# Unlocking academic potential in deaf learners by measuring listening effort

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Hello.

My name is Helen Willis.

At the age of 20 months, just two hours after this photo was taken, I fell ill with meningococcal Meningitis Type B.

I was lucky to survive, but it was at a cost…..

my hearing and balance were completely destroyed.

I had already begun to get to grips with walking and I was starting to talk, but the meningitis infection returned me back to square one.

I needed several months of intensive physiotherapy to re-learn how to walk again

……but speech development took much much longer.

At the age of 3, in 1994, I received a cochlear implant.


But I still struggled to develop speech.

I started primary school (at the age of five) with the language level of a 2 year old.

With hours and hours and hours of……

- Intensive speech therapy

- Specialist support from Teachers of the Deaf

- Supplementary tuition at home outside school hours

…… I was finally able to overcome my language delay and catch up by the time I reached secondary school.

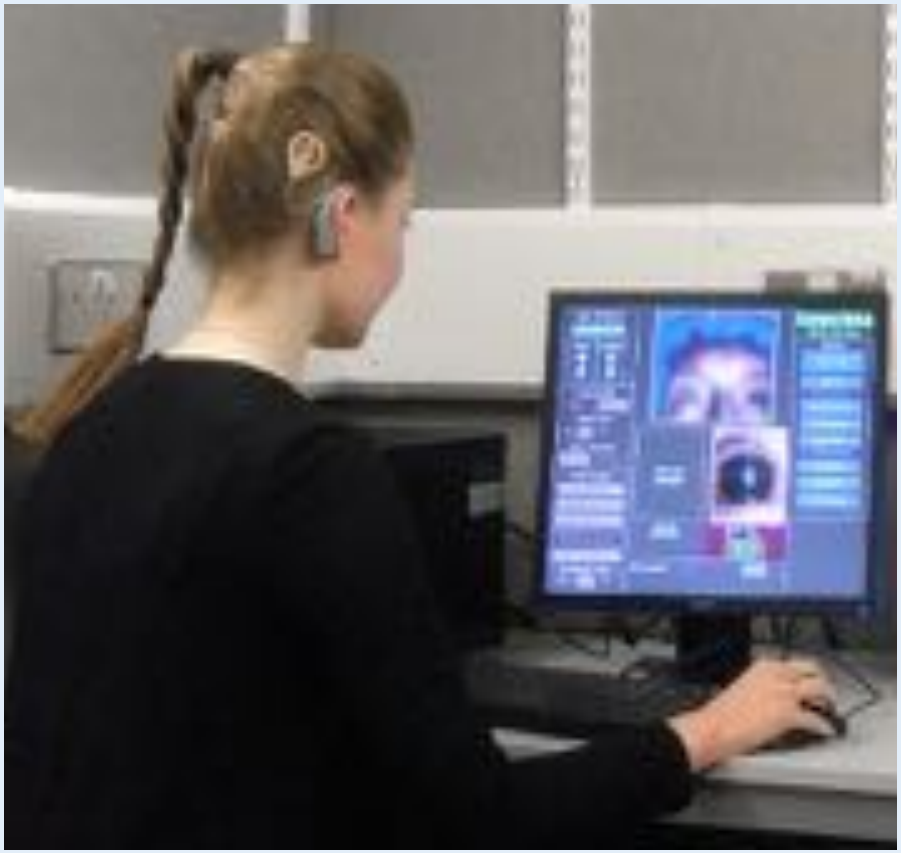
I went to Mary Hare School for the Deaf.

With its bespoke learning environment, I was able to achieve all the GCSEs and A Levels I needed to apply to Oxford University.

In 2013, I graduated from St. John's College, Oxford University, with First Class Honours in Physiology and Psychology.

I remained at Oxford University for one more year to pursue an MSc in Neuroscience.

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



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

Despite being able to catch up on my language delay and pursue my academic dreams, there is one obstacle that I have not overcome and still struggle with to this day…..

**Listening Effort**

**(L.E.)**

Technology has come on in leaps and bounds in its ability to help those with hearing loss access the world of sound.

However, none of this technology is able to completely restore hearing back to its original capacity and ability.

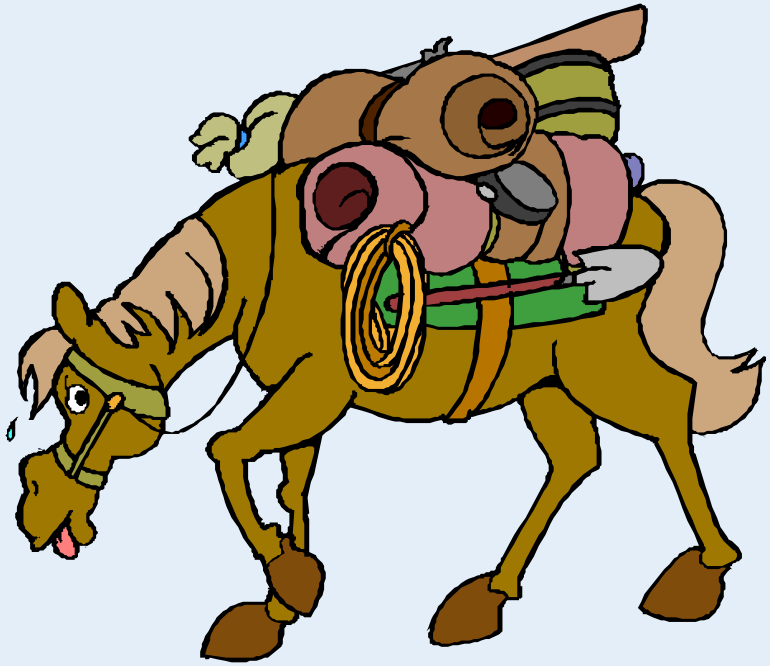
This means that there are still gaps in the auditory information received by any hearing impaired individual, hearing aid user or CI recipient.


Therefore, in order to successfully understand and interact with the world of sound, it is necessary for the brain to compensate for these missing pieces of auditory information.

This requires:

- Higher level interpretative brain processes to enable speech perception
- Higher order cognitive strategies, such as perceptual filling-in and the use of context to resolve ambiguity.

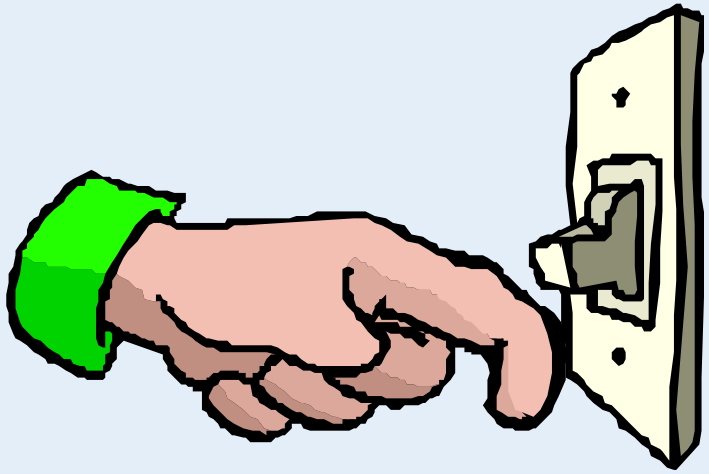
This constant compensation creates an additional cognitive load known as **Listening Effort (L.E.).**



For those with hearing loss, the consequences of L.E. are an everyday burden…..

…. which can quickly lead to tiredness and even exhaustion.

Indeed, the only way that I can physically cope with L.E. (and keep my sanity) is to switch off my speech processor as often as I possible can and retreat into silence.



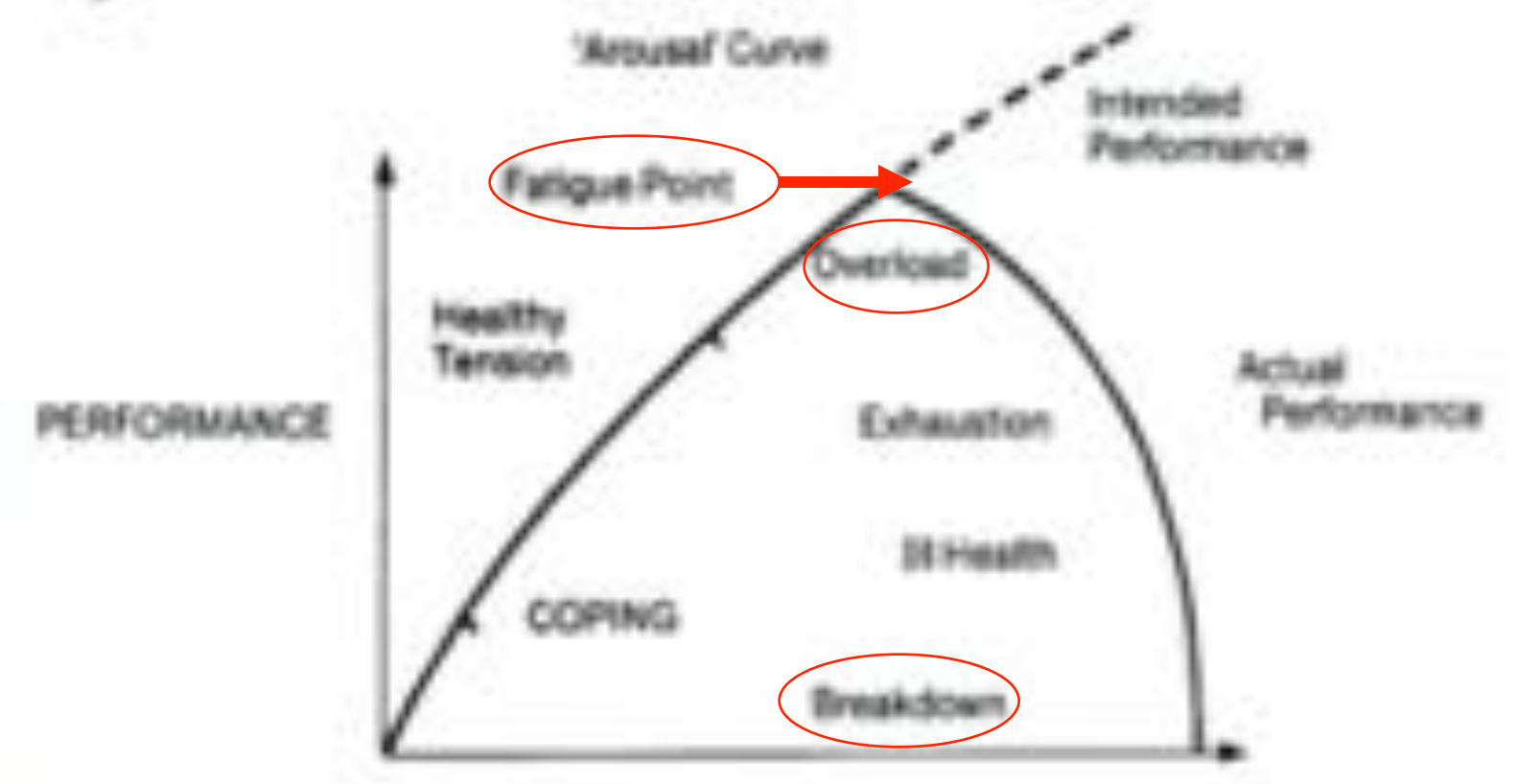
As a result, I spend several waking hours each day switched off.

Worryingly, there is now a substantial body of research evidence showing that if L.E. becomes excessive and chronic, physical and mental health will be compromised.


**LISTENING EFFORT (L.E.)**

(Modified from Hebb, 1955 and Duffy, 1957)

This is because increased L.E. makes it more likely that the deaf individual will reach the point of **overload**, where improved performance becomes impossible and a **fatigue point** is reached.




**LISTENING EFFORT (L.E.)**

(Modified from Hebb, 1955 and Duffy, 1957)

If the deaf individual persists in trying to listen (with these high L.E. levels), they are at very high risk of entering a downward spiral of exhaustion, ill health and even breakdown.


What is even more worrying is that despite all this evidence of how harmful L.E. can be, there is currently no clinical test of listening effort.

Assistive hearing devices are becoming increasingly more sophisticated. Indeed, current clinical assessments (which concentrate principally on speech discrimination in various degrees of background noise) are indicating high performance outcomes with these innovations even in background noise.

So, it would be easy to conclude that those with hearing loss 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 conditions.

However, what is not being assessed is the **cognitive cost** of this performance.

**A price is being paid for this level of functioning, and this is currently not being measured.**


This means that current clinical assessments 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 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 assess listening effort.

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

Recently, there was an article in the NDCS Families Winter Issue talking about how to help deaf children manage with listening fatigue……

What was particularly compelling in this article was 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**.





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

**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.

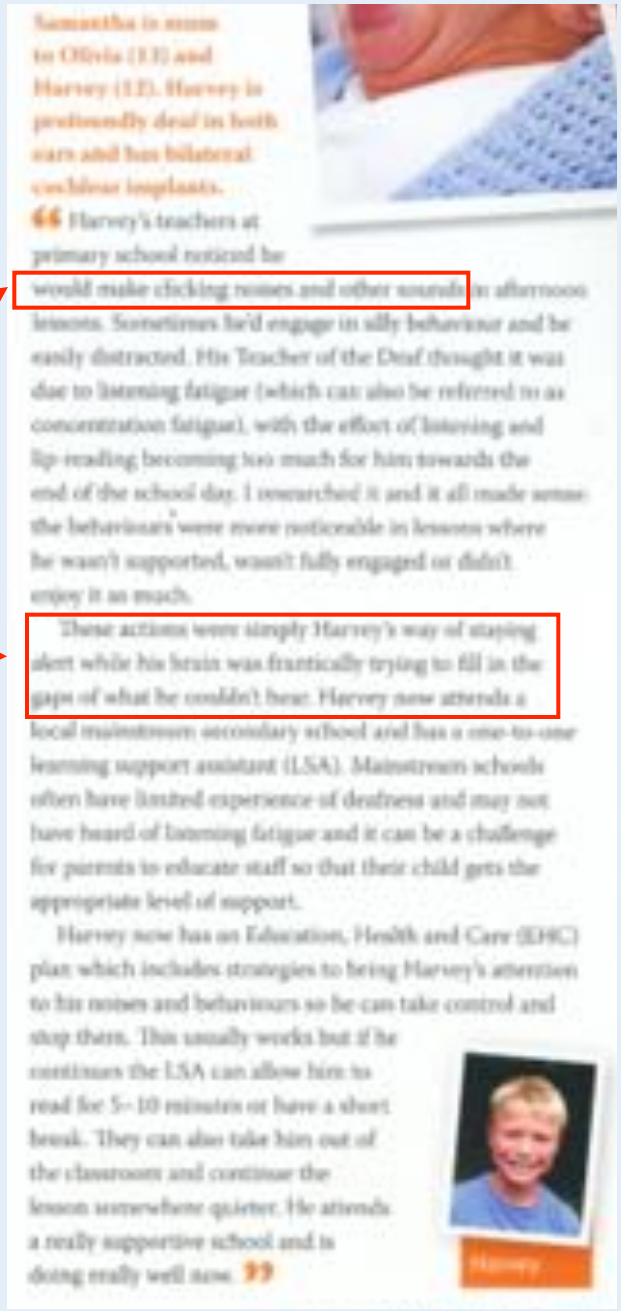
I help Jack break up his homework and studying into manageable chunks and timetable it with lots of breaks in between. I sit with him while he's working to help him stay on task but I let him lead the timetabling process so it's manageable for him. I encourage alone downtime, but I always make sure he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

Jack

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**

Listening effort had reached to such an extent that a 12 year old boy had developed a tic……



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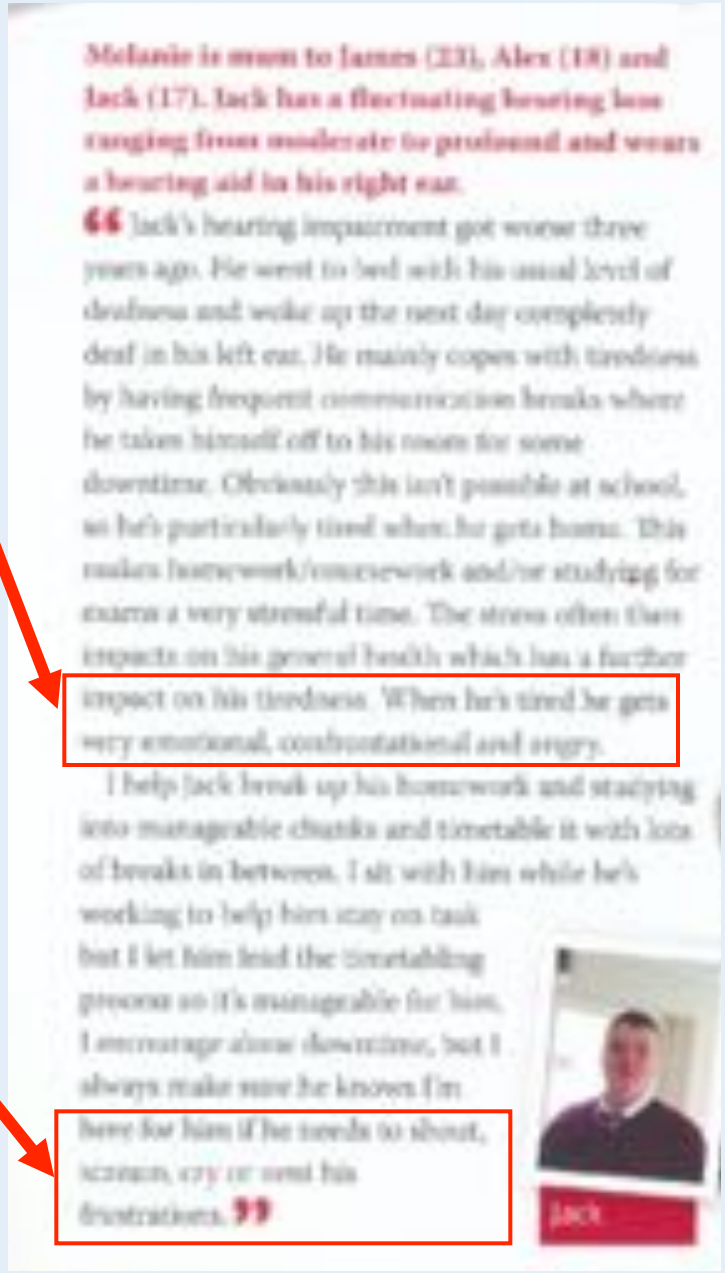
These actions were simply Harvey's way of staying alert while his brain was frantically trying to fill in the gaps of what he (couldn't) hear.

Listening effort was so overwhelming that a 17 year old boy 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 showtime, 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 that a 9 year old girl 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.

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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.

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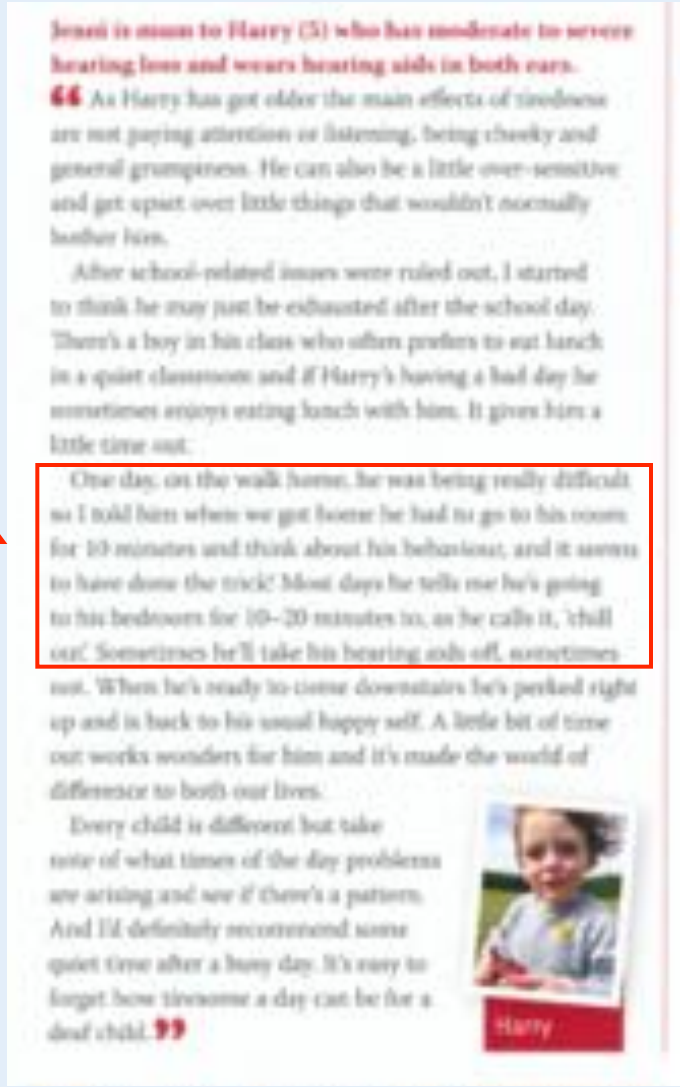
Sometimes she wants to take her hearing aids off and not do anything. More often she becomes emotional and frustrated and hates deafness. Let your child have a break

Listening effort had become so overwhelming that a 5 year old boy 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 room) …….



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Harry

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 20 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.

The parents in these case studies did manage to find strategies to help the child cope with the ongoing burden of listening effort.

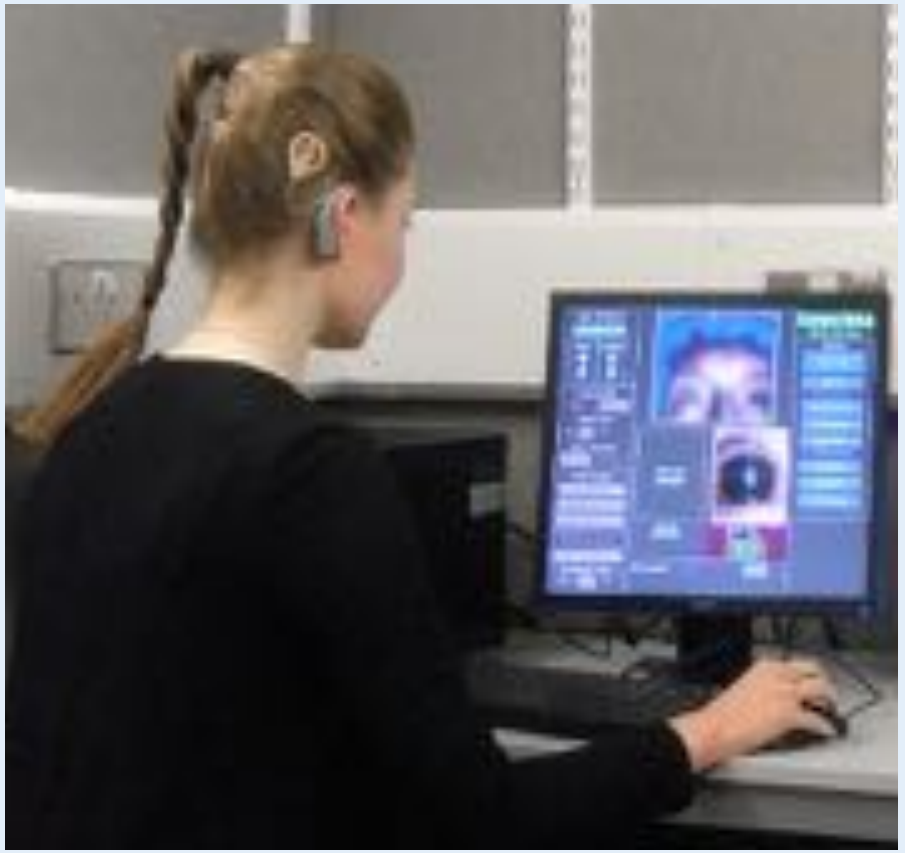
However, those case studies were very clear examples of how much of an impact L.E. can have on the everyday life of a deaf child, especially in school.

Which leads to the question of:

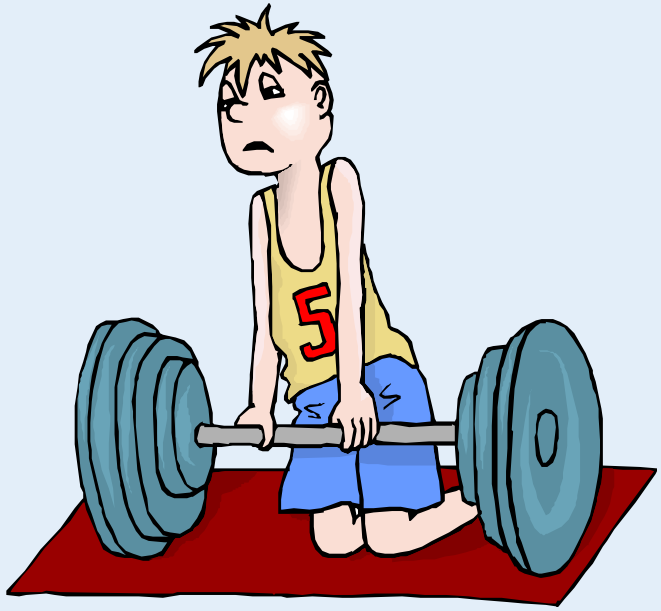
***What is the cost of listening effort on academic attainment?***

I strongly believe that, by deliberately switching of my speech processor to create periods of silence during the day, it is possible to temporarily relieve this debilitating burden of listening effort and liberate cognitive capacity for additional learning.

It is just possible that this is why I have been able to progress as far as I have academically.



Ideally, it should be possible to recognise immediately when the burden of L.E. 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 L.E. is so vital, so that each individual can come to know their own limits and work within them in order to **unlock their academic potential**.

My PhD is focusing on the development of some kind of tool to measure L.E.

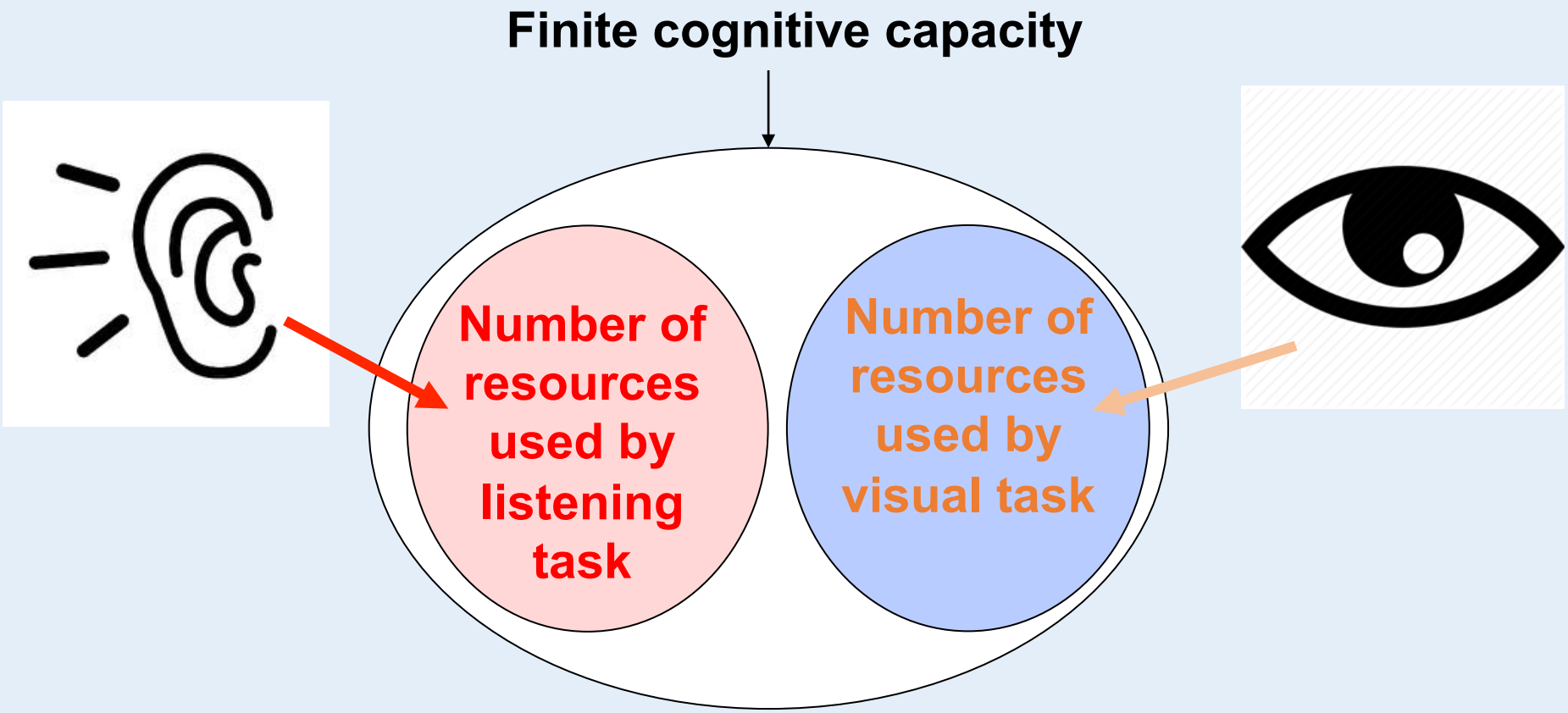
I am currently experimenting with using a kind of multi-tasking, called the **dual-task paradigm**, as the basis of a simple behavioural test that could be implemented at home and at school, as well as in the clinic.

The principle is that, when a participant is forced to multi-task and perform two tasks simultaneously, if one of the tasks becomes more difficult, performance on the second task will suffer.

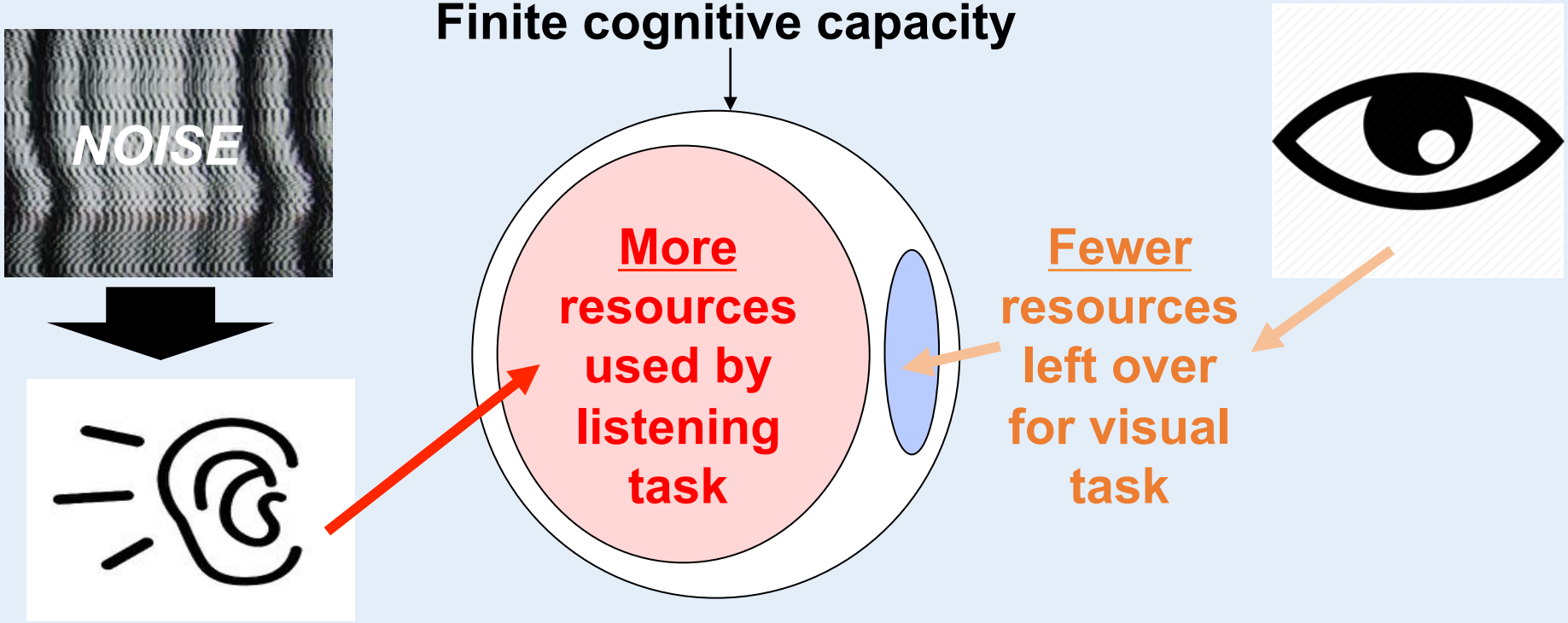
This means that, theoretically, the dual-task paradigm can be used to both generate and measure listening effort.

The dual-task paradigm is currently designed so that:

- The **primary task** (i.e. the task that the brain is required to focus on) is a **listening task**.
- The **secondary task** (which 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), so that the brain is required to move cognitive resources away from the **secondary task** and towards the **primary task**, there will be fewer resources left over for the **secondary task**.




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

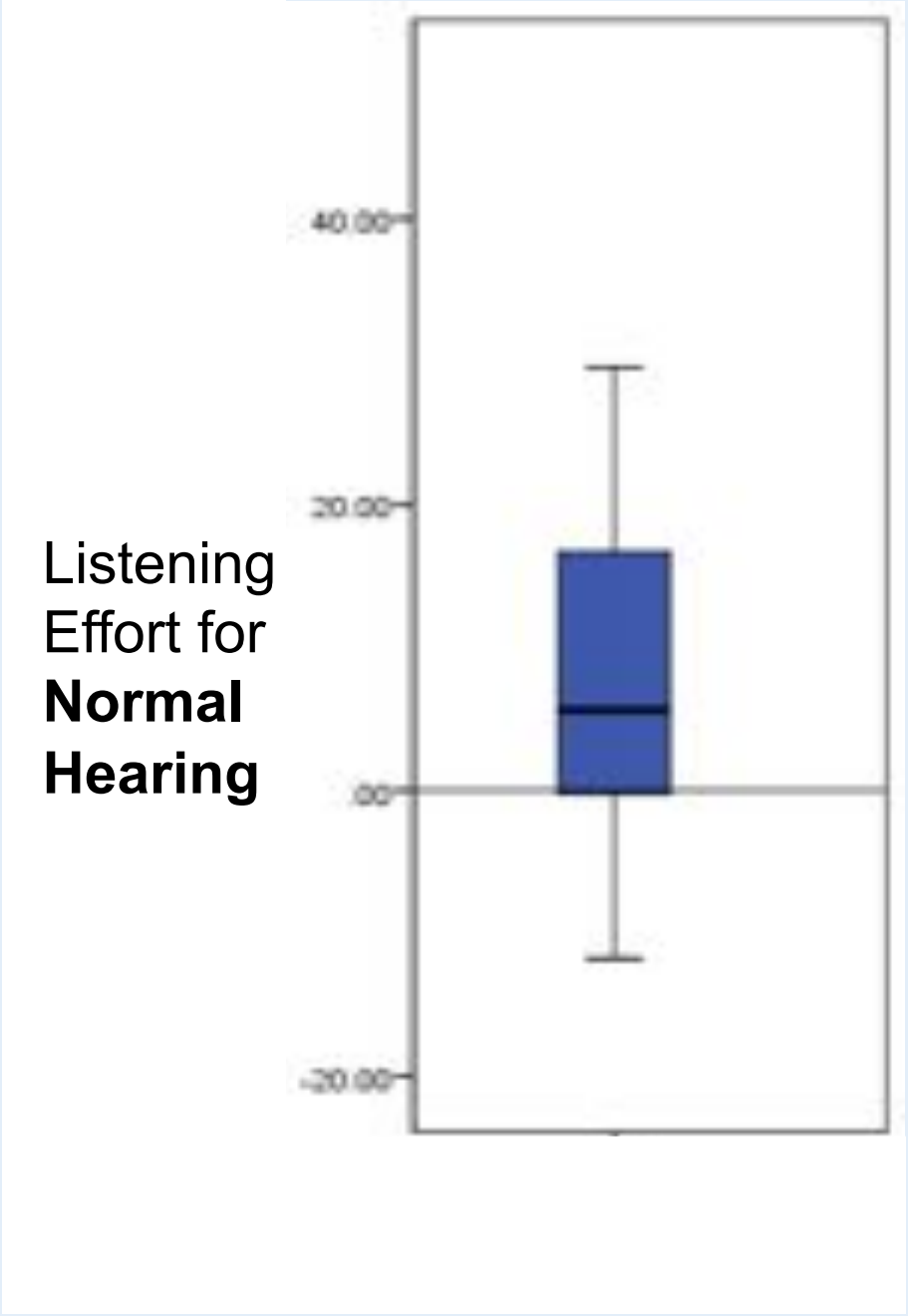
Over the past two years, I have experimented with variations of the dual-task paradigm, with:

- **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 the version of the dual-task paradigm that is the most sensitive for measuring listening effort.

The data gathered so far suggests the following:

1. It is possible to measure listening effort using the dual-task paradigm.
2. Listening effort is significantly higher in those with hearing impairment, and perhaps dangerously so.



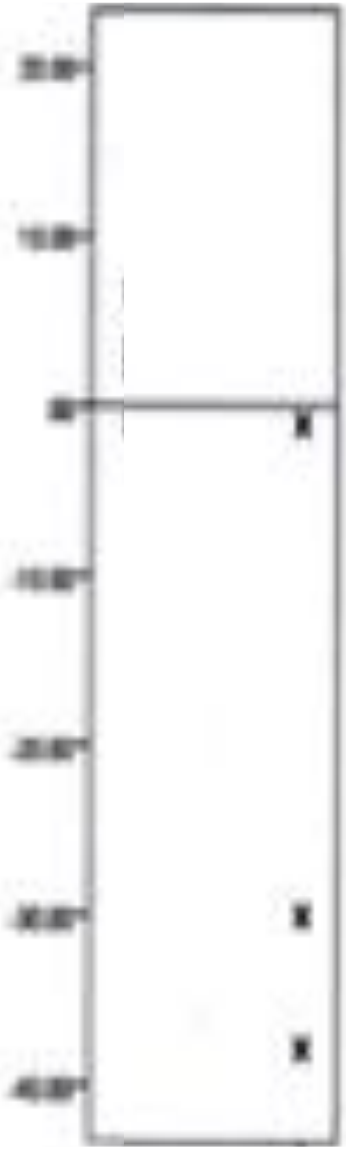

For example, here is a box plot showing the L.E. scores of normal hearing participants listening with background noise (i.e. signal-to-noise ratio of -6dB).

The vast majority of the participants showed a positive L.E. score…..

i.e. their visual accuracy (secondary task performance) **decreased** in noise

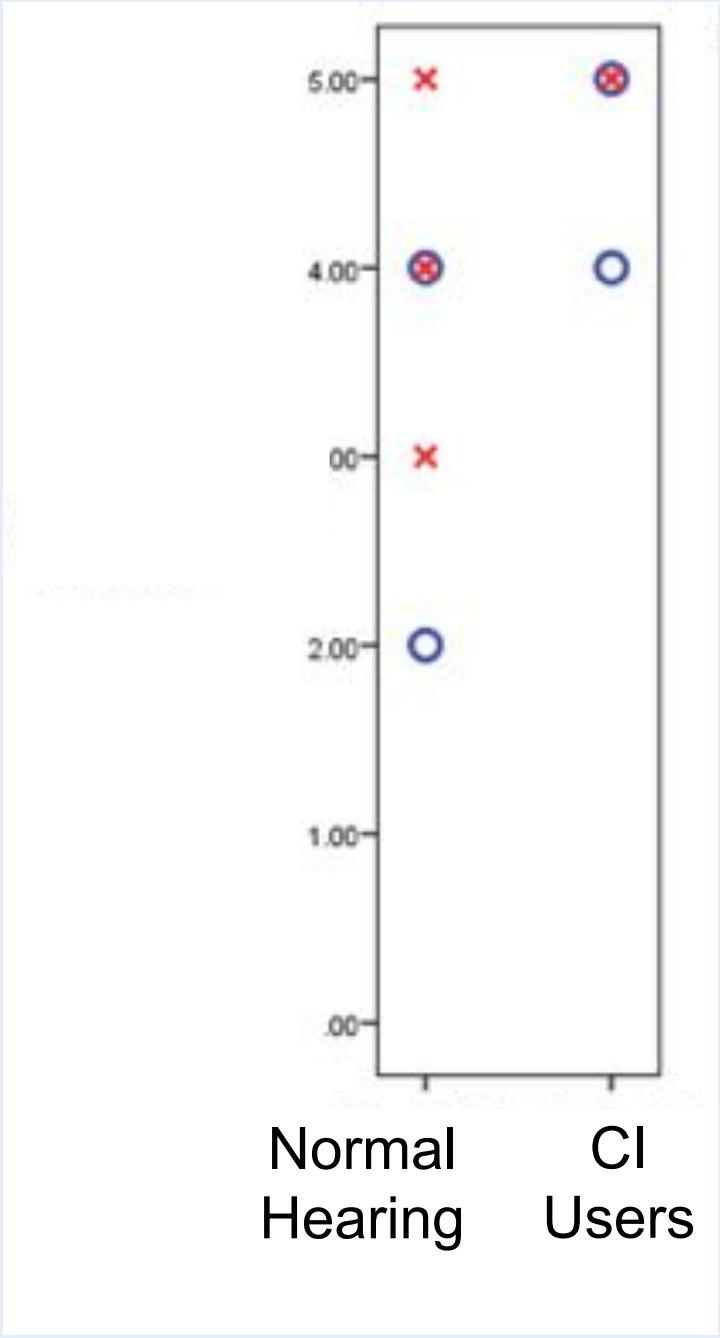
**= increased Listening Effort in noise**

Listening Effort for **Cochlear Implant Users**



However, when the L.E. levels were measured for the CI users, they showed a negative score, suggesting that their listening effort had **<u>decreased</u>** when listening in noise.

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

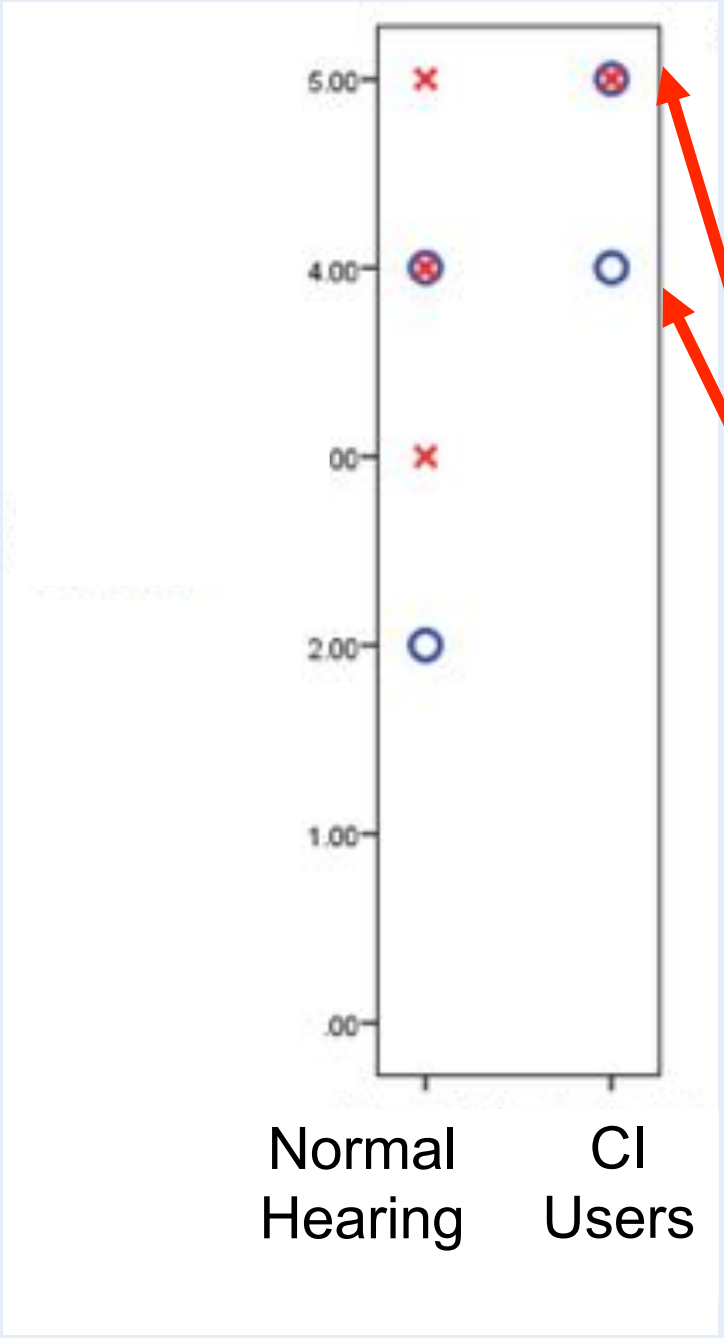



1 = Not at all hard work
2 = Quite hard work
3 = Medium hard work
4 = Very hard work
5 = Extremely hard work

Subjective ratings had been obtained at the same time.

This shows the subjective ratings of listening effort when performing the dual-task paradigm in quiet (the blue circles) and in noise (the red crosses).

As expected, the normal hearing controls perceived listening effort as higher when listening in **noise**.

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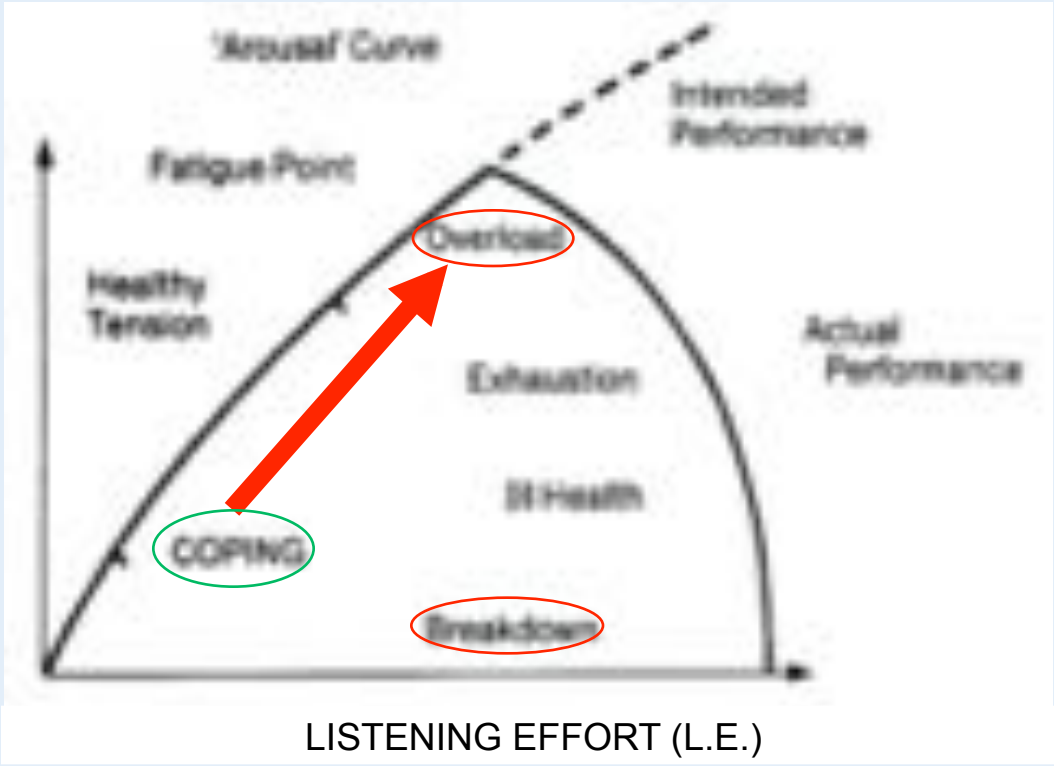
What is particularly striking, however, is that these experienced CI users were rating listening effort as being “very hard work” or “extremely hard work”, **even in quiet**.

So, when the listening conditions were optimal (i.e. in quiet), the addition of the visual task seem to substantially add to the level of difficulty in understanding the auditory stimuli.

For a simple visual task to have such an impact on subjective ratings in quiet suggests that considerable listening effort must **already** be experienced with processing the auditory stimuli, despite there being **no** background noise.

This means that when noise was introduced, the listening demand became so excessive that it actually induced **LE overload** and subsequent **breakdown** in performance.




LISTENING EFFORT (L.E.)

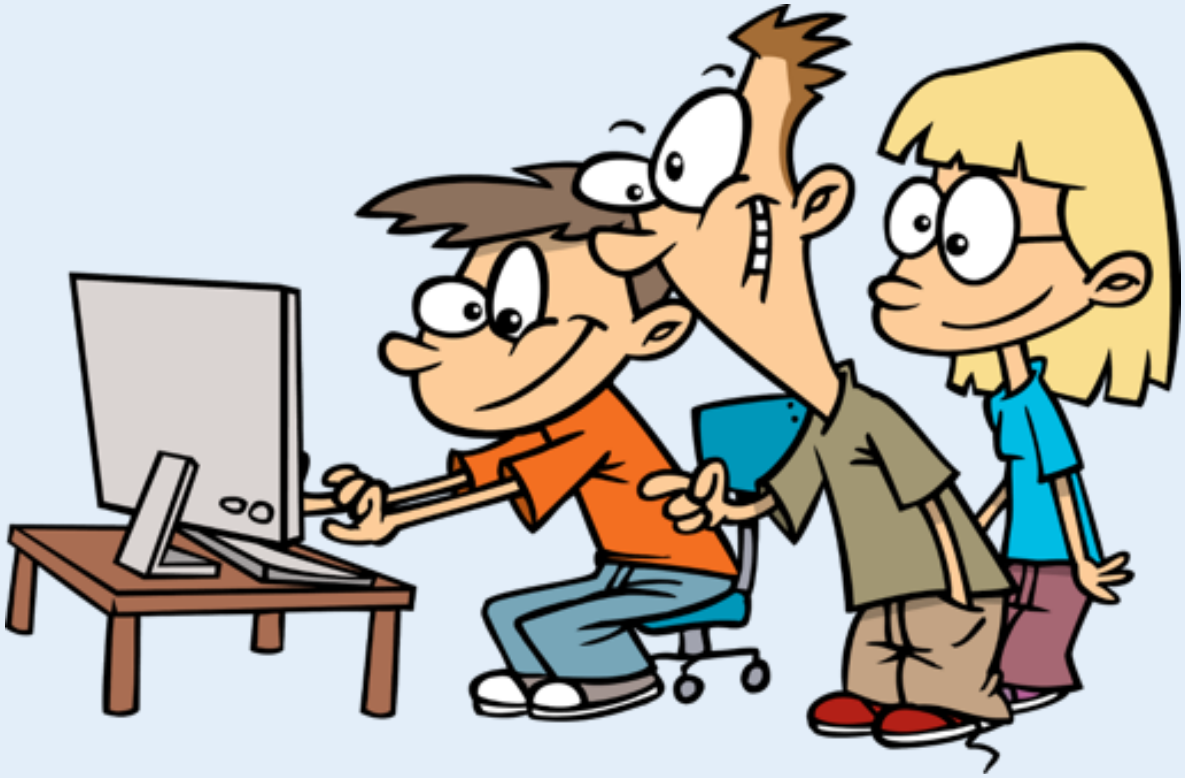
At this point, the CI users then simply “gave up” and stopped trying to distinguish and recall the words spoken in the test. They focused instead on the visual task. This would then bolster their visual accuracy scores.


LISTENING EFFORT (LE)

Since it was the visual accuracy score being used as an index of L.E. in the dual-task paradigm, this improvement in visual accuracy (in noise) would lead to counter-intuitive decreases in the L.E. score.

So, ironically, it seems that in trying to develop a test to measure L.E., I had introduced so much L.E. that I had overwhelmed my CI participants and they could no longer manage.

I am spending this final year of my PhD fine-tuning the dual-task paradigm with the hope that my research could provide the basis of a new clinical test of listening effort that might become part of standard assessment and monitoring for deaf individuals, adult and child.



I sincerely hope in the future that those with hearing loss will be spared the damaging burden of listening effort and also that it will become accepted that reducing listening effort is vital to unlocking academic potential and improving academic attainment.


**Thank you for your listening effort today.**

UCL

Hear now. And always. Cochlear™

ACTION ON HEARING ~~LOSS~~