Use of Frequency Compression to Improve Speech Understanding for Children

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Traditionally Frequency Lowering for Profound HL

Example criteria:

Audiometric thresholds
- Right hand corner audiogram
- Steeply sloping hearing losses
Like these:
Aim: to make inaudible HF speech cues audible by lowering frequency

By: 1. Frequency compression
Compressing the frequency range down from a specified frequency (compression threshold)

2. Frequency transposition
Mixing or overlapping HF with uncompressed low frequency information
SoundRecover, non-linear frequency compression
SoundRecover – Research Studies

Adult studies have reported:
- Increased detection, discrimination and recognition of sounds
- Fast acclimatization
- Significant improvement in intonation and overall voice quality
- Improved hearing of high pitched sounds and better speech understanding
- Reduced whistling in the hearing instrument
- Better perception of accent of speaker
Paediatric Audiologist rule:

“If child well aided, don’t change amplification unless good evidence for benefit”
Can we demonstrate speech recognition benefit on individual basis?
How long will it take for child to acclimatise to new signal?
Is there acoustic feedback?
Is the device robust, also with FM? etc etc
Need to compare hearing aid amplification prescription fitting
Hearing aid amplification prescription with frequency comp
Can we apply FC to flat configurations?
Good speech and language dev (8 yrs and 10 yrs)
<table>
<thead>
<tr>
<th></th>
<th>Trad HA</th>
<th>Freq Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Open set words</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 dB</td>
<td>97%</td>
<td>91%</td>
</tr>
<tr>
<td>50 dB</td>
<td>54%</td>
<td>82%</td>
</tr>
<tr>
<td><strong>Closed set</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Det 60 dB</td>
<td>84%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Closed set</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disc 60 dB</td>
<td>89%</td>
<td>93%</td>
</tr>
</tbody>
</table>
### Sub 2 Speech scores (no acclim)
Open set pre-recorded words

<table>
<thead>
<tr>
<th>Open set words</th>
<th>Trad HA</th>
<th>Freq Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 dB</td>
<td>88%</td>
<td>88%</td>
</tr>
<tr>
<td>60 dB</td>
<td>63%</td>
<td>88%</td>
</tr>
</tbody>
</table>
Dad on watching speech testing: “Wow, how can that hearing aid be making so much difference?”

Report back of improved performance with whole words and connected speech

More confident in class, putting his hand up more to answer class questions

Clearer speech articulation

Enjoying being read to more

*Can’t rely on these informal observations for decision to change hearing aids, need robust assessment*

Subject 2: no overt functional change noted by family
What do we want to check?

Comparison between trad HA and Freq Comp in:

- Detection of high frequency speech sounds
- Discrimination of vowels
- Discrimination between consonants
- Recognition of words
- Understand running speech
- Informal observation
- Opinion of child, including detection of noise floor
Detection of phonemes

- Closed set detection task:
  - eye, ice, lice, slice (/s/)
  - pay, pace, space, face
  - eye, wine, why, wise (/z/)
- Ling 5 (Ling 6 had /u/ /m/ confusions for NH)

Repetition task: oo ar ee sh ss (not live voice)
Speech banana
Speech banana
Consonant discrimination

Closed set testing with four item picture task

- Age 2 – 4 years (40 items)
  Eg horse, fork, ball, door
  hen, peg, egg, bed

- 4 - 7 years (40 items or 60 items)
  Eg fat, cat, bat, mat (word-initial)
  cheese, cheat, cheap, cheek (word-final)

Derive confusion matrix of the errors

Significant difference if > 9.3% (10%) change in score,
(s.d.=2.3)
Subject A: female 6 years old

Closed set test
Take best ear 3 freq average: 80dB x 0.4 = 32 dB
Add to NH level for test = 30 dB
Present at 62 dB
Subject A: Scores (no acclim, in one 2 hour appt)

<table>
<thead>
<tr>
<th></th>
<th>Open set</th>
<th>Trad HA</th>
<th>Freq Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>wds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 dB</td>
<td>88%</td>
<td></td>
<td>97%</td>
</tr>
<tr>
<td>50 dB</td>
<td>76%</td>
<td></td>
<td>91%</td>
</tr>
<tr>
<td>Ling 5 /u i a/</td>
<td>45 dB</td>
<td>45 dB</td>
<td></td>
</tr>
<tr>
<td>/sh s/</td>
<td>55 dB</td>
<td>45 dB</td>
<td></td>
</tr>
<tr>
<td>Closed set</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>detect</td>
<td>71%</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>discrim</td>
<td>75%</td>
<td></td>
<td>97%</td>
</tr>
<tr>
<td>vowel in noise</td>
<td>91%</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>
Subject A: phoneme analysis

Errors on closed set: Trad HA
Disc: kick/tick, bug/buzz, stork/chalk, fat/cat, white/right
Vowel: cat/cut, tar/tie, bark/buck
Det: bee/bees, shoe/sue, bean/bee

Errors on closed set: FC HA
None, except Disc: pick/thick
Why would HF compression improve vowel discrimination?

- Formant frequencies vary widely between speakers
- Vowels give context for identification of consonants
- Cannot separate the consonants from vowels
- Vowel formant frequencies extend to 2500 Hz
Cardinal vowels

F1 & F2 for cardinal vowels, average male speaker

Front vowels (unrounded)  Back vowels (rounded)
aga – velar pinch

Plosive bursts

apa – not much here

ata – high frequency burst
Important to check with low CT that vowel discrimination is good
Improved perception of accent?

May relate to improved vowel information and voice onset time changes

**Subject 1** does a very good imitation of his broad Lancashire accent teacher, since FC

**Subject A** also comments on accents

*Need more research on this observation*
Subject A: female 4 years old

Closed set test
Take best ear 3 freq average: 57 dB x 0.4 = 22 dB
Add to NH level for test = 30 dB
Present at 52 dB
Video clips: 4 year old

No 1: changing hearing aid to Freq compress
No 2: giving some experience of Ling 5 sounds and closed set testing
No 3: open set testing at 50 dB
No 4: her opinion of the hearing aid sound qual
Consideration for FC for steeply sloping HL in complex needs

7 years (twin)
- Pre-term 24 weeks
- Severe delay sp and Ig
- Cerebral palsy
- Mild dysarthria
- Dyspraxia
- Total communication support in early years
Check real ear measure prescription, esp comp thresh (CT)
Video of closed set testing

- Video
Notice high pitched voice quality
Can’t do open set testing due to scoring diffs
**Immediate results:**

<table>
<thead>
<tr>
<th></th>
<th>Eterna 311</th>
<th>Naida VUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing 65dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vowel</td>
<td>66.7%</td>
<td>25%</td>
</tr>
<tr>
<td>Cons Detect</td>
<td>33%</td>
<td>25%</td>
</tr>
<tr>
<td>Cons Disc</td>
<td>80%</td>
<td>47%</td>
</tr>
</tbody>
</table>
One month on:

Refuses to wear Eterna 311 (even though Chelsea blue) rather than Naida

Why? “better”

Hears new high frequency sounds (reversing bleeps, birds etc)

Joining in more to spoken conversation

Less problems with acoustic feedback
3 months later results:

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<tr>
<td>vowel in noise</td>
<td>67%</td>
<td>70%</td>
</tr>
<tr>
<td>Cons Detect</td>
<td>33%</td>
<td>60%</td>
</tr>
<tr>
<td>Cons Disc</td>
<td>80%</td>
<td>77%</td>
</tr>
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</table>
Discrimination performance

- May assume dead regions (DR) above 3 kHz
  - Freq Comp reduces constraints of DR on disc. Important consideration for potential CI candidates

- HA at 18 months, consistent use from 3 years only due to frequent ear infections

- Discrimination may be constrained by limited early exposure to HF sound, extensive auditory work now

- Underlines importance of early amplification to stimulate neural pathways for speech disc
Five Individual Cases:

Can we demonstrate significant speech recognition benefit for an individual child?

_Broadly, yes, need careful attention to test-type and presentation levels_

How long will it take for child to acclimatise to new signal?

_May depend on established listening skills, but often very fast change in performance_
Five Individual Cases:

Is there acoustic feedback?

*Easier to prevent feedback*

Is the device robust, also with FM?

*Check audible noise level, self and ask child*

*Need good FM as always with acoustic HAs*

What age would children benefit from FC?

*If limited hearing above 4000 Hz then probably, from first years of life.*

What can the child tell you?

*We need to be able to listen to them.*
A case-study isn’t a controlled trial

but it’s a good place to start….. and finish