gender; they only use pitch information and do not take into account size information (later published; Gaudrain and Başkent, 2018). Now that we know the cause of this problem that was brought up by the patients, we have the chance to look into better-fitting solutions. We are now working with companies in an attempt to produce technical solutions to this problem.



Slide 11: Research from our lab was able to identify where the difficulty is coming from in cochlear-implant users' perception of a speaker's gender.
Data adapted from Fuller et al. (2014).

Since the hearing system is a complex one, we need to collaborate also across multiple disciplines. Especially in our research field, when we are working on hearing impairment, and on speech perception, and on hearing devices, we need expertise from a wide range of areas. In our project, we could only achieve these fantastic results by combining expertise from medical sciences, perception, and engineering. Similarly, I would like to give another example of a new research direction, where we heavily rely on expertise from psycholinguistics and psychology to more deeply look into the underlying perceptual processes of speech comprehension. Going back to variations of outcome across implant users (Slide 7), the rightmost data show implant users with highest outcome. But this figure only shows one outcome measure, namely, speech comprehension, how many words the implant user can decipher from speech they have heard. This measure perhaps does not provide a full picture of perception, as it only reflects the end result of speech comprehension; do they understand a word they heard or not? It does not give an insight about how much processing this word comprehension may cost to the implant user.

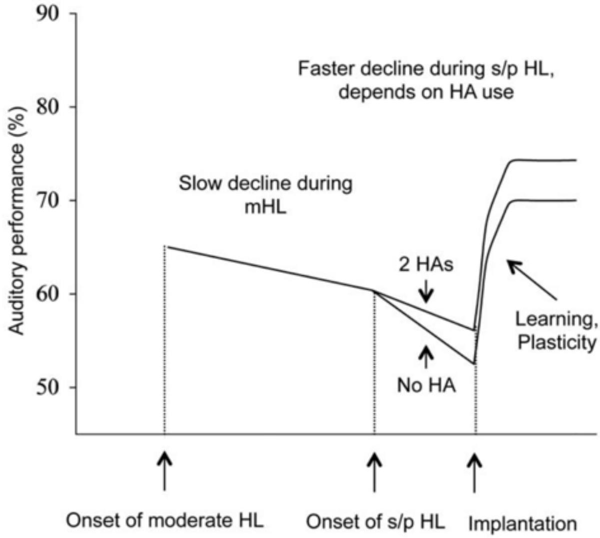
What we now want to do is to go beyond speech audiometry, and look more closely to the brain. How does the brain achieve this speech comprehension? How does the word comprehension evolve over time? To do so, we recently started using eye tracking methods (later published; Wagner et al., 2016).



Slide 12: Research interface for eye tracking study (left), that shows the picture of the target word embedded within three other pictures of non-target words. The results show the time course of speech comprehension (right), with the blue line that represents the eye fixations on the correctly identified target word picture.
Adapted from Wagner et al. (2016).

Here, we play a sentence with a target word in it, while the implant user is looking at four pictures where one of them will correspond to the target word (Slide 12, left panel). When the sentence starts playing and before the target word, the listener does not know which one of the four possibilities is the target word, and the eyes make equal fixations over the four target word picture candidates (shown in initial parts of the eye tracking data, right panel). As soon as the sounds of the target word start becoming available, the proportion of the fixations to the target word picture starts increasing (blue line, right panel), until a decision is made where the proportion of fixations on the target word picture is highest (last parts of the data). While at the end the correct word comprehension is achieved, only the eye tracking data are able to show the actual time course of this comprehension process. Now we want to use these tools to look into comprehension processes across individuals and various listening situations. For example, there could be a situation while clinical speech audiometry may indicate a good outcome, while the actual comprehension process may be effortful for an individual listener, but this cannot yet readily be identified with existing clinical diagnostic tools. Perhaps these individuals will need a rehabilitation route that is better tailored to their needs.

The next point I would like to make about is multicenter studies. And the reason is, our field is relatively small. While worldwide there is a relatively large number of populations, per individual implant center there are often no more than few hundred implant users available for research studies. This is often not sufficient to extract the patterns for how well they are doing with their devices, and how effective and efficient the treatment of hearing impairment is. To have a comprehensive picture, we sometimes have to work together with multiple centers combining our data. And only then some of these patterns become very clear. For this, I would also like to show you an example. These are data compiled from more than 2000 implant users from a large number of implant centers, where we were one of them (Slide 13). Only then the effects of different factors on the auditory performance outcome becomes clear. The model based on large data shows how performance starts decreasing with moderate levels of hearing loss, and the decrease accelerates at profound hearing loss (s/p HL). After implantation performance goes up again. What is new about this figure is that, for the first time, we could see, if someone uses a hearing aid or not (HA) during profound deafness can have an impact on the post-implantation performance levels. This is an interesting finding as these individuals are profoundly deaf. That means that this is difficult group for hearing aid use. It is difficult to find the right hearing aid. Sometimes they are not powerful enough. Maybe some of them would not aid from hearing aids fully given the degree of hearing loss. It may even be that these individuals receive advice against hearing aids if there is no immediate benefit from them. And maybe some individuals may not be able to justify the cost of the hearing aids. These data now imply that even if there seems not much benefit from the hearing aids during profound hearing loss it may still be a good idea to use them as the benefit may show later after implantation. But we need to keep in mind these are results from one study only, and we need to conduct many more multicenter studies to really understand the best treatment options for hearing impaired populations.



Slide 13: Auditory performance outcome model based on 2251 implant users.
Figure from Lazard et al., 2012.

While we do applied research, working with clinicians, patients, and companies, I would like to emphasize that we always need basic science to support applied science. I would like to make this point as I observe a general trend that funding agencies these days really value applied work. There is a desire to see projects where the results can be translated quickly into products and applications. And sometimes basic research is forgotten. In my field, for example, we need tools like auditory models, data from animal physiology, synaptic transmission mechanisms, new approaches such as stem cell research. It may be difficult to see the application now, but when the time comes for application we want to be ready. Only with such support we can make forward steps.

And last, I would like to complete the circle. I would like to also suggest that we work together with industry and institutions. I already mentioned we collaborate with industry. I myself have also worked in a hearing aid company before coming to Groningen to take up this academic position. What I observed is that many people who work in medical companies do really care about the end product and the patients. They are there to make a difference. Some of us work with industry and some of us do not. I observe within academia some researchers are even afraid to work with industry. I would like to suggest that we are not so afraid and instead be open to ideas. There are many advantages to do so. Firstly, this provides a good chance that if there is a good outcome from a product this may be translated into a product faster. Secondly, working with industry we can learn about latest technology which we can incorporate into our research and can support the product-based technology with academic research behind it.

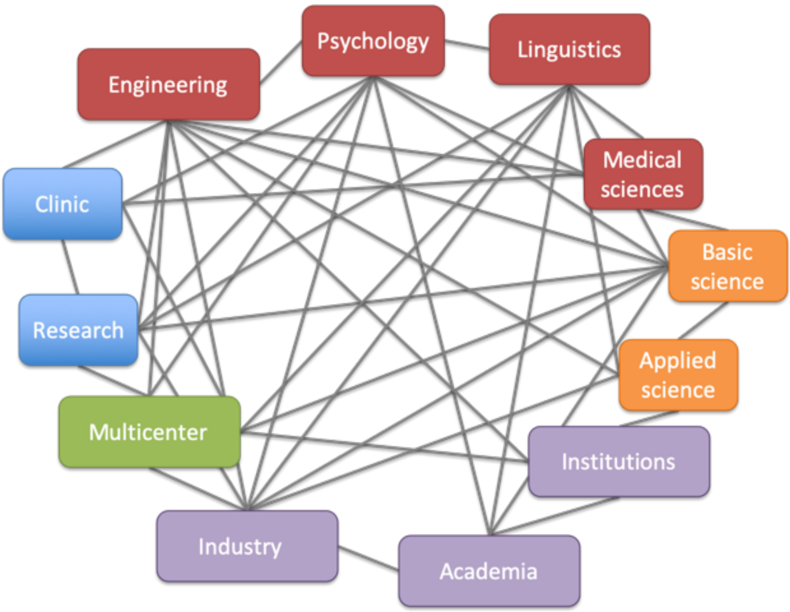
There are also less academic institutions that can provide great collaboration opportunities. In a new project we are working together with a music therapy school (Slide 14), to explore potential therapeutic effects of music in implant users. The reasons for looking at this is two-fold. One comes from recent research that indicates that a person who is musically trained perhaps also has learned to listen better. Perhaps their auditory nervous system has become more sensitive. These advantages may be translated into better comprehension of speech. This motivated us to explore the idea if we musically trained our implant patients if they may also gain advantages in speech perception. But also, second, the few music therapists who have worked with deaf children anecdotally report that even deaf children can enjoy music activities. They also seem to gain confidence and become more social.

We aimed in a new project to systematically explore potential benefits of musical training in implant users, as well as of musical therapy. The difference between the two approaches is that, musical training is a more scientific approach that has been previously and extensively studied. Here the implant user sits in front of a computer and is trained via a computer program. Which can be boring but the method is more scientifically proven. Music therapy, in contrast, can be more fun as it is tailored for implant users.

Slide 14: Music therapy students.

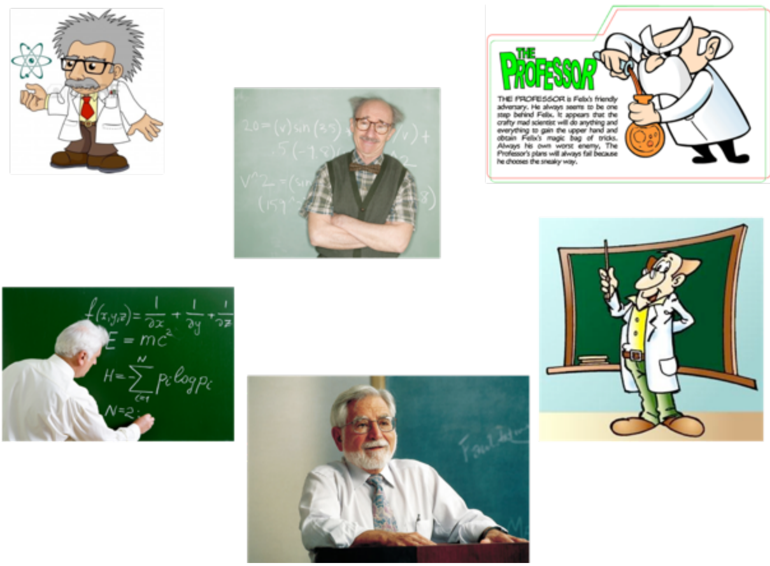
In some fun activities, the implant users make a music train, where they sit in chairs one after another and each person has to follow and contribute to the rhythm that comes from the front and passed on the person behind. All participants of these activities found them fun and they reported to have a good time. However, these methods were not previously investigated with scientific research methods. In our project, we did measure their auditory performance before and after the musical therapy. Their speech perception did not improve, which was disappointing to see. However, we had another interesting finding; the perception of emotions in the voice has become better in the implant users after the therapy. Recognition of vocal emotions is also a challenge for implant users, and therefore it was unexpected but a nice finding, which we would not have come across if we did not work music therapy students. And further, because the implant users really liked the music therapy, they reported that they wanted to listen more, use their device more, they felt more encouraged to listen to music, or even sing together.

This (Slide 15) is basically my vision. This is what I propose, and it is not easy to do, but I think it can be done. I think this is the only way we will achieve the super ears.



Slide 15: Collaborative model of hearing impairment research.

In the last part of my talk, I would also bring up my vision for the academic world. When I had completed the scientific part of my talk, I started thinking about wanting to include something about academic world too. I started by typing the word “professor” in google search, and the first six images that came up were these (Slide 16). You can see the similarities across these six images. According to this search, “The Professor” is always a white man of a certain age with gray hair and gray beard. I thought to myself “this is a starting point.”



Slide 16: Internet search results for “professor”.

Slide 17: Group members, collaborators, and UMCG Rosalind Franklin Fellows (as of 2014).

Because just like what I propose for good science, where diversity is and will be very important, we need also diversity for academic world (Slide 17). We each have weaknesses and strengths, and by complementing each other we will not only achieve super ears, but we will also achieve super academics.

Ik heb gezegd.

Prof. dr. D. Başkent
15 April 2014
Groningen

References

1. Monzani, D, Galeazzi, GM, Genovese, E, Marrara, A, and Martini, A, **2008**. Psychological profile and social behaviour of working adults with mild or moderate hearing loss. *Acta Otorhinolaryngol Ital 28, 61–66.*

2. Kwam, MH, Loeb, M, and Tambs, K, **2007**. Mental health in deaf adults: Symptoms of anxiety and depression among hearing and deaf individuals. *J Deaf Stud Deaf Educ 12, 1–7.*

3. Lin FR, Yaffe K, Xia J, Xue, Q-L, Harris, TB, Purchase-Helzner, E, Satterfield, S, Ayonayon, HN, Ferrucci, L, Simonsick, EM, Health ABC Study Group, **2013**. Hearing loss and cognitive decline in older adults. *JAMA Intern Med 173, 293-299.*

4. Kramer, SE, **2008**. Hearing impairment, work, and vocational enablement. *Int J Audiol 47 Supp2, S124-S130.*

5. Theunissen, SCPM, Rieffe, C, Kouwenberg, M, De Raeve, LJI, Soede, W, Briaire, JJ, and Frijns, JHM, **2014**. Behavioral problems in school-aged hearing-impaired children: the influence of sociodemographic, linguistic, and medical factors. *Eur Child Adolesc Psychiatry 23, 187–196.*

6. Blamey, P, Artieres, F, Başkent, D, et al., **2013**. Factors affecting auditory performance of post-linguistically deaf adults using cochlear implants: an update with 2251 patients. *Audiol Neurotol 18, 36-47.*

7. Fuller, CD, Maat, B, Free, RH, and Başkent, D, **2012**. Musical background not associated with self-perceived hearing performance or speech perception in postlingual cochlear-implant users. *J Acoust Soc Am 132, 1009-1016.*

8. Fuller, CD, Gaudrain, E, Galvin III, JJ, Clarke, JN, Free, RH, Başkent, D, **2014**. Gender categorization is abnormal in cochlear implant users. *J Assoc Res Otolaryn 15, 1037-1048.*

9. Gaudrain, E, and Başkent, D, **2018**. Voice pitch and vocal tract-length discrimination in cochlear implant users. *Ear Hear 39, 226-237.*

10. Wagner, A, Toffanin, P, and Başkent, D, **2016**. The timing and effort of lexical access in natural and degraded speech. *Front Psych 7, 398.*

11. Lazard DS, Vincent C, Venail F, et al., **2012**. Pre-, per- and postoperative factors affecting performance of postlinguistically deaf adults using cochlear implants: A new conceptual model over time. *PLoS ONE 7, e48739.*