Measuring and reducing listening effort…..

The recent research

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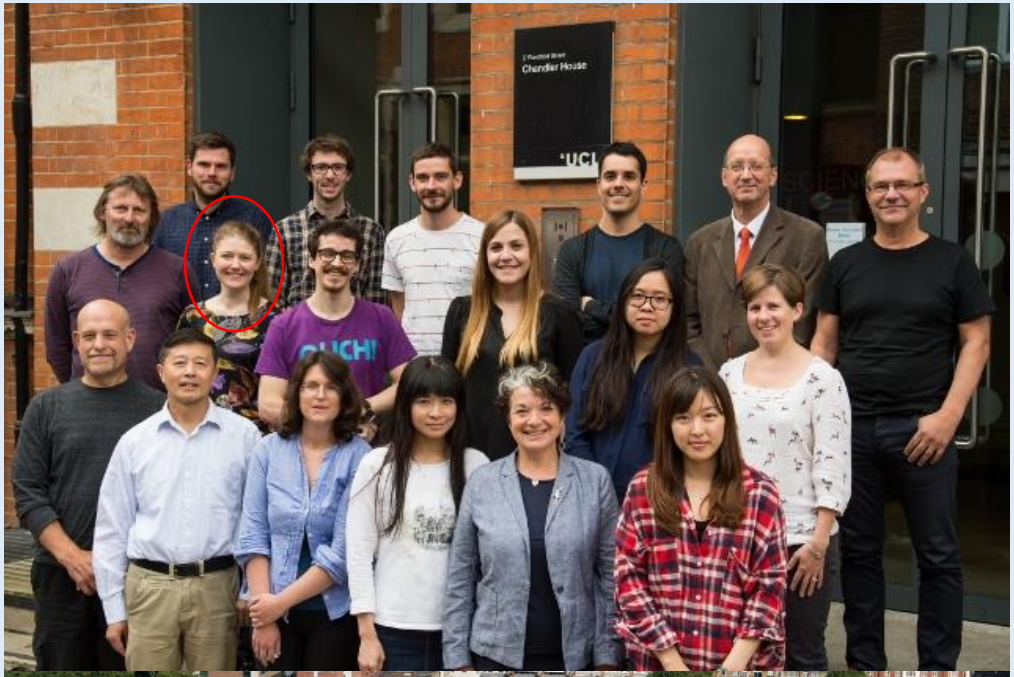
- My name is Helen Willis.
- I was completely deafened by meningitis as a toddler.
- I had a cochlear implant operation at the age of three (23 years ago).

- In 2014, I graduated from Oxford University (St. John’s College) with a First Class honours degree in Physiology and Psychology and an MSc in Neuroscience.

- I am now at the Department of Speech, Hearing and Phonetic Sciences at University College London, in the final year of my PhD.

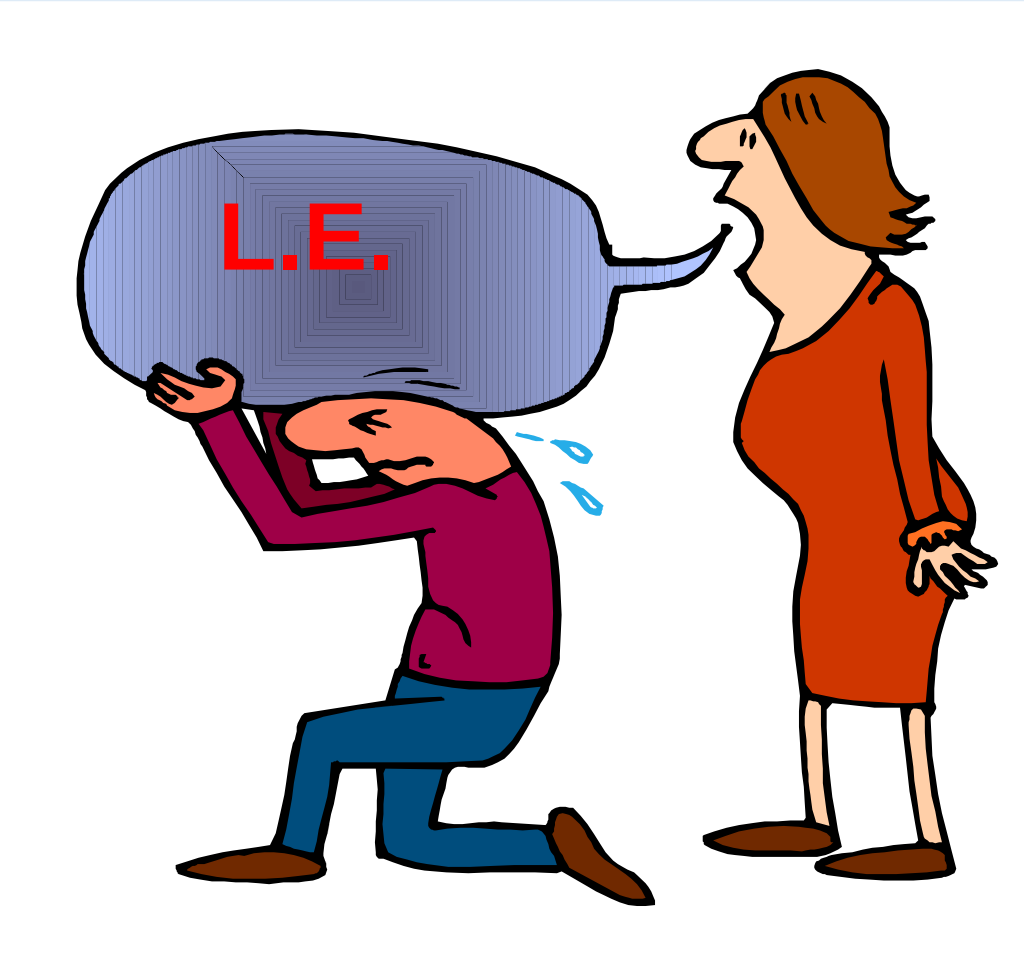


- My PhD studentship is jointly funded by *Action On Hearing Loss* and *Cochlear UK*.

- I am trying to develop the **basis** of a **new clinical test** that is able to measure **listening effort**.

What is listening effort?

- So, **<u>what</u>** is **listening effort?**
- Listening effort is the amount of resources the brain uses in order to process sound.
- Listening effort starts the second you begin to listen.
- If you make listening conditions challenging, more listening effort is needed to cope and succeed in auditory perception.



- The world is a noisy place, so there are constantly challenging listening conditions that we have to cope with.

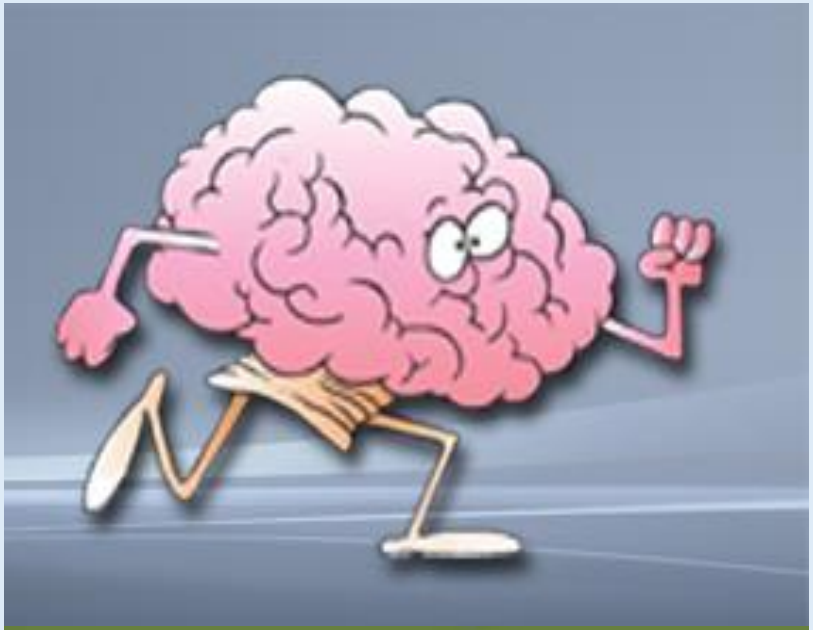
- So, listening in everyday life becomes a marathon (even if you have got unimpaired normal hearing)…..

- Now consider the case of a deaf child. Even with the best of technologies and support, their hearing is never fully restored.

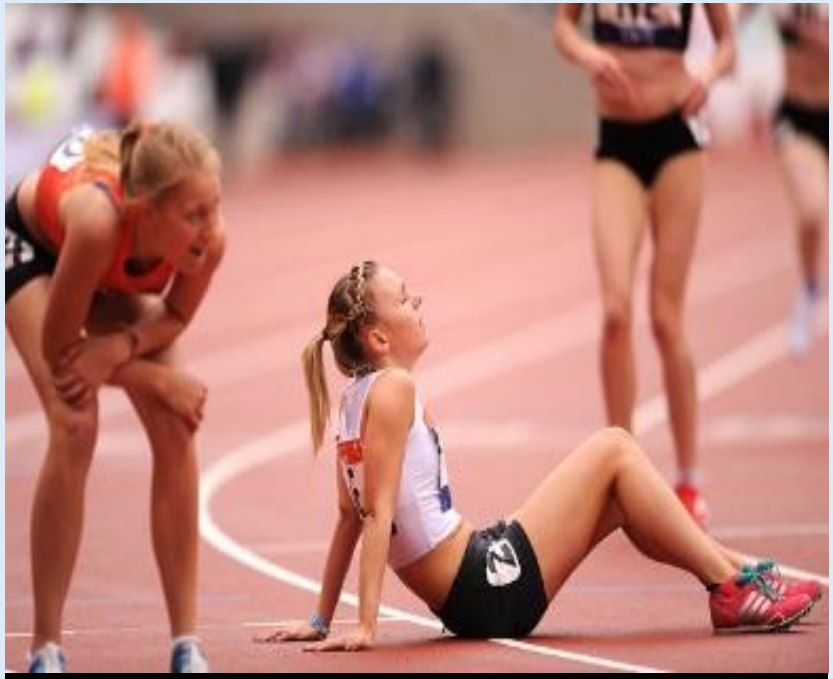
- This means that there is a continuous challenge in everyday listening that should not be there.

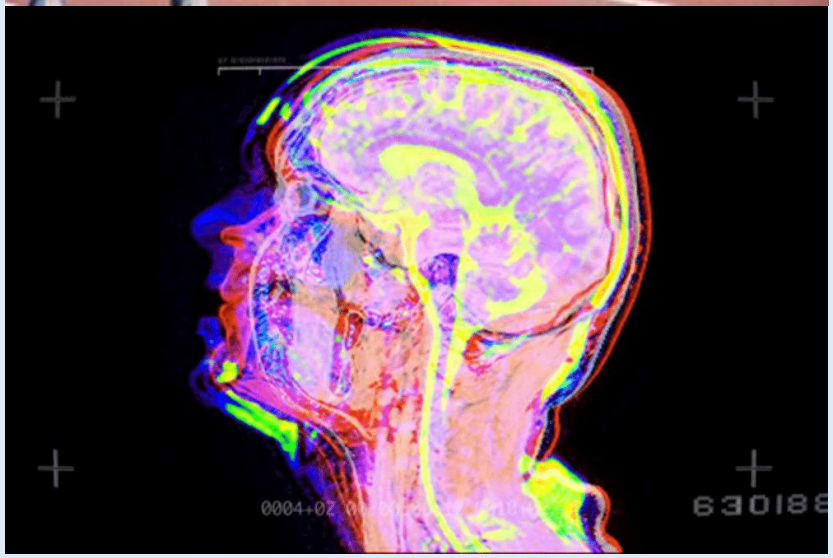
- Put on top of this the typical chaotic and noisy world of sound, it becomes all the more demanding to cope and to try to succeed in understanding.

- Thinking in this way, it becomes quite appropriate to think of deaf children as mental athletes, enduring the marathon that is everyday listening.



- Like athletes at the end of a marathon, deaf children are more likely to become **<u>fatigued</u>** at the end of a day of listening.
- However, unlike the athletes, deaf children do not necessarily have the essential time, or opportunity, to recover from the marathon.
- If anything, life is a constant never-ending listening marathon.
- It is only really now that auditory neuroscience research is beginning to explore the consequences of being in this eternal listening marathon.





• It is important to acknowledge that **listening effort** is a natural consequence of listening and is not a problem…… until the brain becomes **overtired**.

• Worryingly, this state of over-tiredness is very likely to occur during the school day.

• This has a wide range of “knock-on” effects that are only just beginning to be recognised as being a direct consequence of **excessive** **listening effort**.

- For example, the NDCS published an article in their *Winter 2016* magazine about listening fatigue in the classroom.

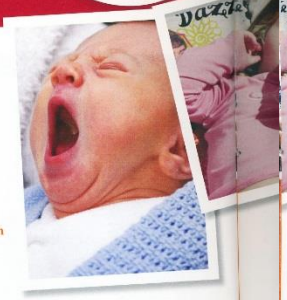
- This article illustrated the behavioural consequences of **listening effort** very well indeed……

- What was particularly **compelling** in this article were the **case studies**……..

How do I...?

...help my child cope with tiredness?

Deaf children are often more prone to tiredness and this can have an effect on behaviour and concentration. Here, four parents share their tips on how to manage tiredness.



Jenni is mum to Harry (5) who has moderate to severe hearing loss and wears hearing aids in both ears.

"As Harry has got older the main effects of tiredness are not paying attention or listening, being cheeky and general grumpiness. He can also be a little over-sensitive and get upset over little things that wouldn't normally bother him.

After school-related issues were ruled out, I started to think he may just be exhausted after the school day. There's a boy in his class who often prefers to eat lunch in a quiet classroom and if Harry's having a bad day he sometimes enjoys eating lunch with him. It gives him a little time out.

One day, on the walk home, he was being really difficult so I told him when we got home he had to go to his room for 10 minutes and think about his behaviour, and it seems to have done the trick! Most days he tells me he's going to his bedroom for 10–20 minutes to, as he calls it, 'chill out'. Sometimes he'll take his hearing aids off, sometimes not. When he's ready to come downstairs he's perked right up and is back to his usual happy self. A little bit of time out works wonders for him and it's made the world of difference to both our lives.

Every child is different but take note of what times of the day problems are arising and see if there's a pattern. And I'd definitely recommend some quiet time after a busy day. It's easy to forget how tiresome a day can be for a deaf child."

Harry

Samantha is mum to Olivia (13) and Harvey (12). Harvey is profoundly deaf in both ears and has bilateral cochlear implants.

"Harvey's teachers at primary school noticed he would make clicking noises and other sounds in afternoon lessons. Sometimes he'd engage in silly behaviour and be easily distracted. His Teacher of the Deaf thought it was due to listening fatigue (which can also be referred to as concentration fatigue), with the effort of listening and lip-reading becoming too much for him towards the end of the school day. I researched it and it all made sense: the behaviours were more noticeable in lessons where he wasn't supported, wasn't fully engaged or didn't enjoy it as much.

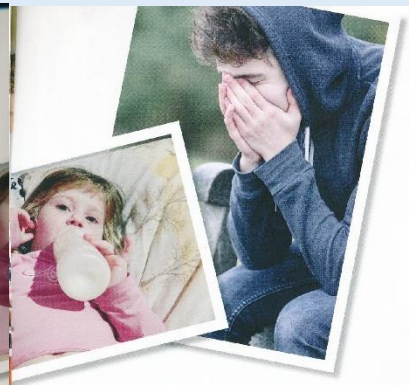
These actions were simply Harvey's way of staying alert while his brain was frantically trying to fill in the gaps of what he couldn't hear. Harvey now attends a local mainstream secondary school and has a one-to-one learning support assistant (LSA). Mainstream schools often have limited experience of deafness and may not have heard of listening fatigue and it can be a challenge for parents to educate staff so that their child gets the appropriate level of support.

Harvey now has an Education, Health and Care (EHC) plan which includes strategies to bring Harvey's attention to his noises and behaviours so he can take control and stop them. This usually works but if he continues the LSA can allow him to read for 5–10 minutes or have a short break. They can also take him out of the classroom and continue the lesson somewhere quieter. He attends a really supportive school and is doing really well now."

Harvey

Join our family panel

Next time in *Families* magazine: **"How do I... support my child to travel independently?"**
If you have any tips, advice or suggestions to share, get in touch at **magazine@ndcs.org.uk**.



Melanie is mum to James (23), Alex (18) and Jack (17). Jack has a fluctuating hearing loss ranging from moderate to profound and wears a hearing aid in his right ear.

"Jack's hearing impairment got worse three years ago. He went to bed with his usual level of deafness and woke up the next day completely deaf in his left ear. He mainly copes with tiredness by having frequent communication breaks where he takes himself off to his room for some downtime. Obviously this isn't possible at school, so he's particularly tired when he gets home. This makes homework/coursework and/or studying for exams a very stressful time. The stress often then impacts on his general health which has a further impact on his tiredness. When he's tired he gets very emotional, confrontational and angry.

I help Jack break up his homework and studying into manageable chunks and timetable it with lots of breaks in between. I sit with him while he's working to help him stay on task but I let him lead the timetabling process so it's manageable for him. I encourage alone downtime, but I always make sure he knows I'm here for him if he needs to shout, scream, cry or vent his frustrations."

Jack

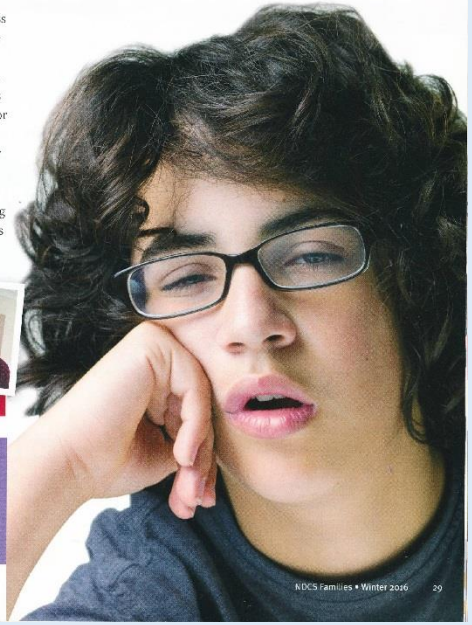
Lucy is mum to Edward (12) and Emily (9). Emily has moderate to severe hearing loss, wears hearing aids and uses a radio aid and a soundfield system.

"Emily is always tired, especially on school days, so we limit after-school activities. Days out are planned in advance and quiet time is factored in.

Sometimes she wants to take her hearing aids off and not do anything. More often she becomes emotional and frustrated and hates deafness. Let your child have a break from their hearing aids when they choose. This shows them that they are in control, not their deafness. If your child doesn't like too much noise check your holiday destination – once we made the mistake of going to a seaside that was too noisy and Emily became exhausted.

Tell them it's okay to be tired and if they become frustrated stop whatever you were doing, hug them and ask what's making them feel that way. Let them take out their frustration on bubble wrap or rip up paper with them and soon the frustration may turn into laughter."

Emily



For more information and tips on how to manage tiredness in deaf children see **www.ndcs.org.uk/tired**.

To find out more about EHC plans visit **www.ndcs.org.uk/SEN**.

- In one case, **listening effort** had such an impact that a 12 year old boy had developed a tic……

Samantha is mum to Olivia (13) and Harvey (12). Harvey is profoundly deaf in both ears and has bilateral cochlear implants.

"Harvey's teachers at primary school noticed he would make clicking noises and other sounds in afternoon lessons. Sometimes he'd engage in silly behaviour and be easily distracted. His Teacher of the Deaf thought it was due to listening fatigue (which can also be referred to as concentration fatigue), with the effort of listening and lip-reading becoming too much for him towards the end of the school day. I researched it and it all made sense: the behaviours were more noticeable in lessons where he wasn't supported, wasn't fully engaged or didn't enjoy it as much.

These actions were simply Harvey's way of staying alert while his brain was frantically trying to fill in the gaps of what he couldn't hear. Harvey now attends a local mainstream secondary school and has a one-to-one learning support assistant (LSA). Mainstream schools often have limited experience of deafness and may not have heard of listening fatigue and it can be a challenge for parents to educate staff so that their child gets the appropriate level of support.

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“Harvey’s teachers at primary school noticed he would make clicking noises and other sounds in afternoon lessons. Sometimes he’d engage in silly behaviour

These actions were simply Harvey’s way of staying alert while his brain was frantically trying to fill in the gaps of what he couldn’t hear.

- **Listening effort** was so overwhelming for a 17 year old boy that he became confrontational and angry, needing to scream and shout……

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Jack

The stress often then impacts on his general health which has a further impact on his tiredness. When he's tired he gets very emotional, confrontational and angry.

I encourage alone downtime, but I always make sure he knows I'm here for him if he needs to shout, scream, cry or vent his frustrations.

- **Listening effort** was so unbearable for a 9 year old girl that she had to take off her hearing aids and just rest…….

Lucy is mum to Edward (12) and Emily (9). Emily has moderate to severe hearing loss, wears hearing aids and uses a radio aid and a soundfield system.

"Emily is always tired, especially on school days, so we limit after-school activities. Days out are planned in advance and quiet time is factored in.

Sometimes she wants to take her hearing aids off and not do anything. More often she becomes emotional and frustrated and hates deafness. Let your child have a break from their hearing aids when they choose. This shows them that they are in control, not their deafness. If your child doesn't like too much noise check your holiday destination – once we made the mistake of going to a seaside that was too noisy and Emily became exhausted.

Tell them it's okay to be tired and if they become frustrated stop whatever you were doing, hug them and ask what's making them feel that way. Let them take out their frustration on bubble wrap or rip up paper with them and soon the frustration may turn into laughter."

Emily

Sometimes she wants to take her hearing aids off and not do anything. More often she becomes emotional and frustrated and hates deafness. Let your child have a break

- **Listening effort** had become so overpowering for a 5 year old boy that he had actually turned a punishment into a source of refuge.
- He was sent to his room to think about his misbehaviour.
- The resulting isolation and peace of being alone in a quiet room was precisely what he needed to escape **listening effort**.
- So he now asks repeatedly to go to his bedroom immediately he comes home from school….

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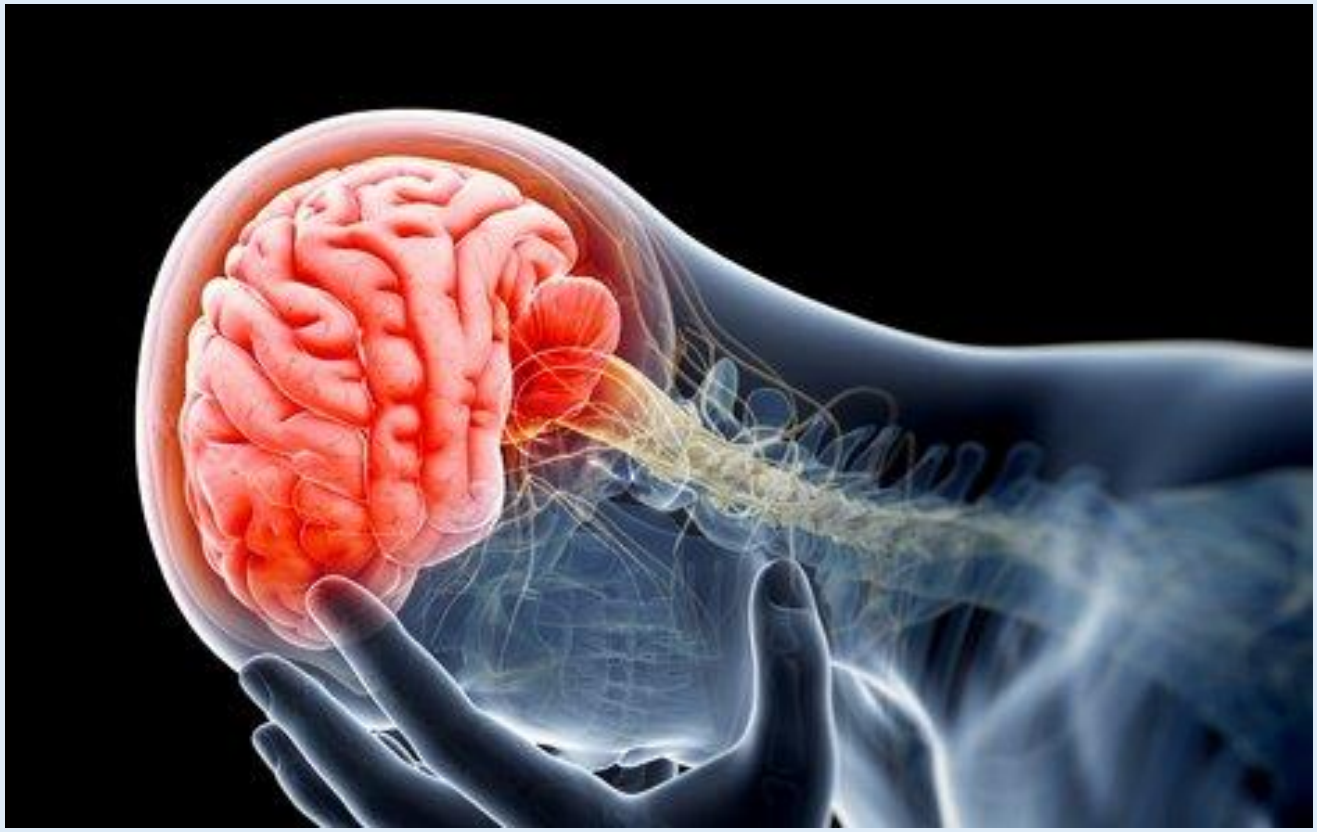
• So, it is being acknowledged that **excessive listening effort** has a direct negative influence on the child's behaviour and ability to manage school work.

- However, the implications of **listening effort** go beyond this……
- New research into **listening effort** is revealing alarming findings.
- The most alarming of all is that not only does **excessive listening effort** lead to over-tiredness, it also has negative consequences for both **physical** and **mental health.**



- These health consequences happen ultimately because the brain has become overwhelmed and has run out of **cognitive** resources to process the outside world, in order to respond to it and cope with it.

- So, **excessive** **listening effort** needs a health warning……

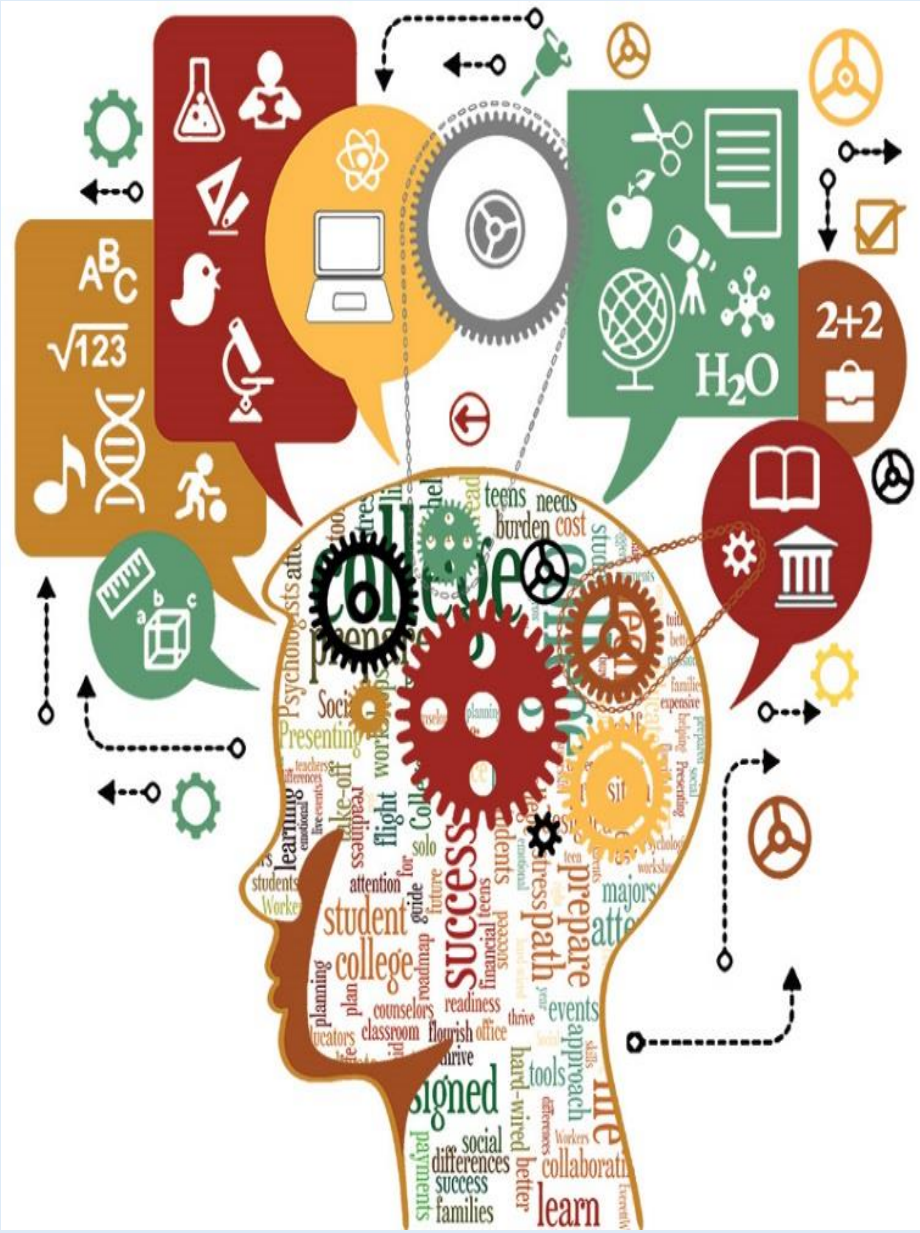
- Unfortunately, this is simply **not** being generally ***accepted***, or sufficiently ***recognised***.

• It may be that the effects of **listening effort** have not been quite so obvious before, because the technology has only recently (over the past 20-25 years) become sufficiently sophisticated to enable deaf children to "successfully" enter the hearing world …….

• Having done so, the deaf children are now being encouraged (and expected) to perform on an equal basis to their hearing peers.

• The majority of deaf children are now routinely mainstreamed where they become more likely to be exposed to **excessive** levels of **listening effort**.

• The negative effects of **listening effort** accumulate over time, so it only becomes more obvious as the child is exposed over a longer and longer period of time, as well as being required to carry out increasingly complicated **cognitive** processing, as the academic curriculum becomes more complex as they progress through school (from primary to secondary).



• More deaf adults are also now accessing Higher Education……

….. where this problem can only be made worse as the **cognitive** demands of processing academic information are combined with the increased exposure to excessive **listening effort**.

• Ironically, the problems of **listening effort** had occurred as a direct consequence of being given “equal” access to the hearing world through the increasing range and sophistication of assistive listening technologies

…..along with constantly increasing expectations of success in hearing outcomes and academic achievement for deaf children and young deaf adults.

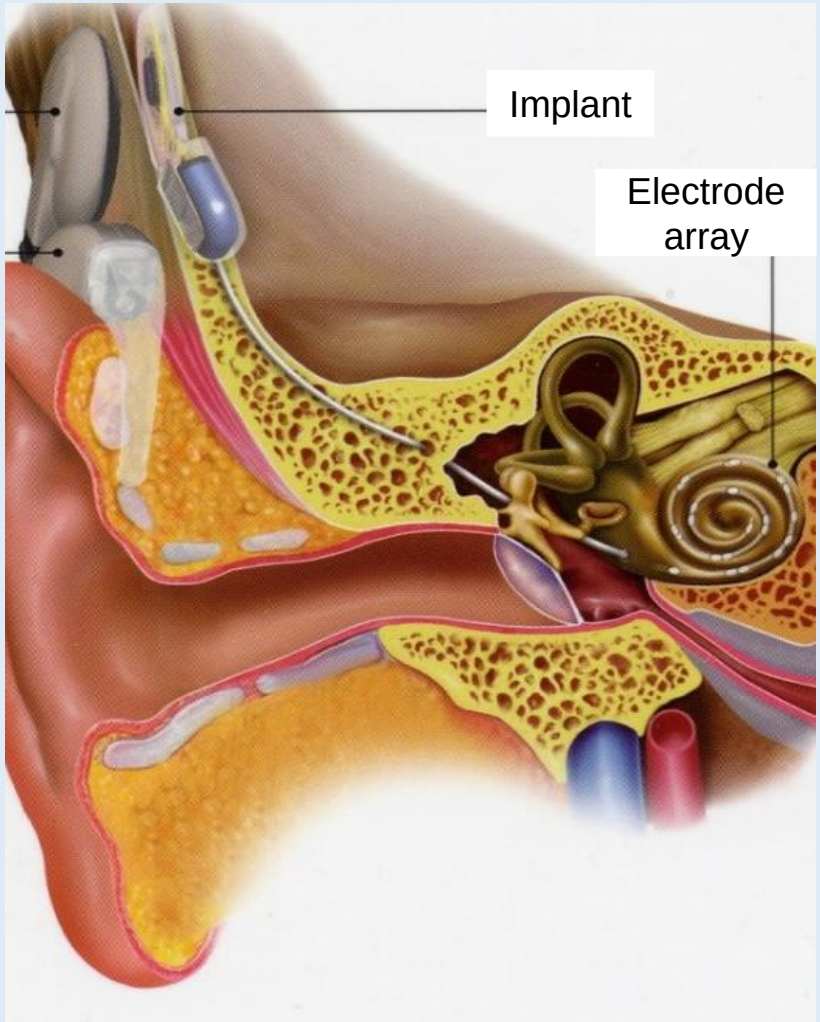
• One of the reasons for the high expectations for hearing outcomes is the high level of faith in the ability of the technology to change deaf individuals into hearing individuals, functioning on an equal basis with their hearing peers.

• It is easy to say that, if you can sufficiently compensate for the hearing difficulties (through, for example, bilateral cochlear implantation at a very early age), then all of these consequences of **listening effort** would not be an issue.

- But there is a need for a reality check at this point…

- For example, in the case of bilateral cochlear implantation, we need to ask this:

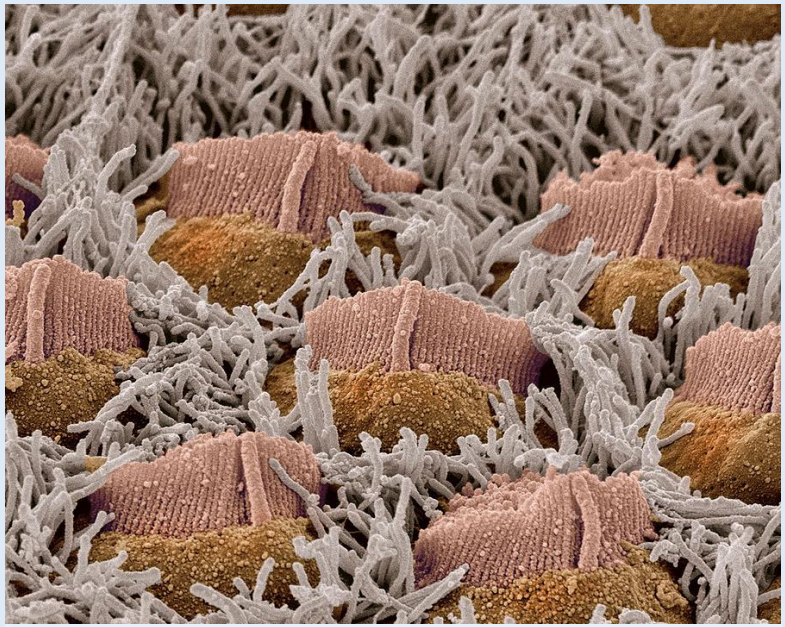
“What can the cochlear implant actually do?”



- There are only ***20-22*** electrodes per cochlear implant to replace functions that were originally taken care of by ***30,000*** hair cells.

- As a result, there will be gaps in the auditory information the cochlear implant provides.

- The brain is able to compensate for these gaps very well, using extra clues available from the outside world (such as visual cues) as well as extra processing (for example, using prior knowledge and experience) to fill in the gaps, leading to excellent outcomes



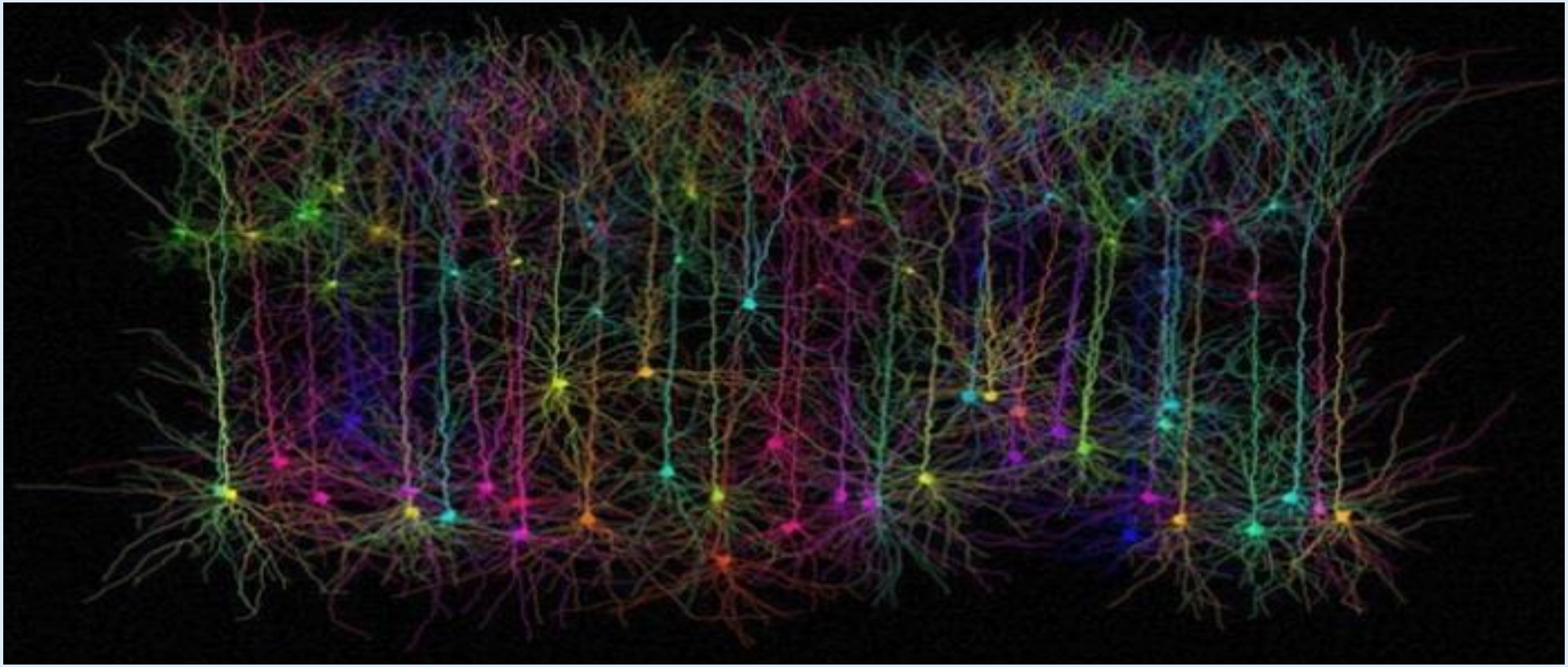
……but at a **cost**.

• This cost is **increased listening effort.**

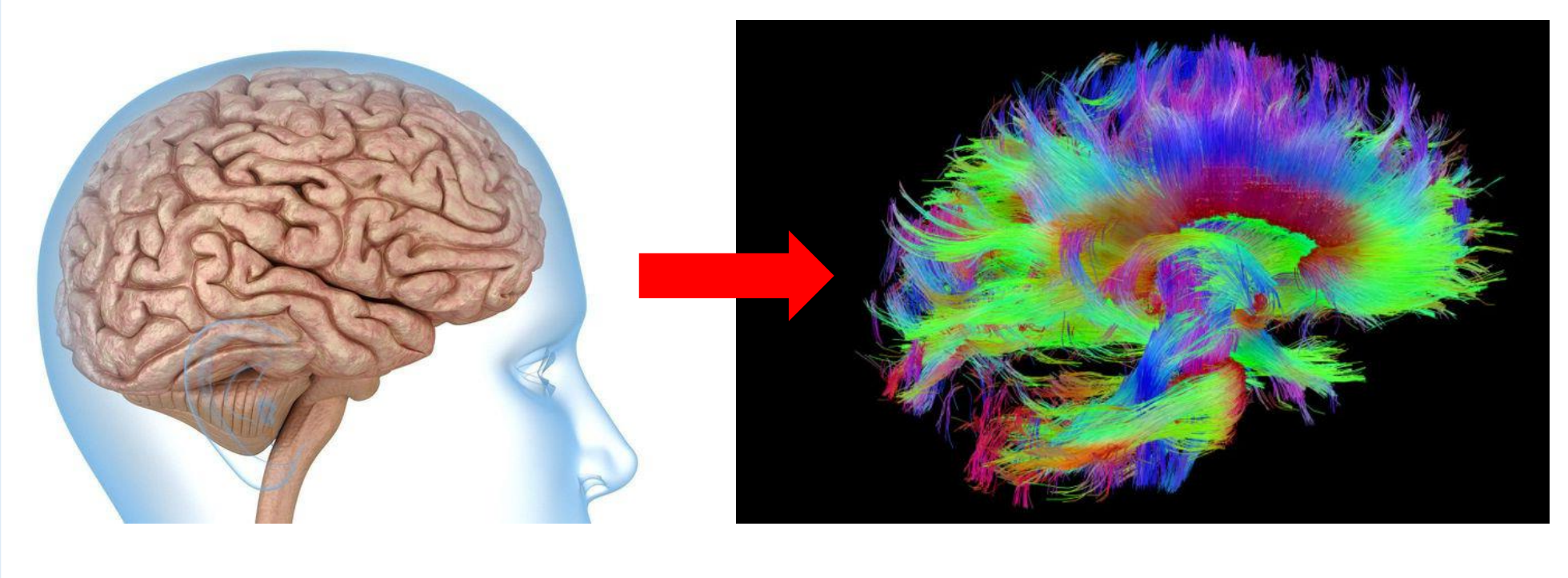
• There is no way round it, because of the need to compensate for the missing information.

- Even the most successful user of the cochlear implants (or the best technology) is still in danger of experiencing **excessive listening effort** in their daily lives.
- They may be unaware of it, but it will be happening.

- This issue of **listening effort** becomes even more worrying when you think about the fact that the brain is a “connectome”.
- The **connectome** is the complete “**map**” of the connections made between all the brain cells in the brain.



- There are **100 billion** neurons ***(100, 000,000,000)*** and around **700 trillion** connections ***(700, 000,000,000,000)*** in the human brain……
  a truly breathtakingly number.



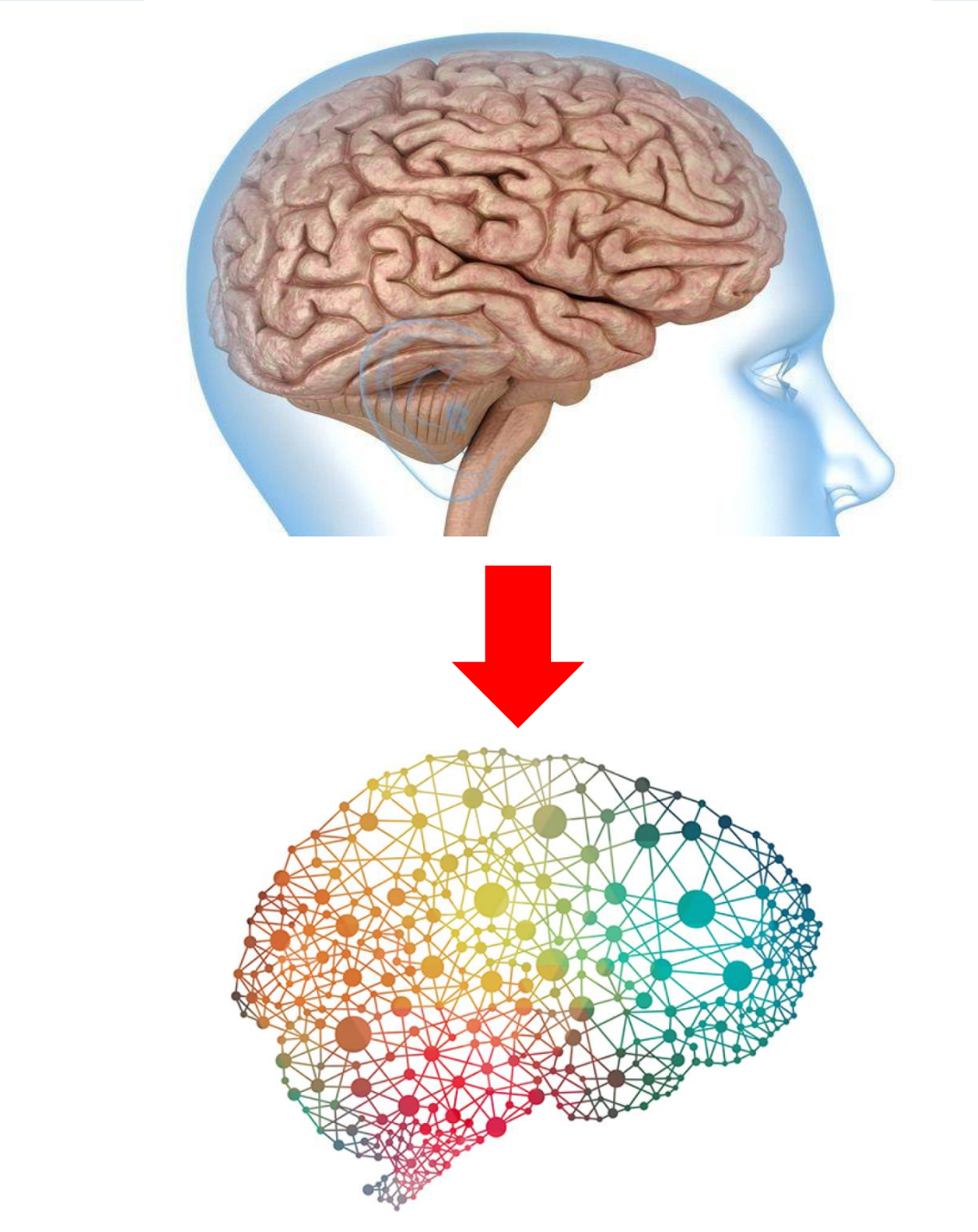
- We are only beginning to properly investigate the complexity of how the brain is “wired”.

- So far, there have been all kinds of exciting findings, including the finding that the “wiring” of the human brain may be completely **unique** and **individual** to each human being.
- This has led to some of the top neuroscientists saying this:

“You are your connectome”.

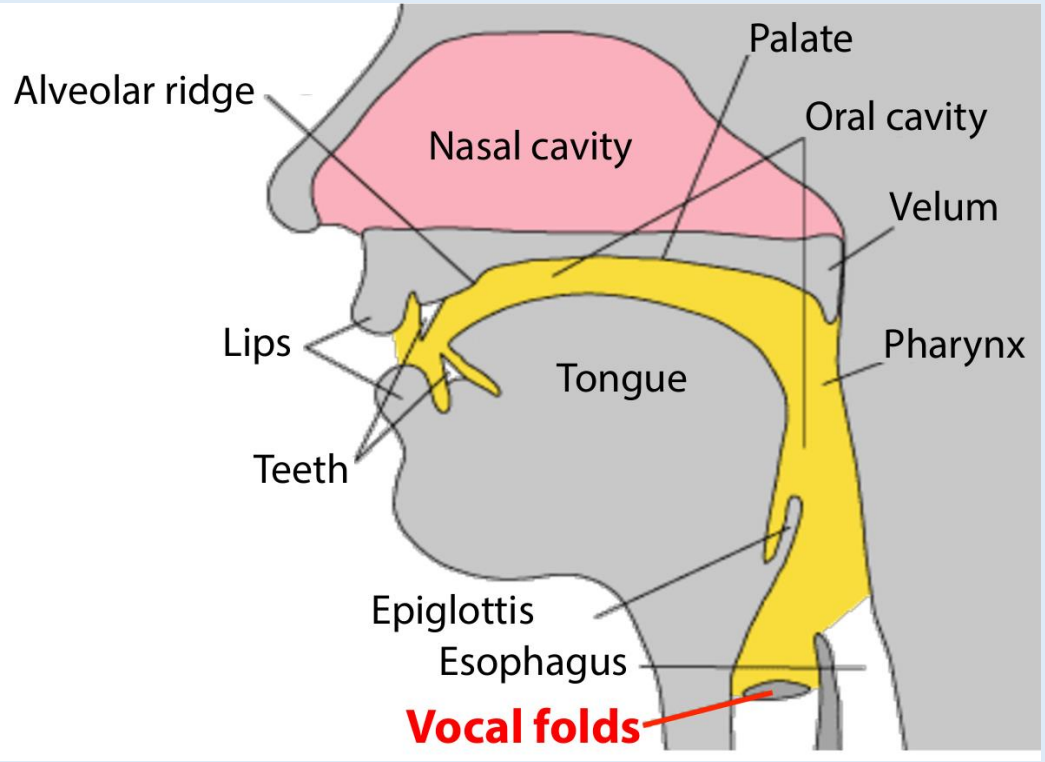
- The **connectome** of the brain is what makes you "**you**" (and not someone else).

- Now, there is an important reason why I am telling you about the connectome.
- The connectome means that all the different areas of the brain are heavily **<u>interconnected</u>** (with all kinds of possible connections going in all possible directions). This then means that no one brain system works completely on their own.
- It also means that brain processing is nowhere near as straightforward as it is normally thought.



- So, when we apply this idea of the “connectome” to **<u>hearing</u>**, it means that the hearing system of the brain does not work completely independently of the rest of the brain…..
- Instead, there is a huge amount of interaction between the hearing (the auditory) system with all kinds of other systems, such as:
    - The other senses (sight, taste, smell, touch)…….

… and also motor control, particularly that involved in speech production (e.g. controlling the movement of the lips, jaw, tongue and vocal folds to produce speech)…..



• The fact that the other senses and also motor control are involved in hearing means that processing of **<u>language</u>** actually becomes “multi-modal”.

• This “multi-modality” goes in two directions.

• One direction is that language collects and groups information from across many sensory types/ “modalities” (sight, touch, etc), as well as the other types/ “modalities” of processing (such as the motor processing).

• The other direction is that language **<u>itself</u>** can take on many different forms/ “modalities” (i.e. across multiple senses).

- What this “multi-modality” ultimately means is that there seems to be a “universal” language network in the brain that does not care what form the language takes (e.g. spoken English or sign language).....
- So long as it is a language, the language “network” in the brain is activated and starts collecting all possible information (from across the senses) so that it can start performing all the necessary processes involved in learning and understanding language.

- Cognition, such as executive function, also plays a really important role in hearing.

- “Executive function” is a very broad term for all the higher level processes that ultimately enables the brain to make decisions and co-ordinate the processing of different systems, so that we are able to respond to the outside world appropriately.

• Social processing too is important in hearing.

• This is because language is a social behaviour, happening within a social context.

- So, hearing is not just simply sound arriving at the ear and then being sent to the brain….
- Instead, all kinds of processes are involved. Not only this, but everyone's brains are also "wired" in unique (and not entirely understood) ways.

- This then means that in the case of deafness, it is not just the hearing system that is affected, there are all kinds of other types of knock-on effects (and, unfortunately, lots of them).

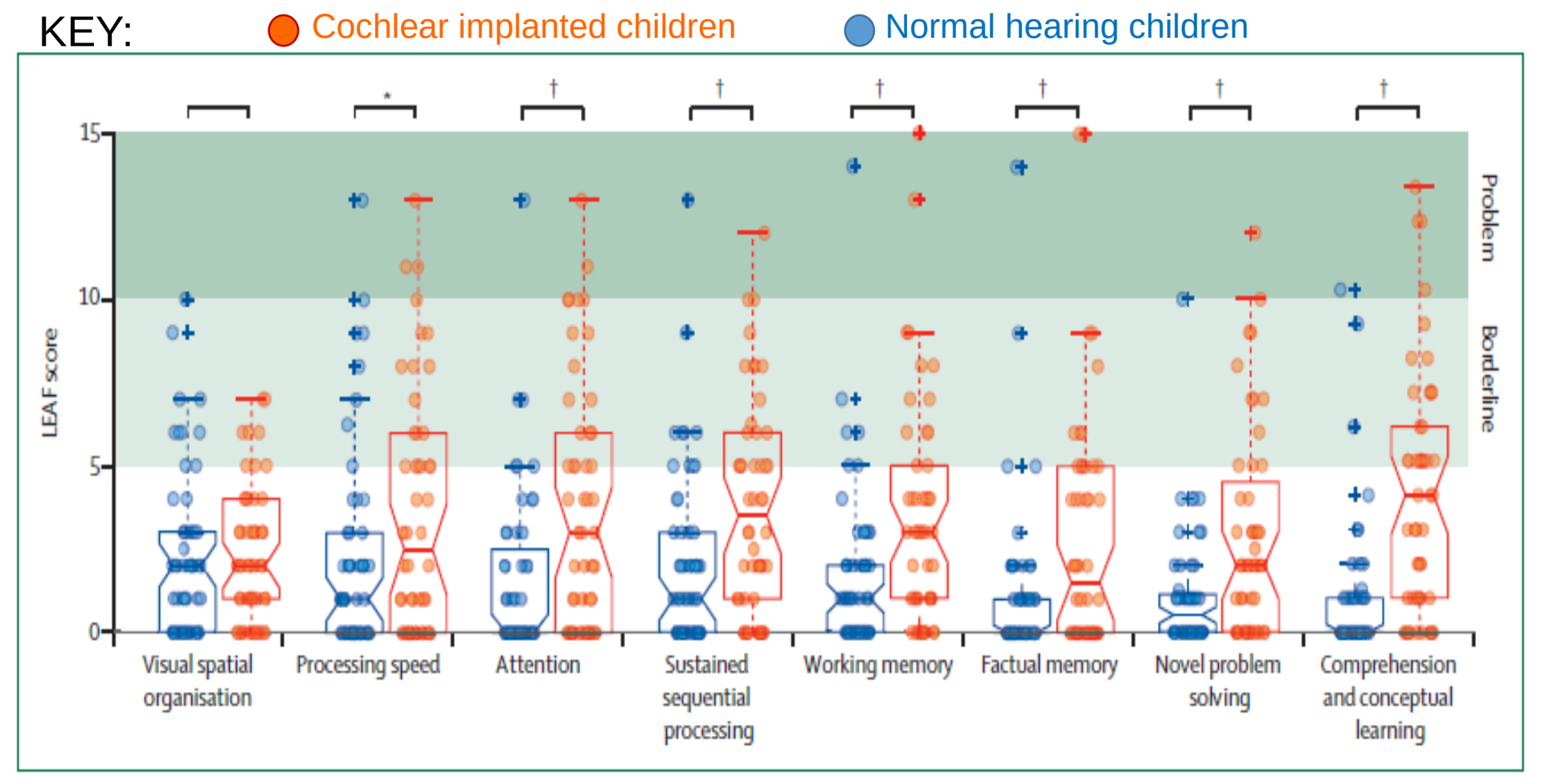
- In fact, deafness has sometimes been called a **“connectome disease”**.

• You can almost think of deafness as the cause of a damaging **“domino effect”** in the brain: knock down **<u>one</u>** domino and the **<u>rest</u>** will surely fall.

• This domino effect is a **hidden <u>cost</u>** of deafness that needs to be understood and recognised.

• There is already evidence of this “domino effect” available from previous research …..

- For example, when performance on standardised executive function tests (which test the different “subtypes” of executive function) in cochlear implanted children was compared to normal hearing children……



…. it was found that a substantial portion of the *deaf children* are lying within the “problem” or “borderline” areas in terms of their executive function ability.

• Also, there is quite a lot of literature showing that there is a particular problem in social processing that deaf children are vulnerable to: the lack of development of “Theory of Mind”.

• Theory of Mind is the understanding that other people have different minds and different ways of thinking (or “mentalising”) compared to you.

- It is recognised that deaf children may struggle with this “mentalising”.
- This lack of Theory of Mind is worrying because it increases the likelihood that deaf children show inconsiderate, or anti-social, behaviour.

• Not only does lack of Theory of Mind lead to poor social behaviour, there is also an increased risk of the deaf child developing “blinkered” and inflexible ways of thinking.

• This “tunnel vision” in their style of thinking can really damage the process of learning, because learning requires the ability to take on new ideas and new ways of thinking.

• It is also because of this domino effect that **listening effort** is able to have such devastating consequences on the health and wellbeing of the individual.

How do you measure listening effort?

- Currently, the clinical tests concentrate on testing speech understanding in various levels of background noise.

- On the basis of these tests, and the ongoing technological innovation and sophistication of the assistive hearing devices available, it would be easy to conclude that deaf people are enabled to access the world of sound successfully.

- This may be true in terms of their ability to understand speech in a wide range of challenging listening conditions.

- However, what is **not** being assessed is the **cost** of this performance on the brain. Worryingly, we do not have a way measuring **listening effort** at the moment.

- This means that speech perception tests can be successfully completed but still potentially induce unacceptably high levels of **listening effort**, without any indication that this has occurred.
- So, apparent success in speech understanding is not really success at all. It could actually be the brink of **listening effort breakdown**.

- Potentially, every:
  - new noise-reduction algorithm;
  - improvement in sound-field technology;
  - development in radio FM systems;
  - new generation of hearing aids and cochlear implants

….. could return the hearing ability of the deaf individual back to a state that is closer and closer to the original capability of the hair cells.

- All these innovations could reduce the burden of **listening effort**.

- But, how is it possible to know if this is the case?
- There is currently no established objective measure to identify **listening effort**.

- These innovations could actually be <u>increasing</u> the burden of **listening effort** and nobody would know that this was happening.

- So, how can you clinically measure **listening effort**, especially as no-one has really attempted to do this before?

- There are three categories of measurement we could potentially use:

(1)Subjective

(2) Physiological

(3) Behavioural

• ***Subjective measurement*** involves the use of rating scales and questionnaires, where you try to subjectively gauge the impact of **listening effort** by how hard work it feels, or how difficult you find a listening activity.

1 = Not at all hard work
2 = Quite hard work
3 = Medium hard work
4 = Very hard work
5 = Extremely hard work

• The “pro”s of this approach to measuring **listening effort** are:

  • It is an intuitive way of thinking about **listening effort** (you just feel how hard work it is).

  • It is easy to fill out a questionnaire, or mark a rating scale.

• However, the “con”s include the fact that everyone varies in how they define **listening effort**.

• It is a personal opinion and people may have different “thresholds” for how much **listening effort** they consider to be too much.

• This makes it difficult to apply statistics to the data, as there is so much variability.

- Therefore, **subjective measurements** are not an appropriate method for "*gold standard*" clinical research.

1 = Not at all hard work
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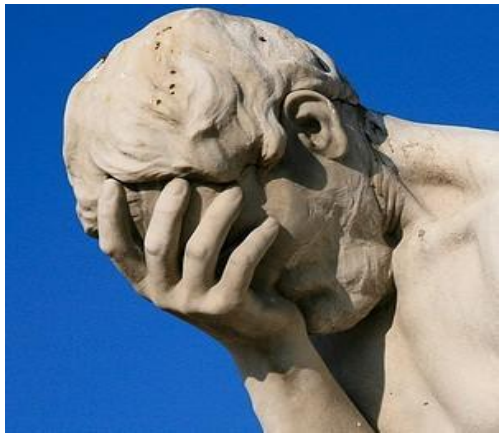
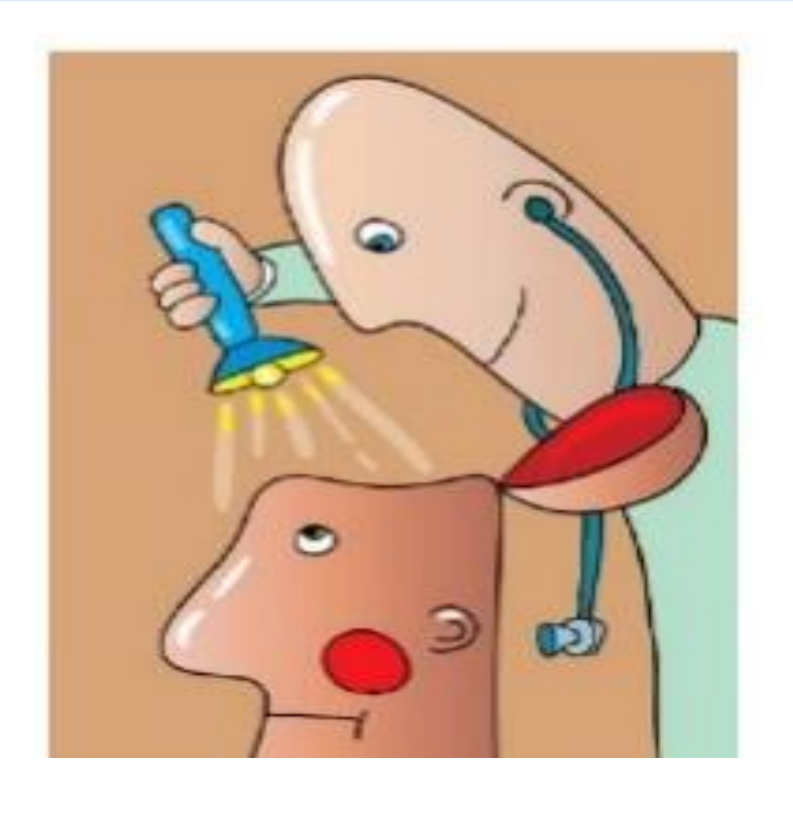
- **Physiological measurement** on the other hand is objective (i.e. there are no subjective opinions, or feelings involved in this measurement).

- Instead, **physiological measurement** involves measuring an automatic body reaction/process such as: heart rate, cortisol level (produced by the adrenal gland), ***pupil dilation***, galvanic skin response (the amount of sweat generated), or EMG (measurement of muscle tension).

- The fact that **physiological measurements** are objective is a real “pro”.
- However, the exact relationship between these automatic body responses and **listening effort** is not completely understood.
- For example, we do not necessarily know whether there is a straightforward relationship between **listening effort** and any one of these responses (i.e. we do not know whether an increase in **listening effort** does lead to a direct and proportional increase in the automatic response).



- The other problem is that the automatic responses are not exclusive to **listening effort**.
- They can be caused by other factors such as anxiety, or even how much sleep they had the previous night.
- So **physiological measurements**, therefore, are an indirect measurement of **listening effort**.
- Another “con” of **physiological measurements** is that the data produced are naturally “noisy”.
- What this means is that the data that you are interested in are being hidden by background physiological activity of the human body.

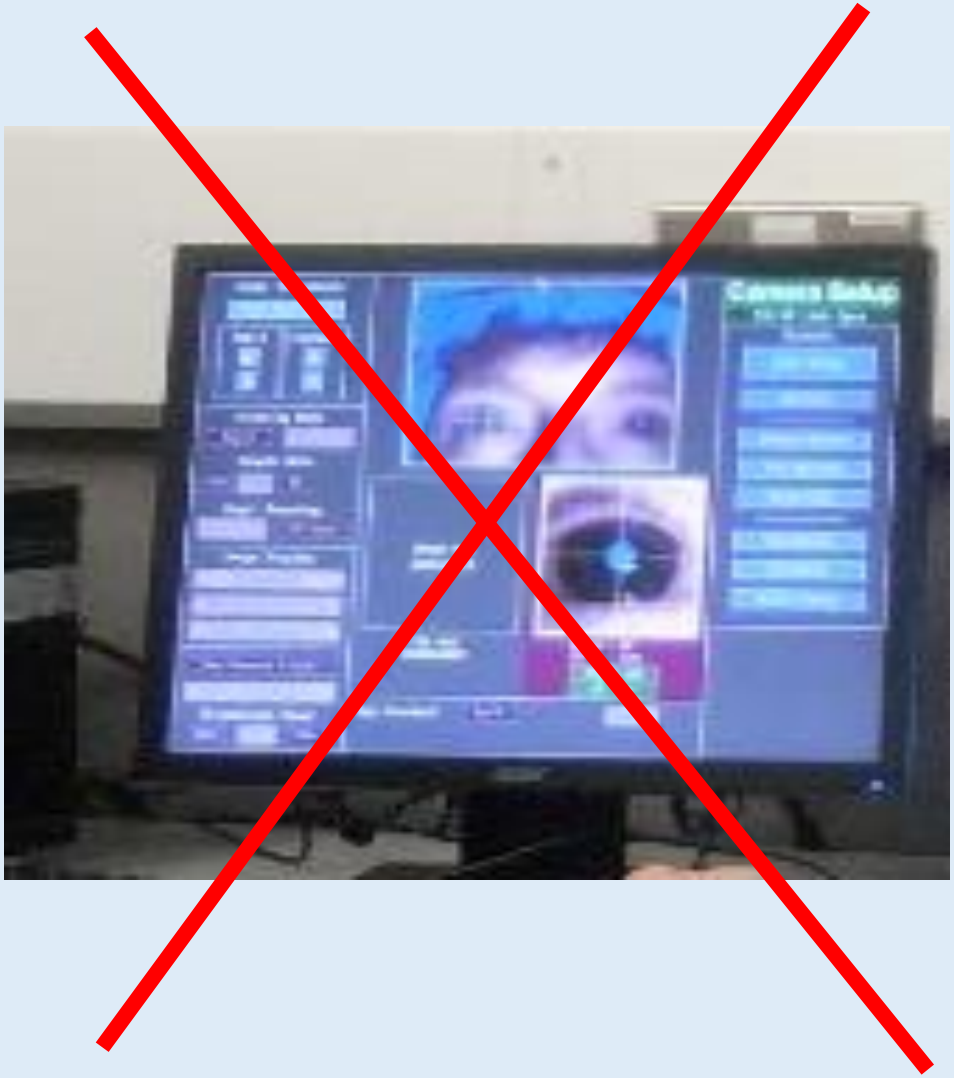


- This means that you have to spend a lot of time and energy (often using complex mathematical algorithms) in order to analyse the data and extract what you are actually interested in.

- And, even then, you *cannot* be entirely sure that what you have extracted is actually measuring **listening effort** at all.

- Expensive equipment (that requires expertise to use) is also often needed, making it not so easy to use within the clinical setting.

- Therefore, **physiological measurements** are not (at least, not yet) an appropriate method for "*gold standard*" clinical research.



- **Behavioural measurements** are another way of objectively assessing **listening effort**.
- What this involves is doing some kind of task and seeing how performance of that task is affected when listening conditions become more difficult.
- You try to make the task involved as relevant and as close to **listening effort** as possible, to try to make the measurement of **listening effort** itself more direct.
- However, it is still essentially an indirect way of measuring **listening effort**, which is the main "con". We still do not really know how task performance directly relates to **listening effort**.
- The "pro"s of this approach is that you don't necessarily need clever or expensive equipment, which makes it more feasible for use in the clinic, or even at home.

- Over the past three years, I have experimented with **behavioural measurements** using:

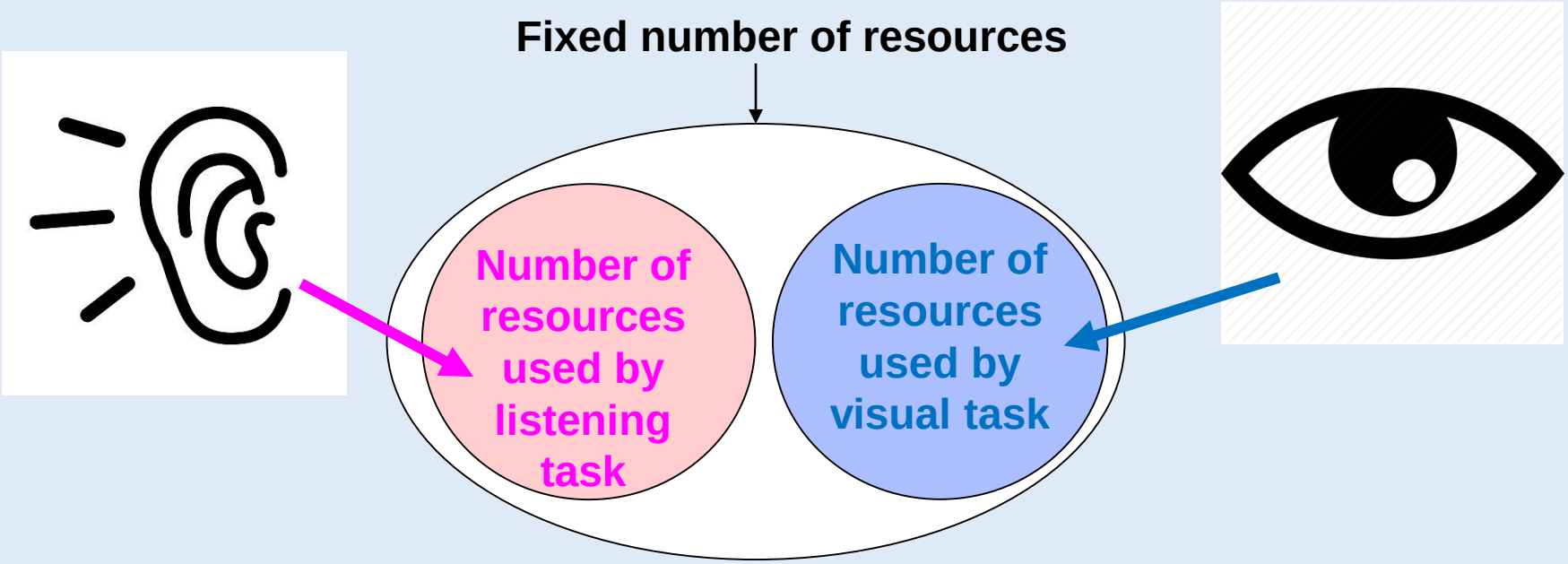
Different types of auditory stimuli
- Predictable sentences with a fixed structure
- Unpredictable random sentences

Different types of visual stimuli
- Geometric shapes
- Flashing digits

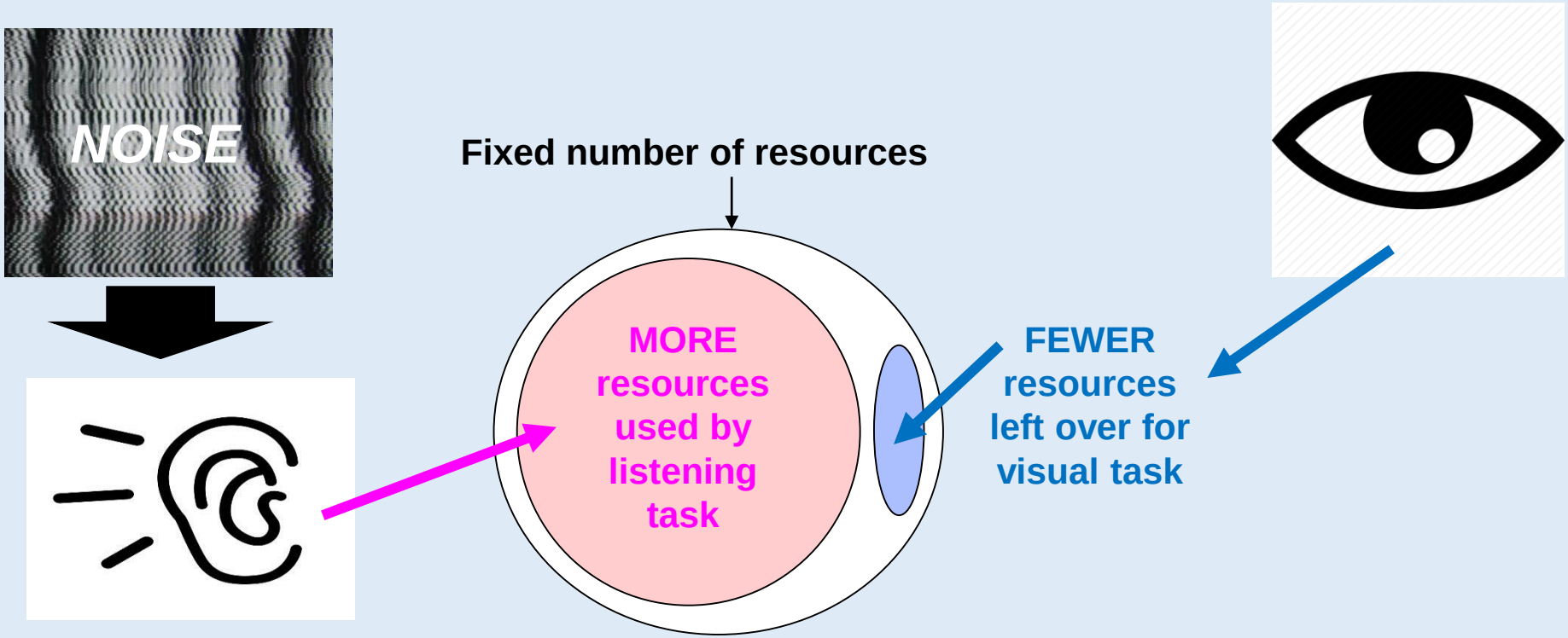
Different participants
- Normal hearing participants listening to normal sounds
- Normal hearing participants listening to simulations of the cochlear implant
- Cochlear implant users

….. in order to try and find a **dual-task paradigm** that is the most sensitive for measuring **listening effort**.

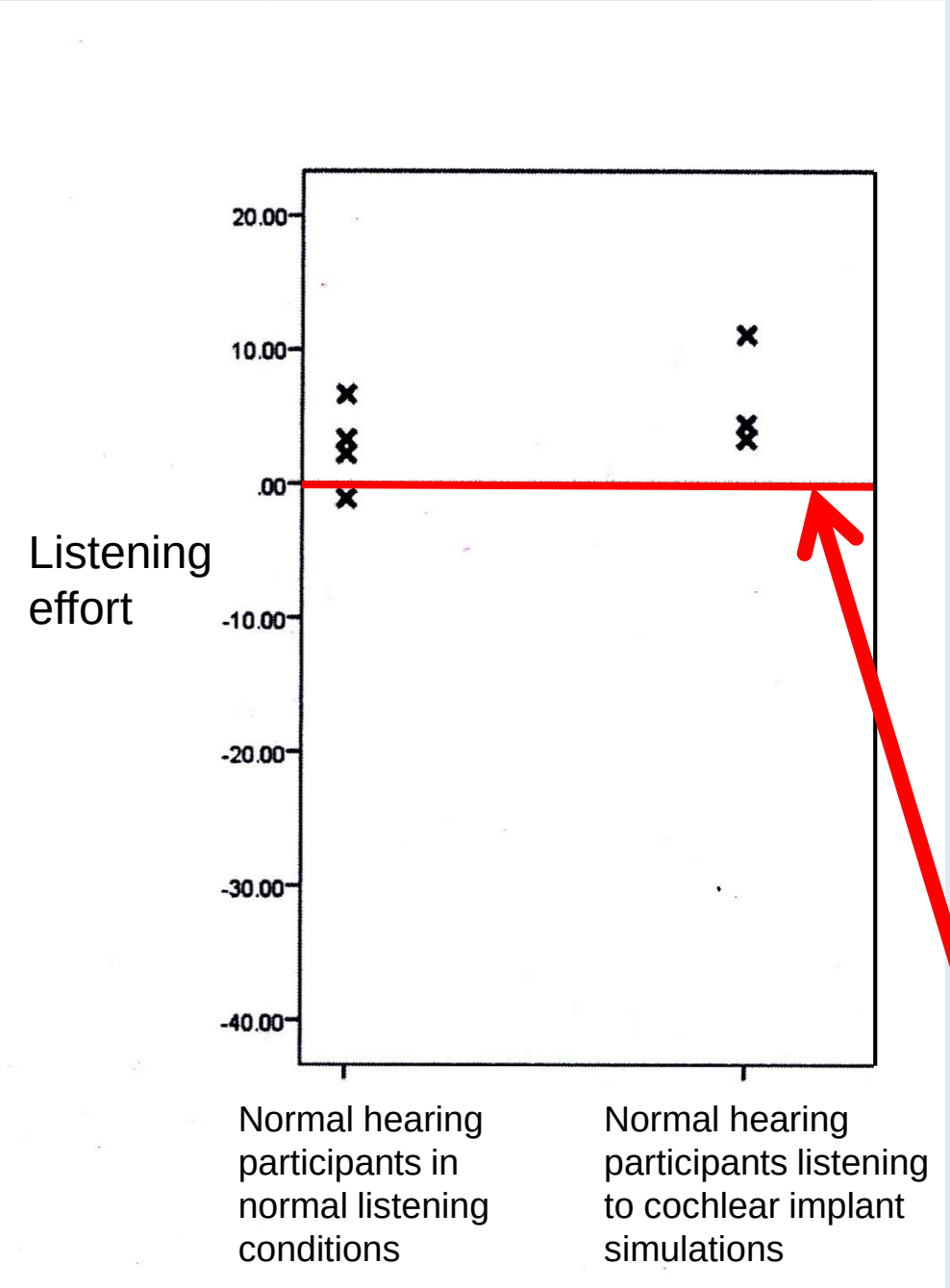
- The dual-task paradigm involves forcing the brain to **multi-task**. We ask the participant to perform two tasks at the same time: a ***primary task*** and a ***secondary task***.
- Because the brain only has a fixed number of **cognitive resources** that it can use, it has to share these resources between these two tasks.
- The **primary task** (i.e. the task that the brain is required to focus on) is a **listening task**.
- The **secondary task** (i.e. the other task that is lower on the priority list for the brain's focus and, therefore, has to use up what is left over of the cognitive resources) is a **visual task**.



- If we then increase the level of difficulty of the **primary task** (for example, we increase the level of background noise present when listening), the brain is required to move cognitive resources away from the **secondary task** and towards the **primary task**.
- This means that there will be **fewer** resources left over for the **secondary task** and so performance will become poorer……..

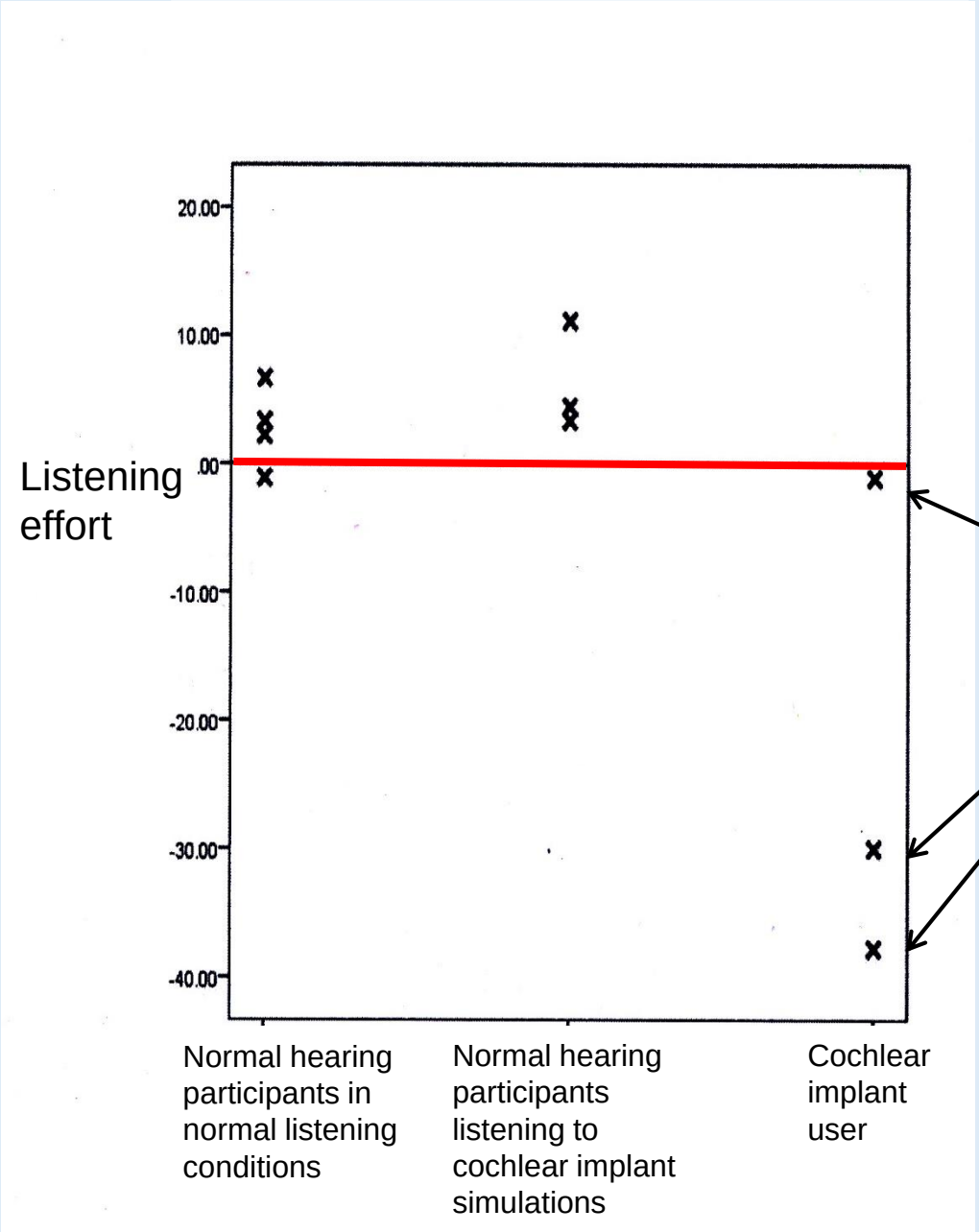


…….i.e. **decreased *visual accuracy*** = **increased listening effort**.



- So far, it has been possible, using the dual-task paradigm, to successfully measure the **listening effort** score for normal hearing control participants both when they are listening to **normal** sounds and also when they are listening to **simulations** of the cochlear implant.

Values above the line indicate an increase in listening effort.



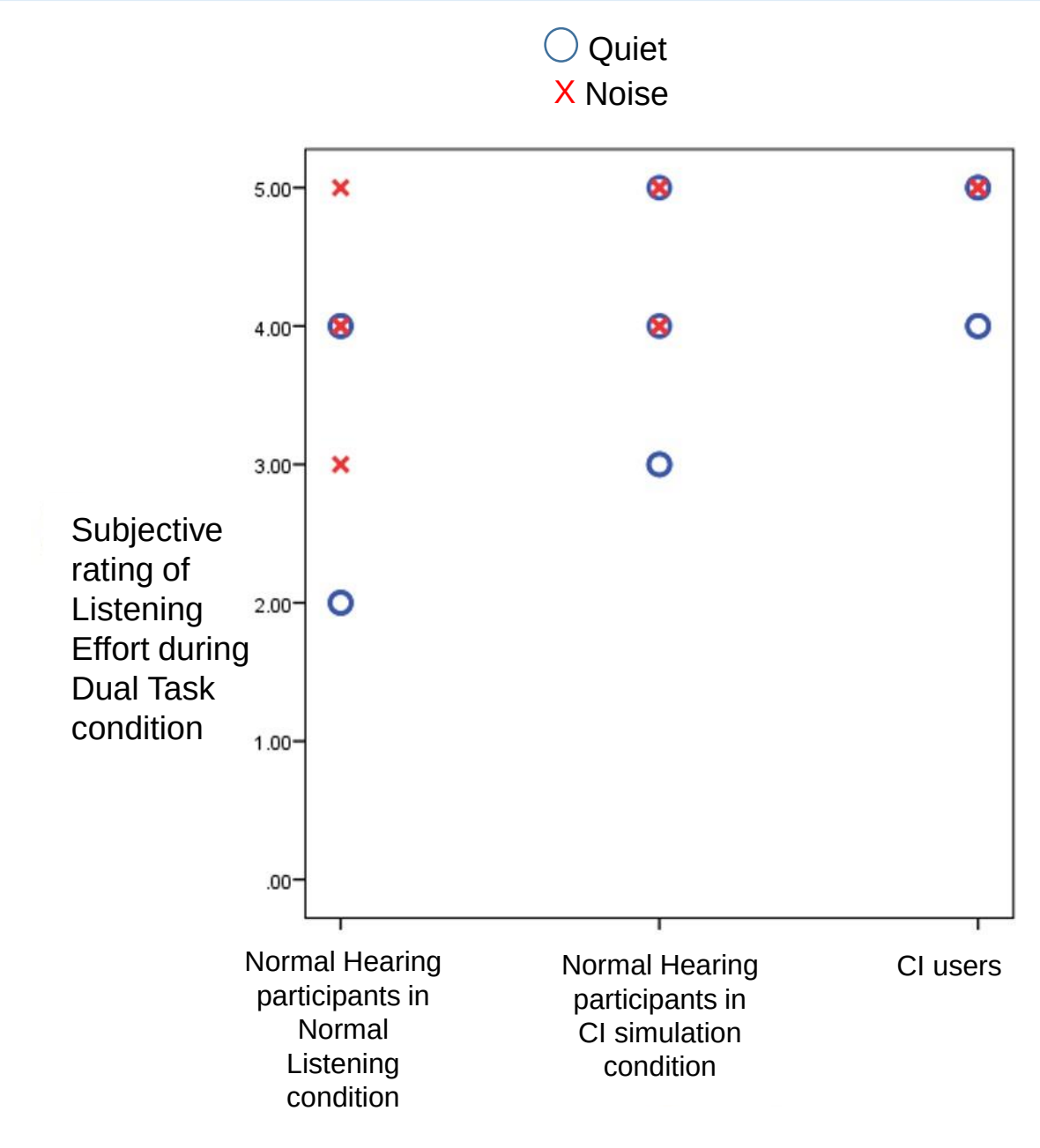
- However, when the **listening effort** levels were measured for the cochlear implant users, they showed a negative score, suggesting that their **listening effort** had **decreased** when listening in noise.

- This was puzzling, so the other data were analysed to see if an explanation could be found.

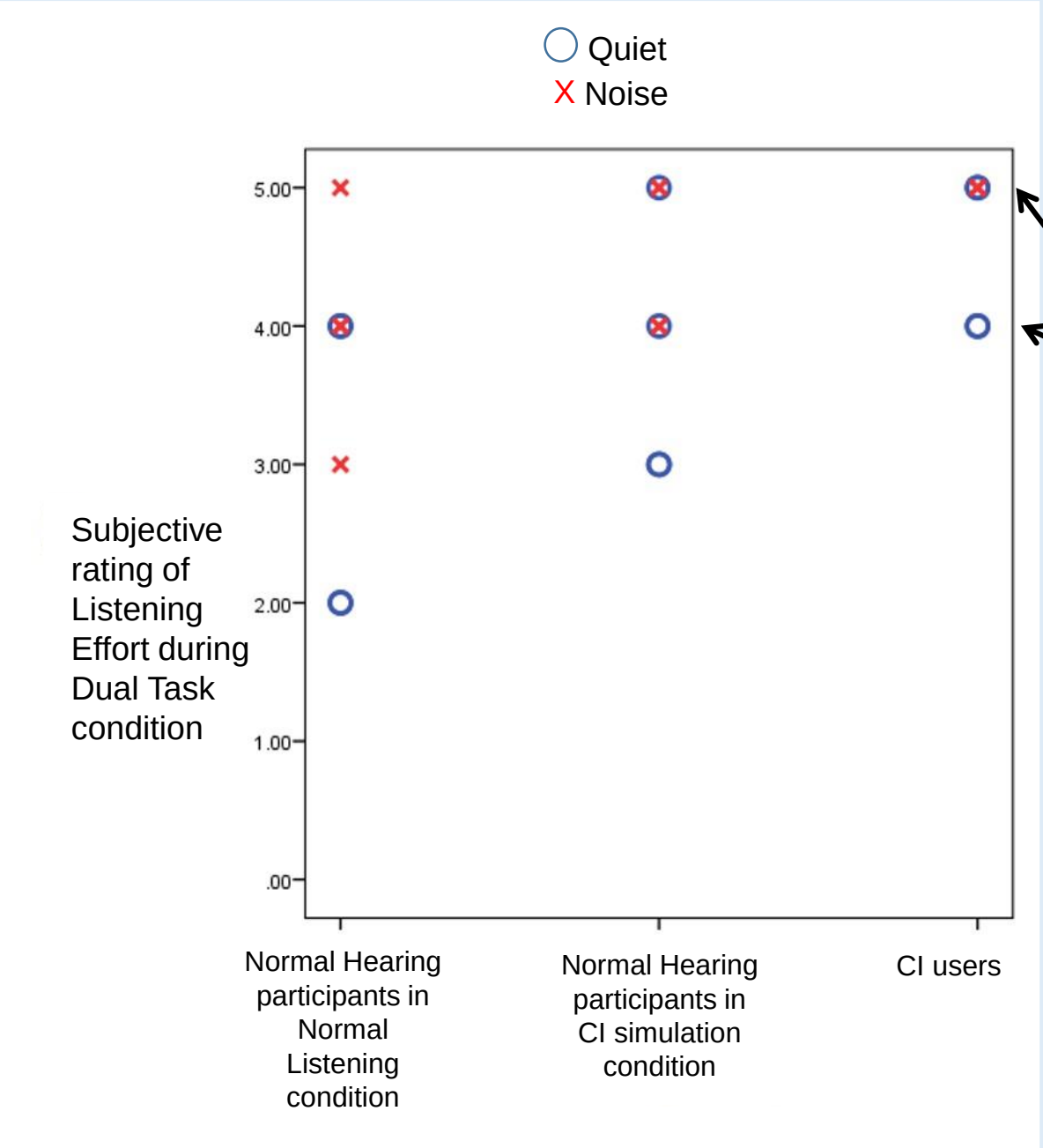
- We had obtained **physiological measurements** (we measured the size of the pupil in the eye) and **subjective ratings** at the same time we asked the participants to perform the dual-task paradigm.

1 = Not at all hard work
2 = Quite hard work
3 = Medium hard work
4 = Very hard work
5 = Extremely hard work

- Although these two types of measurements are not sufficient to form a clinical test in their own right, they still provided very useful information to work out whether or not the dual-task paradigm was working as we had designed it.



- This shows the **subjective ratings** when performing the dual-task paradigm in quiet (the blue circles) and in noise (the red crosses).
- As expected, the normal hearing controls experienced **listening effort** as higher when listening in noise, and higher still when listening to simulations of the cochlear implant (i.e. where the sound had been distorted to resemble what would be provided by a cochlear implant).



- What was particularly interesting, however, is that the cochlear implant were rating **listening effort** as being “very hard work” or “extremely hard work”, **even when they were listening in quiet**.
- So, when the listening conditions were optimal (i.e. in quiet), the addition of the visual task seem to significantly add to the level of work needed for understanding the auditory stimuli.

- For a simple visual task to have such an impact on **subjective ratings** in quiet suggests that **<u>considerable</u> listening effort** must already be experienced with processing the auditory stimuli, despite there being no background noise.
- This meant that when noise was introduced into the background, the **listening effort** became so much that it actually caused **overload** of the brain.

- At this point, the cochlear implant users then simply “gave up” and stopped trying to distinguish and recall the words spoken in the test.

- They focused instead on the visual task. This would then bolster their visual accuracy scores.

- Since it was the visual accuracy score being used to actually measure **listening effort** in the dual-task paradigm, this improvement in visual accuracy (in noise) would lead to the counter-intuitive decreases in the **listening effort** score we were seeing.
- So, the early experiments of my PhD research were already showing the **cost** that listening through a cochlear implant has on the brain, even when it was quiet.

- The dual-task paradigm has undergone a lot of changes and refinement to try and make it as accurate as possible in how it measures **listening effort**.
- I am now in the middle of my last study of my PhD research, where I am road-testing my latest version of the dual-task paradigm with as many cochlear implant users possible that I can recruit.

- So, my PhD research seems to be showing so far is that it **is** possible to develop a clinical test of **listening effort**.

- My work is still in the **very early stages**, but the principle stands.

- Ultimately, this test could help the deaf child, or any deaf individual, monitor the levels of **listening effort** they are experiencing. This would then mean that it could become possible for the individual to adjust their exposure to whatever situation is causing this extra **listening effort** accordingly, or to develop further strategies to cope with **listening effort**.

- The important thing is that **listening effort** should **never** become so excessive that the physical and mental health and wellbeing of the individual becomes compromised.

- Having a clinical test (that could even be used in the home environment as well) that is able to measure **listening effort** should help make this objective possible.

How can you reduce listening effort?

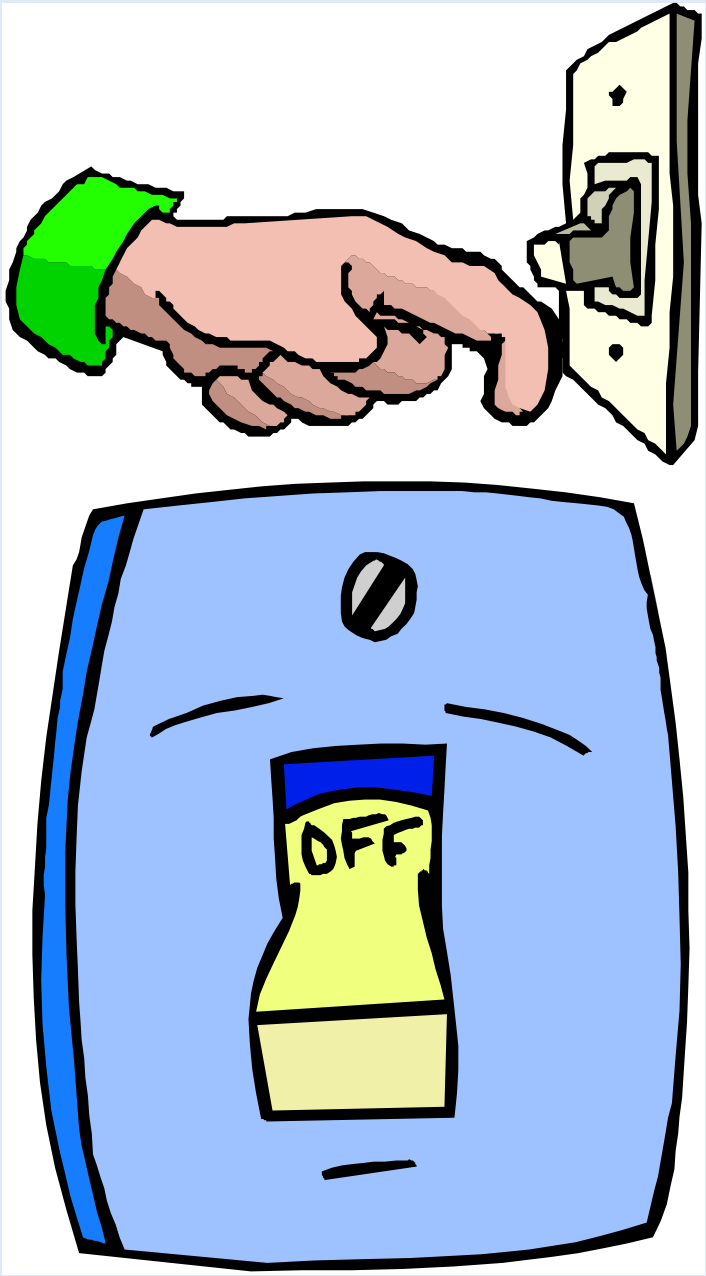
• I became involved in this field of **listening effort** research because of my personal experience as a cochlear implant user.

• Although I have the greatest admiration for the cochlear implant technology and I am very grateful for it (I wouldn't be here where I am today without it)……..

- I find that the price I pay for being a "successful" cochlear implant user is **excessive listening effort** on a **daily** basis…..

- It leaves me absolutely **exhausted**.

- I have tried all kinds of ways to reduce the **listening effort** I am experiencing.
- However, the very best solution for me is to “switch off” my implant as often as I can.
- If I don’t need to listen to anything, or talk to anyone, I switch off.
- On working days (in the university faculty), this means that the maximum I would be switched on would be ***six hours***.
- On study days, when I am working at home, I remain switched off for the ***entire day***.



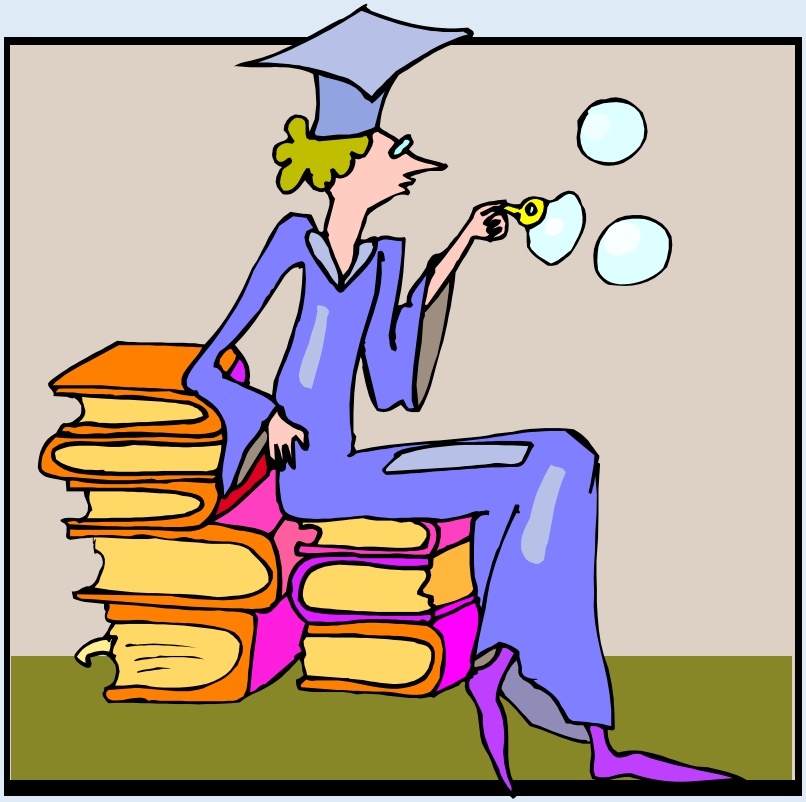
- This habit began as a child - I only switched on when I absolutely had to.

- I switched on at the beginning of the school day, and I switched off the minute I came home.

- At university, I switched on for lectures and tutorials and hanging out with my friends.

- However, if I was on my own, I was always switched off.

- I really believe that this “switching off” was the only way I could create the additional cognitive capacity that I needed to cope with the complexity of information processing I was encountering with GCSE, ‘A’ level and (later) university study.



- The more complex the study requirements became, the more I had to switch off.

- My successful academic results may be a reflection of this.

- It is possible that I created the cognitive capacity for advanced study, by limiting the cognitive demand of **listening effort**.

- I achieved this by being switched off as much as possible.

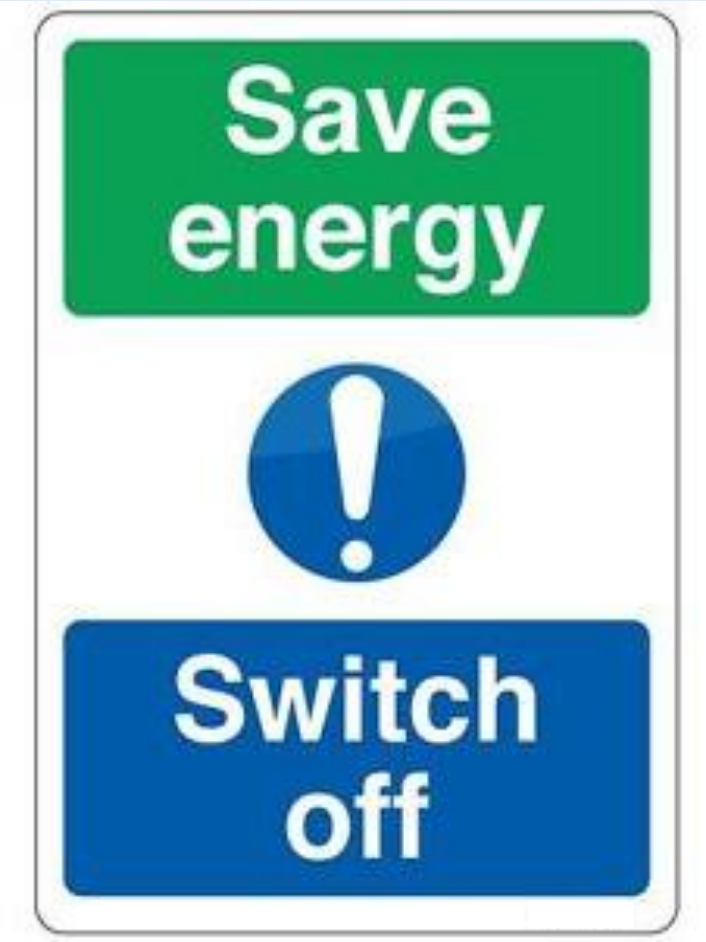
• I fully recognise that this is a strategy that directly goes against all medical professional advice.

• Even now, I repeatedly get told off by the audiologists at Nottingham (when I go back for my annual tuning appointments) about my low "***wear time***" for my cochlear implant.

• I am told on every visit that I must wear my implant much more and keep switched on constantly during all my waking hours, in order to gain optimum benefit from it.

• The fact that their assessments show that I am already a very successful cochlear implant user with excellent listening thresholds (despite my low "wear time") is always totally disregarded.

• So, my motivation for my research was to try to find a way to measure **listening effort**, so I could provide some explanation (with ***real numbers***) as to the amount of **listening effort** I was actually experiencing.

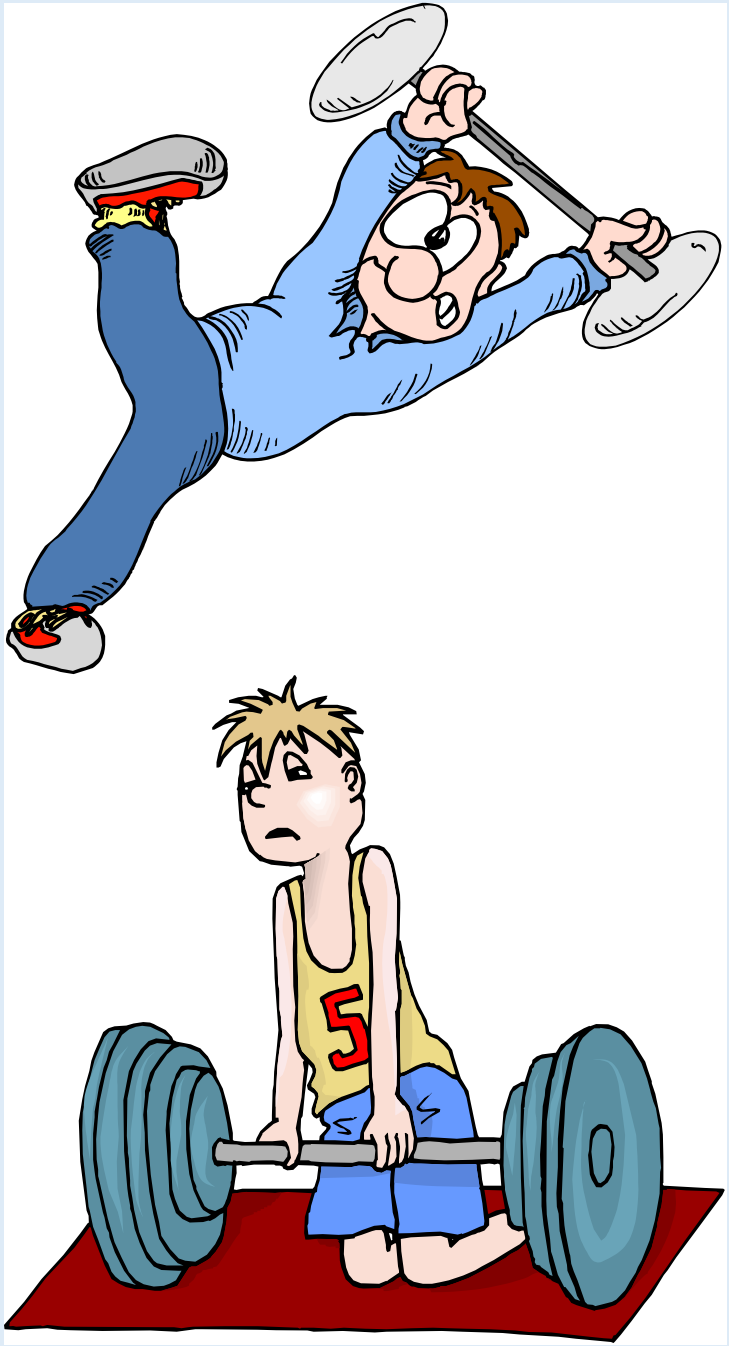


• I wanted to find a way to clearly demonstrate why I had to do what I was doing, in switching off so often.

• Now, I am not saying that switching off as much as I am is necessarily the best way of coping. However, at the same time, if I did follow the professional advice of increasing my “wear time”, I am definitely at increased risk of exposure to the burden of **excessive listening effort**.

• Until audiologists and other professionals are able to actually “see” the levels of **listening effort** being generated, with an actual clinical test able to measure it, it is currently very difficult for anyone to provide truly useful advice about ***“wear time”***.

- Ideally, it should be possible to recognise **immediately** when the burden of **listening effort** is becoming too much and “switch off” at that point, rather than persisting into a state of mental exhaustion.



- In my experience, however, the exhaustion creeps up on you before you realise the damage has been done. This is why the development of some tool to monitor **listening effort** is so vital, so that each individual can come to know their own limits and work within them.

- The feedback about **listening effort** may eventually enable changes in design, or tuning, of the cochlear implant, adjusting for the effects of **listening effort** and even removing the need to “switch off” (to reduce **listening effort**) in the first place.

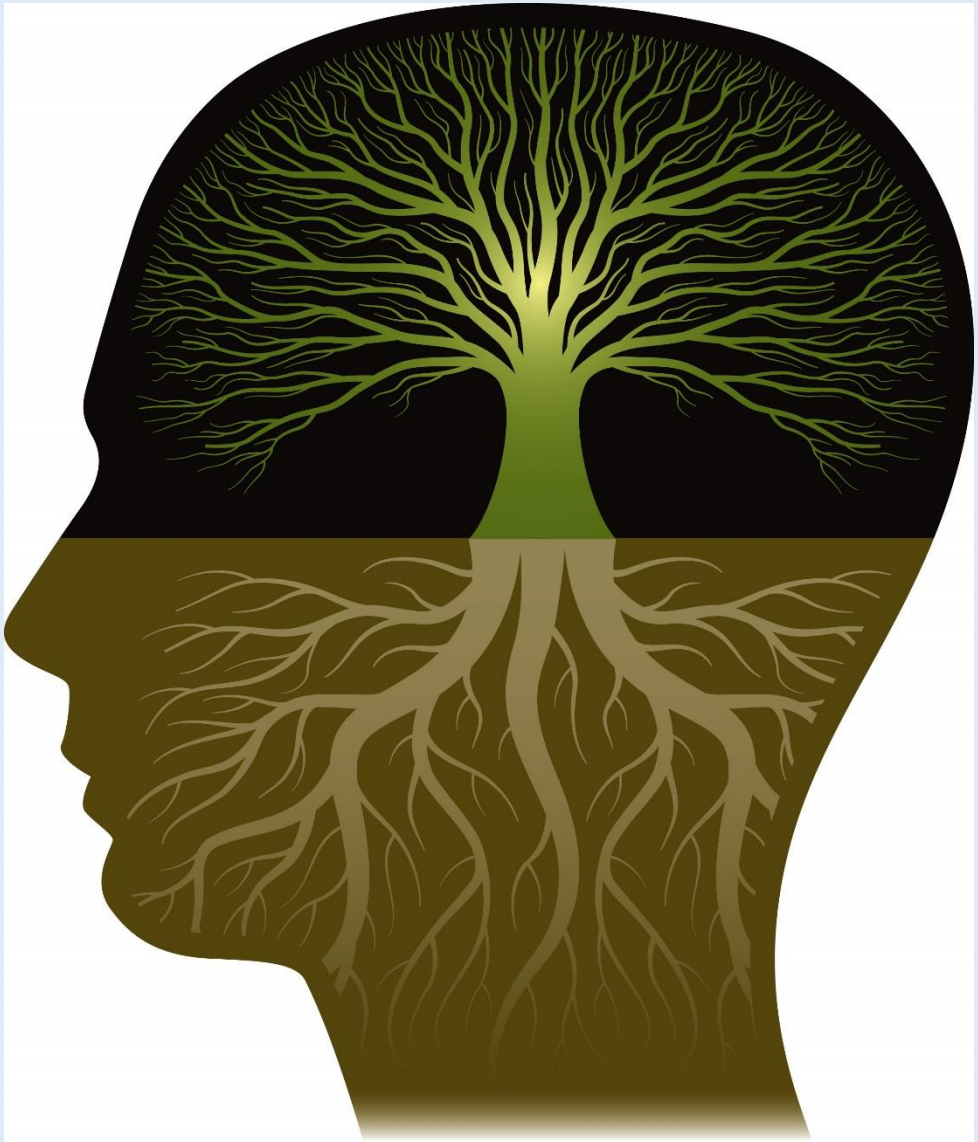
- We also need to very seriously consider the idea of the brain being a **connectome,** and deafness being a form of **connectome disease.**

- Because the brain is a highly interconnected network of many different systems (i.e. a connectome), there is a very real danger that deafness will cause a “domino effect” where not only is the hearing system affected, but many others too.

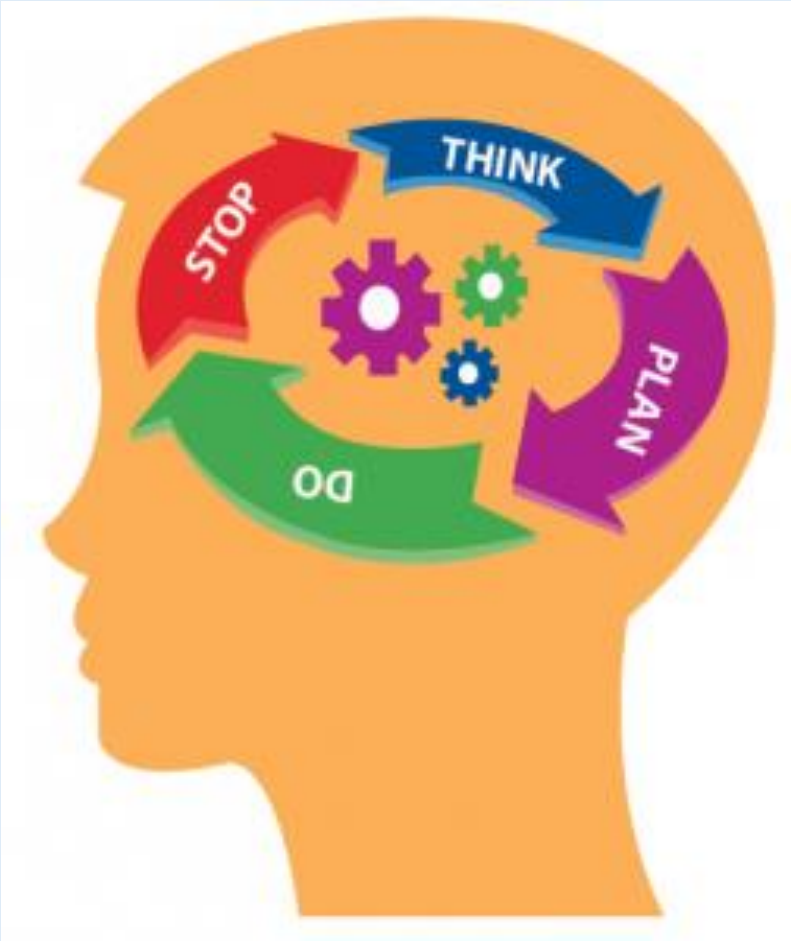
- So, deafness may have other consequences on the individual that may not be currently recognised to be a problem. As a result, the deaf child may be suffering issues that could be avoided, or treated.

- So, a **“holistic”** approach is really important for when deciding on rehabilitation and intervention – i.e. the **whole** brain is considered, **not** just auditory processing (so that all possible consequences are taken into account).

- Then, and only then, could you say that the deaf individual can be **fully** supported.



• In fact, there is a new idea (or approach) to hearing rehabilitation and language intervention that is beginning to emerge: neurocognitive interventions.

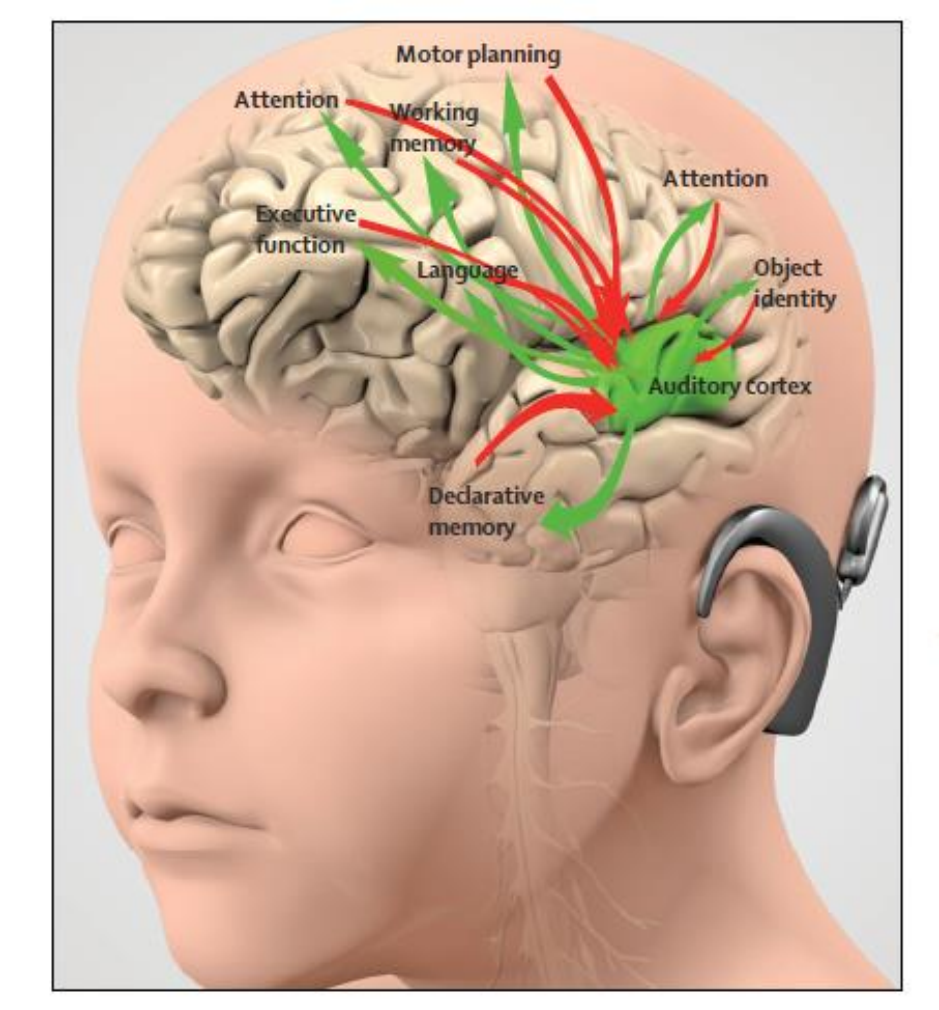


• This is where not only is language being promoted, but so is executive function and social processing.

- This is because the executive function (red arrows) and language (green arrows) act as scaffolding for each other.

- So, if you bolster executive function development, you may then be able to bolster language development and hearing outcomes too.

- This neurocognitive intervention approach active recognises the fact that the brain is a connectome.



- Social development also feeds into language development and execution function development, so addressing social processing (and Theory of Mind problems) is essential too in improving hearing outcomes.
- This is because nurturing social processing will then help to encourage flexible thinking (especially lateral “outside-the-box” thinking), which is absolutely key to helping anyone to gain new knowledge and apply new concepts.

- Not only is there a need to think holistically, there should also be no “one fits all” solution.
- This is because of the fact that the connectome is unique to each person, i.e. the brain’s wiring is completely individual to the person.

- So, an approach or method that works for one person **may not** necessarily work for the other person. The **conventions** and the **“should”s** of the medical profession should not restrict the approach to rehabilitation.

- Yes, the **“should”s** are helpful as a form of guidance, but if the deaf child needs more, or something different, to what is considered the “norm”, there must be no hesitation to try something else.

- The individual case needs to be considered carefully as to what works for them (and also what doesn’t work for them). There is no “right” or “wrong” answer per se. Having an open mind is absolutely crucial.

• I remain inordinately grateful that I was one of the first of my generation in the UK to receive the cochlear implant. I would not be where I am without my cochlear implant.

• However, I do sincerely hope that, in the future, those with hearing loss will be spared the damaging burden of **excessive listening effort**.

• Not only this, I also hope that it will become accepted that reducing **listening effort** is vital in improving hearing outcomes and unlocking the deaf child's true potential.

Thank you for your listening effort today.

UCL

Hear now. And always Cochlear™

ACTION ON HEARING ~~LOSS~~