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

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**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)

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)

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)*

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

Advantages:

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

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

### Pure Tone Audiometer

**Case#1**

- Source: And Tar
- Target Octaves: 280, 800, 2200

**Case#2**

- Source: And Tar
- Target Octaves: 1600, 3200, 6400

**Case#3**

- Source: And Tar
- Target Octaves: 1600, 3200, 6400

### Source And Target Octaves
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

<table>
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<tr>
<th>Case #1</th>
<th>Detection</th>
<th>Identification</th>
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<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>é out AE</td>
<td>100%</td>
<td>75%</td>
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<tr>
<td><strong>Case #2,3</strong></td>
<td></td>
<td></td>
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<tr>
<td>é AE</td>
<td>100%</td>
<td>75%</td>
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<tr>
<td>é out AE</td>
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</table>
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**

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Consonants
(Laterals, Nasals & Glides)

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<td></td>
<td>/r/</td>
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<td>✓</td>
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<tr>
<td>é out AE</td>
<td>✓</td>
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Stops

Cues for perception:
- **Voice onset time** (VOT)
- Silence duration
- Formant transition (FT)

Case #1,2,3 Detection and identification

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<td>✔</td>
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<tr>
<td>é out AE</td>
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Fricatives

Cues for perception:
- Formant peak
- Formant transition

Cues for voiced fricatives perception:
- Periodicity
- High amplitude of 1st harmonic
Voiceless Vs Voiced Fricatives

Fricatives

<table>
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<tr>
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<td>voiced</td>
</tr>
<tr>
<td>é AE</td>
<td>x x x x ✓ ✓ ✓ x x x</td>
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<td>voiced</td>
</tr>
<tr>
<td>é AE</td>
<td>✓ x x x x ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
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<tr>
<td>é out AE</td>
<td>x x x x x ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
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Fricatives

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.

References


3. Francis Kuk, PhD; Denise Keenan, MA; Heidi Peeters, MA; Petri Korhonen, MS; and Jane Auriemmo, AuD12 Lessons Learned About Linear Frequency Transposition. [document on the Internet]. Vaerloese, Denmark.; -november2008.availablefrom:http://www.hearingreview.com/issues/articles/asp.


References


8. Francis Kuk, PhD; Petri Korhonen, MSc; Heidi Peeters, MA; Denise Keenan, MA; Anders Jessen, BSEE; and Henning Andersen, MS. Linear Frequency Transposition-[document on the Internet]. Vaerloese, Denmark; october2006. available from: http://www.hearingreview.com/issues/articles.


Thank you