FREQUENCY TRANSPOSITION IN HIGH FREQUENCY SNHL

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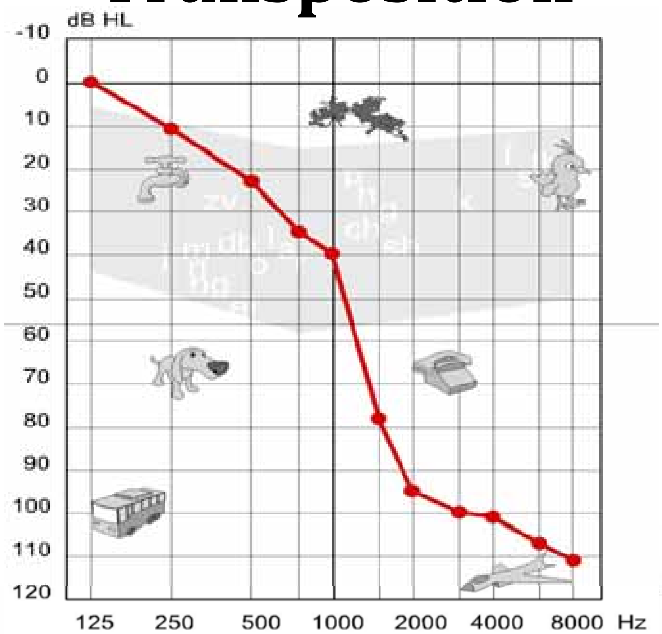
Background

Concept Of Frequency Transposition

Frequency **transposition** (**lowering** or **compression**)is an audio **signal processing** method used in digital hearing aids. (1)

In severe hearing loss, **inaudible high frequencies** are **compressed** into **regions of residual hearing** in an attempt to improve their audibility and discriminability.(1)

Importance Of Frequency Transposition



Cochlear Dead Regions

Frequency transposing hearing aids are intended to patients with cochlear dead regions.

Characteristics :

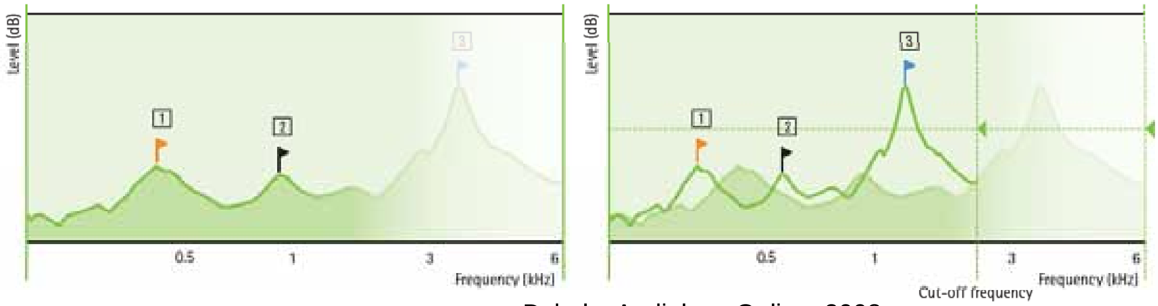
- **HL of >90 dBHL** at high frequencies
- Audiogram **slope is > 50 dB/Octave**
- Extremely **poor speech recognition** scores in quiet and noisy situations
- Distorted "**noise -like**" perception of pure tones (2)

Earlier Trials For Frequency Transposition

- Directional microphones
- Open-fit instruments
- Inter-modulation distorted signals (3,4)

Early Schemes For Transposition

Shifts **all frequencies** within the **amplified** sound upon detection of a signal above a particular high frequency.



Dybala, Audiology Online, 2008

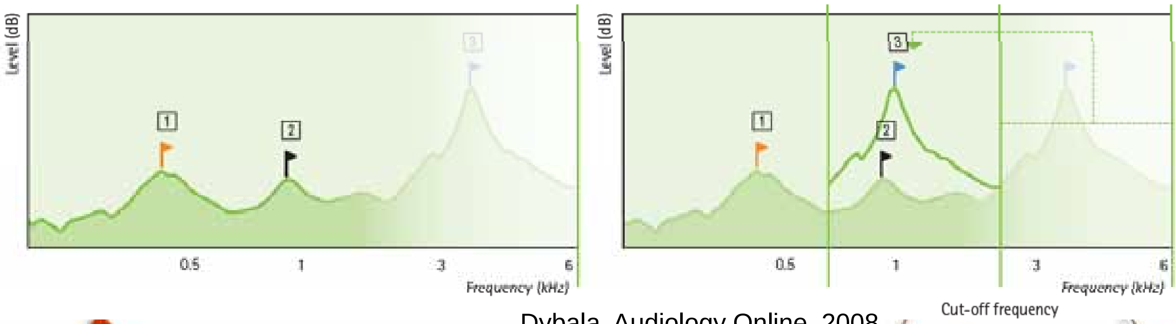
Early Schemes For Transposition

Drawbacks:

- Enabling and disabling the transposition can produce **distracting artifacts** that are audible to some hearing instrument users.
- Changing **fundamental & formant frequencies** of talker (female may sound like a male) .(5)

Early Schemes For Transposition

Identifies a **range** of **amplified** high frequencies to be shifted downward **overlapping** with the lower frequencies present in the input signal. *(5)*



Dybala, Audiology Online, 2008

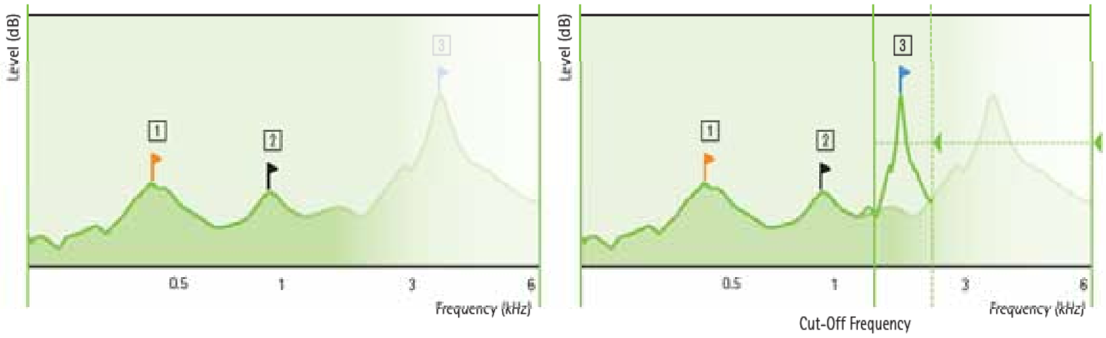
Early Schemes For Transposition

Drawbacks:

- Production of **artifacts** such as **blurring of vowel** sounds in the overlapping region &impacting sound quality. *(5)*

Non-linear frequency compression

An algorithm moves and **compresses** the sounds above a defined **cut-off frequency** to an **adjacent** area with less cochlear damage, where they can be processed and **amplified.** *(5)*



Dybala, Audiology Online, 2008

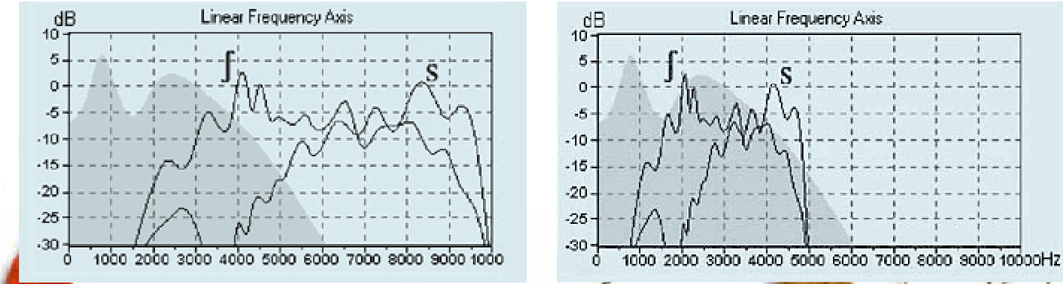
Non-linear frequency compression

Advantages:

The compressed frequency **do not overlap** with lower frequencies. *(5)*

Proportional Frequency Compression

Dynamic Speech Re-Coding ,a selective compression process ,first identifies **specific characteristics** in speech to determine if it needs to be frequency compressed. Only the **desired sounds** are **proportionally compressed** into lower frequencies .(6,7)



Davis, Hearingreview, 2001

Proportional Frequency Compression

Advantages:

Relationships of the energy peaks within a sound and between sounds are **maintained** giving the sound its identity and allow for discrimination. (6,7)

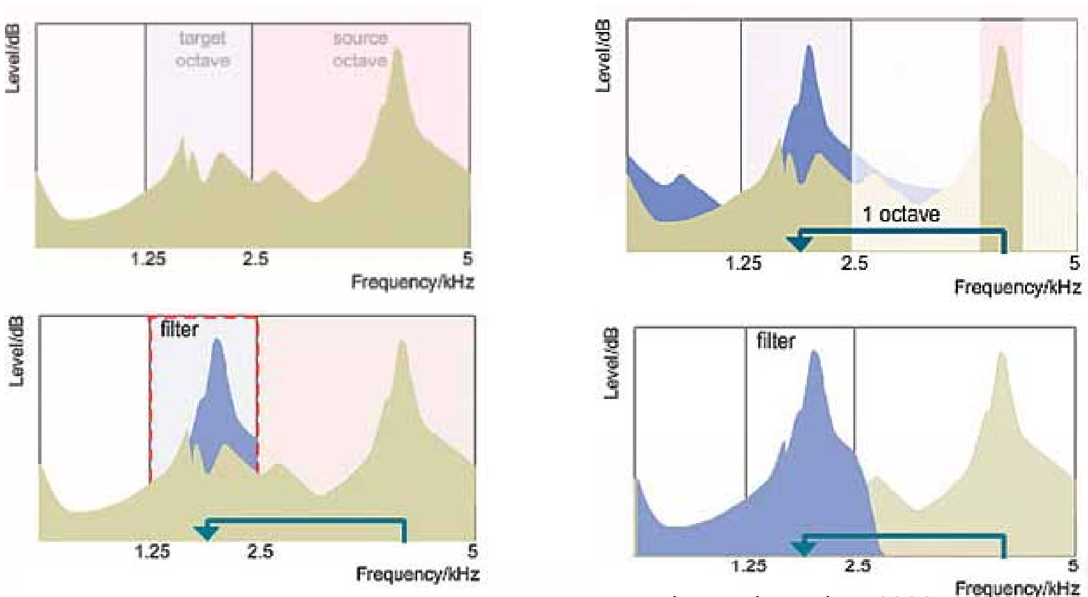
Linear Frequency Transposition

Using the **Audibility Extender** (AE) algorithm one **octave** of high frequency sounds above a **start frequency** is transposed down in frequency by one octave.

The **spectral peak** of the sound is identified and **filtered** out to avoid the need for compression.

The transposed signal is **mixed** with the original signal and then **amplified.** *(8,9,10)*

Linear Frequency Transposition



Kuk, Hearingreview, 2006

Linear Frequency Transposition

Advantages:

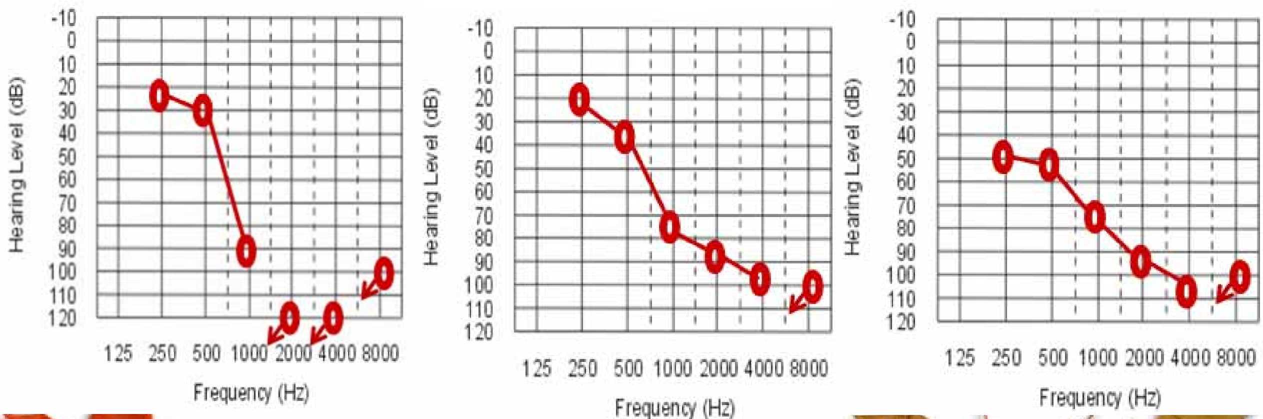
The mixing of transposed sound with the original signal give a more "**natural**" sound perception. *(8,9,10)*

Study Cases

Pure Tone Audiometer

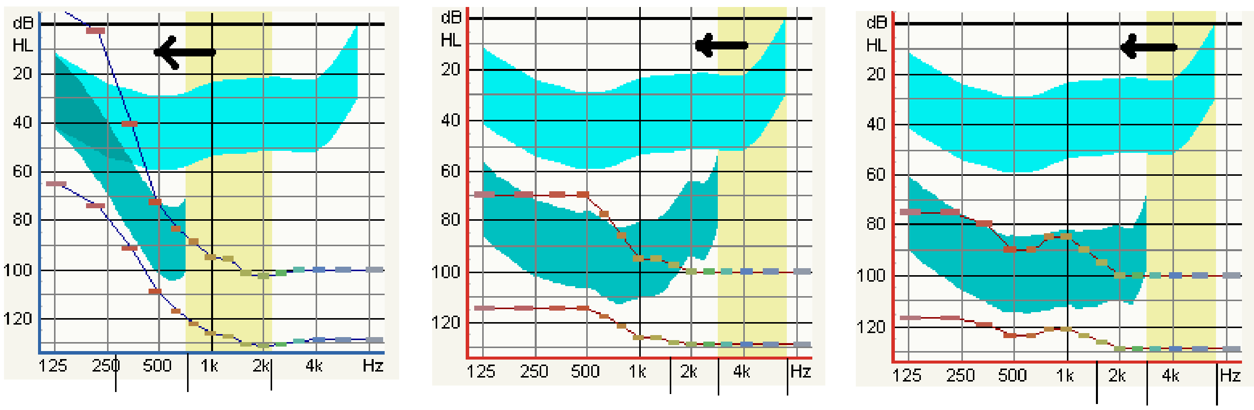
In an attempt to study the effect of **linear** frequency transposition, **3 adults** with high frequency **steeping SNHL** were selected.

Case#1 Case#2 Case#3



Source And Target Octaves

Case#1 Case #2 Case#3



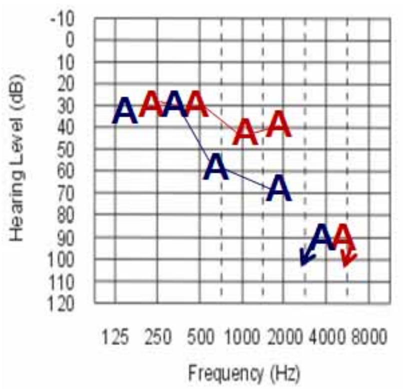
280 800 2200

1600 3200 6400

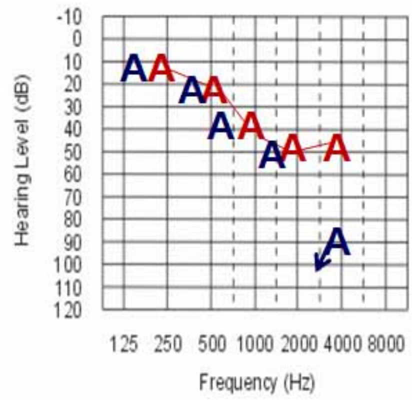
1600 3200 6400

Aided Free Field Responses

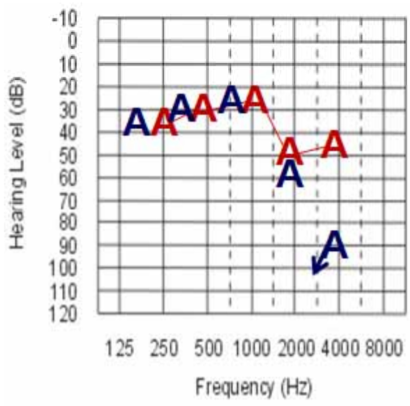
Case#1



Case#2



Case#3



A - A With AE

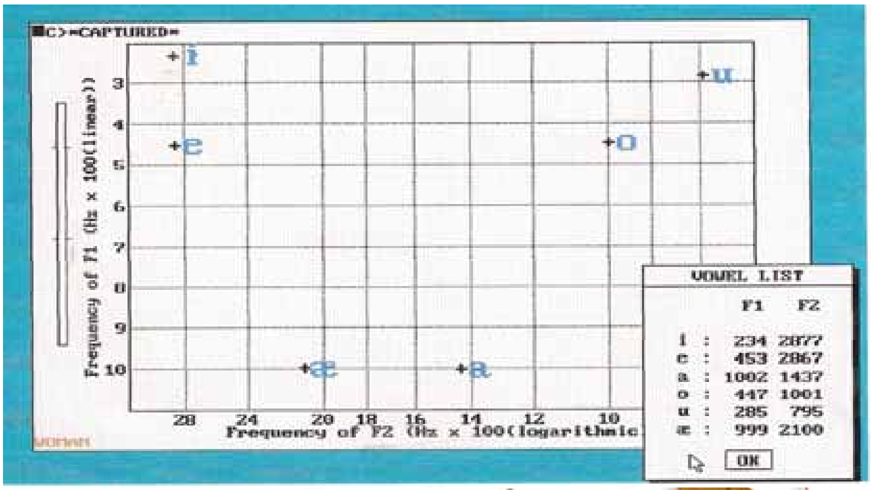
A - A Without AE

Auditory Perception Tests

Vowels

Cues for perception:

➢ The **relationship** between **F1 and F2**



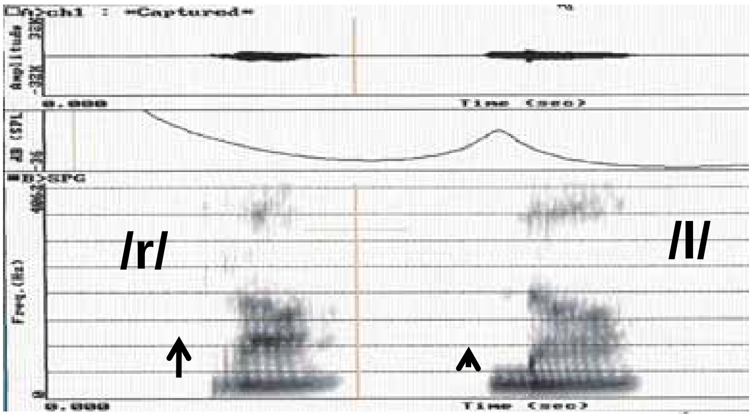
Vowels

Case #1	Detection	Identification
é AE	50%	50%
é out AE	100%	75%
Case #2,3		
é AE	100%	75%
é out AE	100%	100%

Consonants
Laterals

Cues for perception:

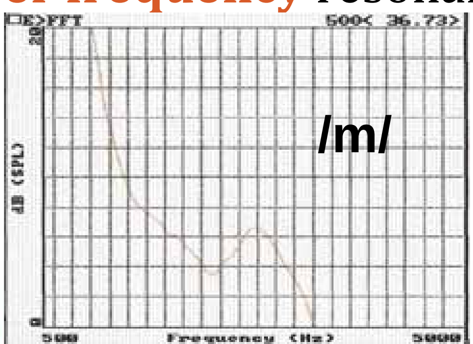
- **Formant transition** (FT)

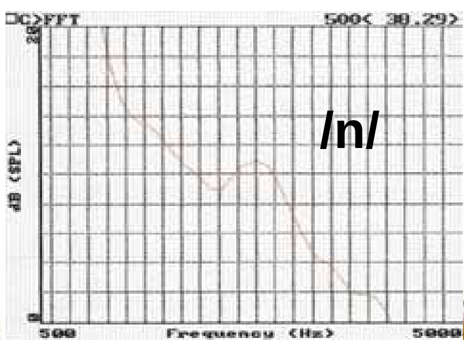


Consonants
Nasals

Cues for perception:

- **Formant transition** (FT)
- **Direction** of transition
- **Lower frequency** resonance

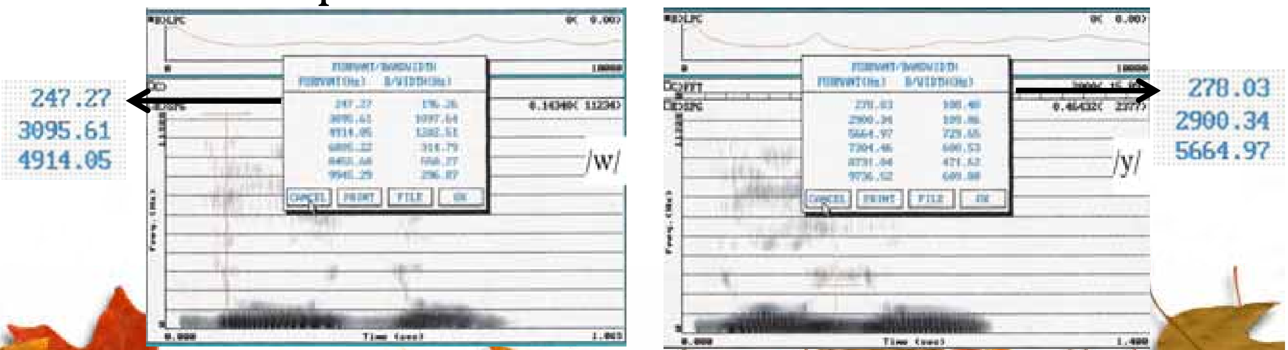




Consonants
Glides

Cues for perception:

- Long **Formant Transition** (FT) due to slow movement from one articulatory position to another.
- Relationship between **F2 and F3**



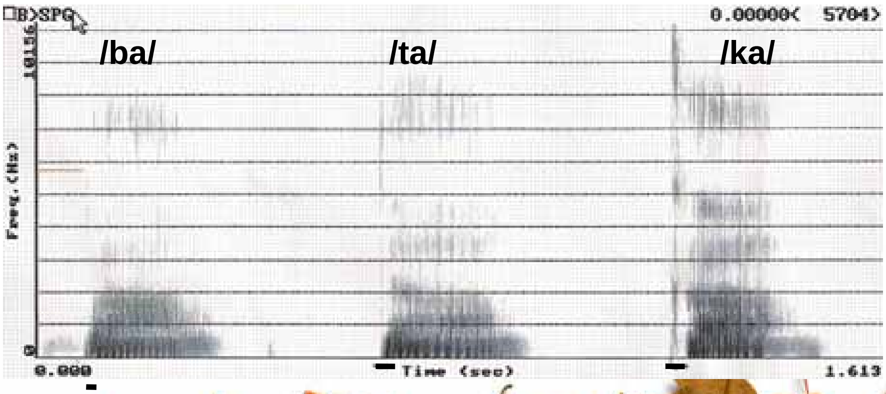
Consonants
(Laterals, Nasals & Glides)

Case #1,2,3	Detect and identification					
Aided	laterals		nasals		glides	
	/r/	/l/	/m/	/n/	/w/	/y/
é AE	✓	✓	✓	✓	✓	✓
é out AE	✓	✓	✓	✓	✓	✓

Stops

Cues for perception:

- **Voice onset time** (VOT)
- Silence duration
- Formant transition (FT)



Stops

Case #1,2,3	Detection and identification				
Aided	/b/	/t/	/d/	/k/	/g/
é AE	✓	✓	✓	✓	✓
é out AE	✓	✓	✓	✓	✓

Fricatives

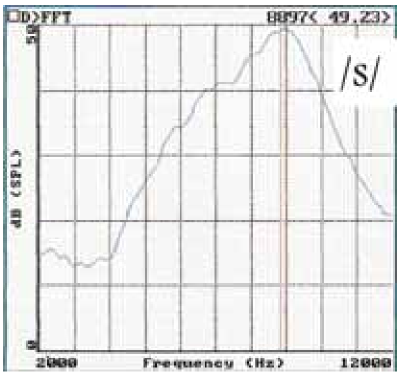
Cues for perception:

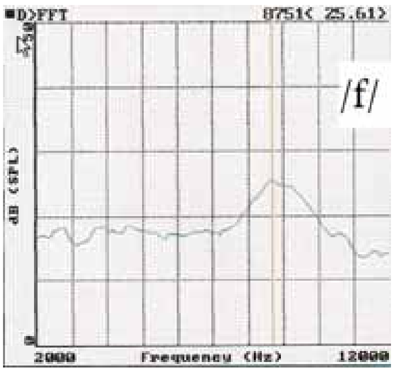
- Formant peak
- Formant transition

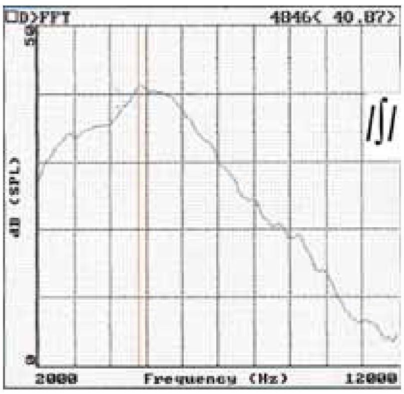
Cues for voiced fricatives perception:

- Periodicity
- High amplitude of 1st harmonic

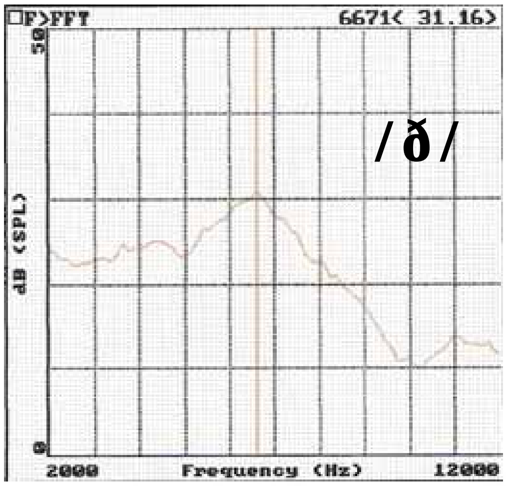
Fricatives







Voiceless Vs Voiced Fricatives

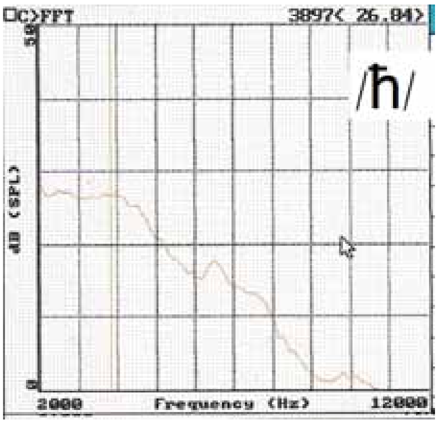


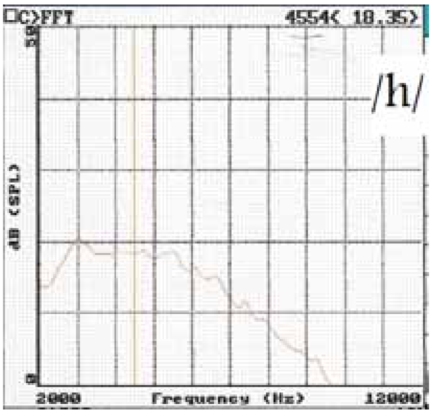
Fricatives

Case #1	Detection										Identification
Aided	/ʃ/	/s/	/f/	/θ/	/x/	/ð/	/z/	/ç/	/ħ /	/h/	voiced
é AE	×	×	×	×	×	✓	✓	✓	×	×	×
é out AE	×	×	×	×	×	✓	✓	✓	✓	✓	✓

Case #2,3	Detection										Identification
Aided	/ʃ/	/s/	/f/	/θ/	/x/	/ð/	/z/	/ç/	/ħ /	/h/	voiced
é AE	✓	×	×	×	×	✓	✓	✓	✓	✓	✓
é out AE	×	×	×	×	×	✓	✓	✓	✓	✓	✓

Fricatives





Conclusion

With the **AE on** ,study cases showed:

- Improved free field aided responses.
- An overall poorer results in Auditory perception tests.
- Overlap of vowels by the transposed sounds.
- Better detection of mid frequency and voiced consonants.
- Difficulty in perception of place of articulation of consonants.

Why some Hearing Aid Wearers React Negatively to Transposition?

(Literature)

At a **cortical level** , the new information that becomes available will be **"foreign"** to the brain and could be perceived as **unnatural.**

For the brain to recognize the new information as natural, **new space** will have to be allocated for the new cues, or a **different neural representation** that utilizes the existing neurons must be formed.*(2)*

Recommendations of present study

- A **less aggressive approach** will minimize the disturbance on the original signals.
- If the unnaturalness is unavoidable because of the extent of frequency lowering , make the frequency lowering **algorithm optional.**

Considerations in Frequency Transposition from present study

- Apply an appropriate structured **training program** directed towards improving sound recognition for both **speech and non-speech** sounds in view of amplitude versus frequency cues based on FFT contrast.

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Thank you