The effect of nonlinear frequency compression on consonant recognition as a function of acclimatization time

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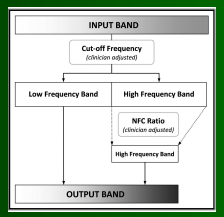
Background:

Hearing impairment is most commonly found in the high-frequencies, affecting perception of high-frequency sounds. Nonlinear frequency compression (NFC), a type of frequency lowering hearing aid technology, compresses the high-frequency output bandwidth of a signal by a specified ratio (Figure 1). NFC hearing aid technology aims at improving audibility of high-frequency sounds presenting the sounds at a lower-frequency region, and where the listener has usable hearing.

Recent studies provide evidence of speech perception benefit with NFC for listeners with high-frequency hearing loss (Glista et al., 2009; Simpson, Hersbach, & McDermott, 2005, 2006; Wolfe, Caraway, John, Schafer, & Nyffeler, 2009). Frequency compression studies report some high-frequency speech sound confusions (Simpson et al., 2005, 2006). Similar reports can be found in studies of frequency transposition (another type of frequency lowering hearing aid technology); consonant confusions around phonemes including, but not limited to, /s/, /ʃ/, /f/, and /t/ have been reported for adult and child listeners (Rees & Velmans, 1993; Robinson, Baer, & Moore, 2007; Robinson, Stainsby, Baer, & Moore, 2009). It has been suggested that auditory training and/or adaptation time is needed for listeners to overcome sound confusions introduced by frequency lowering technology (Auriemmo et al., 2009; Robinson et al., 2009).

Figure 1. An illustration of NFC processing from Hearing Review, November 2009.



Purpose:

Our area of interest is in the impact of NFC technology on speech perception ability in children. This poster presents data from a subset of participants and measures from a larger project on perceptual acclimatization in children wearing hearing aids with NFC technology. Results include consonant recognition scores with NFC hearing aid technology as a function of acclimatization time. Specifically, consonant confusions and error patterns have been analyzed for 5 child participants.

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Methods:

Five children with sloping, high-frequency hearing loss (Figure 2) were fitted with Phonak V SP BTE hearing aids. We used a withdrawal design including repeated measures over three phases: 1) Baseline (which tested performance without NFC until asymptotic performance was achieved), 2) Treatment (with NFC), and 3) Withdrawal (without NFC). For the purpose of this poster, speech recognition performance is reported for 2 testing sessions within the treatment phase only: NFC1 (initial activation of NFC) and NFC6 (the 6th and final testing session with NFC). Testing at NFC 6 took place after 16 weeks of acclimatization time, on average.

Consonant recognition was measured using the Distinctive Features Difference (DFD) test (Cheesman & Jamieson, 1996). This includes four talkers (two male, two female) and 21 nonsense disyllables including: /b, tʃ, d, f, g, h, dʒ, k, l, m, n, p, r, s, ʃ, t, ð, v, w, j, z/. All 84 items are presented in a fixed, word-medial context (i.e., ʌCil). Participants were instructed to select the target nonsense words from an orthographic display on a computer monitor.

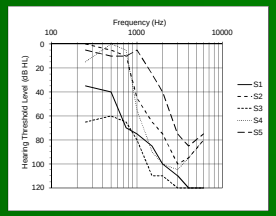

Figure 2. Better-ear hearing thresholds displayed in dB HL across participants.

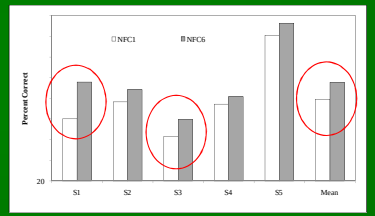

Figure 3. Percent correct scores obtained on the DFD task for individual participants and the group mean. Results are displayed for NFC1 and NFC6 testing sessions. Circles mark data also shown in Figs 4-6.

Results:

Analysis revealed a statistically significant acclimatization effect for group level consonant recognition (Figure 3); large absolute changes in scores over time are observed for S1 and S3.

Raw scores were used to generate confusion matrices per test session. "Difference" confusion matrices were calculated between NFC1 and NFC6 test sessions, to measure change in performance over time. Stimuli are labeled by the orthographic response options presented to the participants.

Group level confusion analysis (Figure 4) of fricatives/affricates suggest large improvement in /ch/ and /th/ identification over time; smaller improvements in identification of /j/, /s/, /sh/, /z/, /f/, and /h/ are also reported. S1 experienced fewer confusions for the sound /s/ over time, and smaller improvements in identification for /ch/, /j/, /th/, /f/, /h/, and /z/; identification for the sound /v/ decreased slightly over time (Figure 5). S3 experienced small improvements in identification over time for most affricate/fricative sounds (Figure 6).

The participants also experienced identification errors due to within-category confusions (e.g., fricatives were commonly confused with other fricative sounds, and the same for affricates). Less categorical confusions were reported over time, especially for affricate sounds (Figure 7).

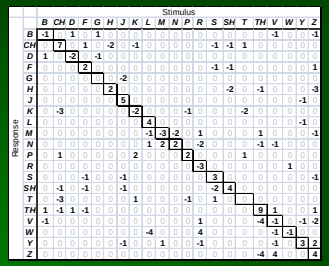

Figure 4. Group level 'difference' confusion matrix, showing the change in confusions over time with NFC (i.e., NFC6 – NFC1).

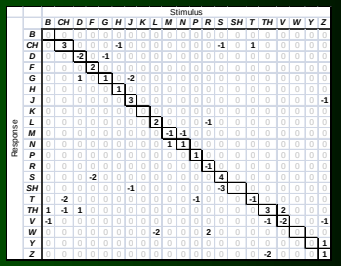

Figure 5. 'Difference' confusion matrix for S1, showing the change in confusions over time with NFC (i.e., NFC6 – NFC1).

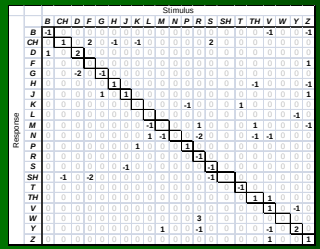

Figure 6. 'Difference' confusion matrix for S3, showing the change in confusions over time with NFC (i.e., NFC6 – NFC1).

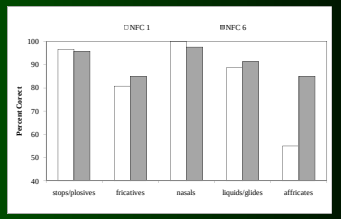

Figure 7. Group level percent correct identification within each feature category for 2 NFC testing sessions.

Conclusions:

Findings suggest that consonant recognition improves over a period of adaptation time with NFC hearing aid technology for these listeners with severe-profound high-frequency hearing loss. This may relate to learning of novel speech cues due to: 1) improved audibility of certain speech sounds with NFC, and/or 2) change in perceptual understanding of specific speech sounds. Large perceptual acclimatization effects were reported for several affricate and fricative sounds.

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