AR Topics #2

Training for adults with frequency transposition hearing aids: A case study

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INTRODUCTION

A high frequency (2kHz and above) hearing loss results in reduced or total lack of access to many important speech elements, and can lead to great difficulty in following conversational speech, especially in the presence of competing noise. Speech elements particularly affected include the second formant (F2) of the front vowels, the higher formants (F3, F4, etc.) of all vowels and vowel-like consonants, the voiceless consonants [p, t, k, f, θ, s, ʃ, tʃ, h], the voiced sibilants [z, ʒ], and the voiced affricate [dʒ]. This set includes two of the most frequently occurring consonants, [s] and [t], in spoken American English,[1] and three consonants, [s], [z], and [t], which fulfill many important grammatical functions in spoken English. For example, [s] and [z] are used to mark regular plurals (one cat/ two cats, one dog/two dogs), signal possession (Pete's book/Jenny's car), and occur in many contractions (it's/where's), while [t] is used to mark past tense in many regular verbs (hopped, skipped).

Loss of access to high frequency speech cues can also lead to a decline in the precision of production of these consonants. Plant, for example, found that listeners were able to accurately differentiate between speakers with normal hearing or an acquired deafness, based, in part, in changes in the latter group's production of the fricative consonants.[2] These changes included the substitution of what Cowie and Douglas-Cowie[3] called "archetypal sounds" for others in a subordinate class, so that gross contrasts are maintained. They cite the collapsing of the set of sibilants and affricates towards [ʃ] as an example of this phenomenon.

Although conventional hearing aids do offer great benefit to many listeners with hearing loss, lack of access to the high frequency speech sounds often remains a problem,even after fitting of the best possible device(s). Several factors may be responsible for this including "dead regions" which are areas "of the cochlea in which IHC (inner hair cells) or auditory nerve fibers are not functioning,"[4] and, in some cases, amplification of the higher frequencies can result in *degraded* rather than enhanced speech understanding. [5] One possible solution to this problem is *frequency transposition*, which shifts high frequency speech information into a lower region where the listener is "better able to analyze sounds."[6] Although frequency transposition dates from the pioneering work of Johansson,[7] the approach has not been widely adopted. One possible reason for this may be that people with hearing loss find it difficult to assimilate the new frequency shifted signal, and may be unwilling to continue using it without

[1] Plant, G. 2001. **Speech Stuff: Speech Testing & Training Resources for Teenagers & Young Adults**. The Hearing Rehabilitation Foundation, Somerville

[2] Plant, G. 1993. *"The speech of adults with acquired profound hearing losses I: A perceptual evaluation."* **European Journal of Disorders of Communication**, 28, 273 - 288

[3] Cowie, R. & Douglas-Cowie, E. 1993. *"Speech production in profound postlingual deafness,"*

[4] Yanz, J.L. 2002. *"Cochlear dead regions and practical implications for high frequency amplification."* **Hearing Review**, April

[5] Dillon, H. 2001. **Hearing Aids**. Boomerang Press, Sydney, p. 245.

[6] Ibid, p. 203

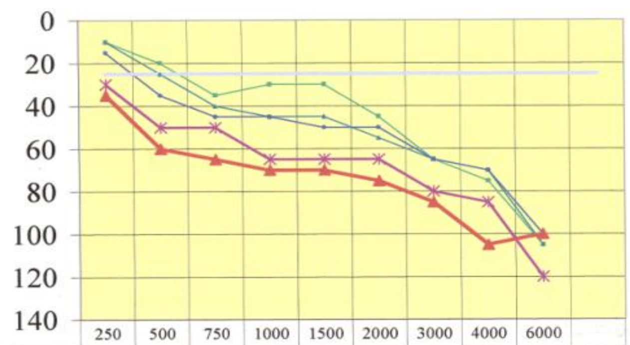
[7] Johansson, B. 1961. *"A new cosding amplifier for the severely hard of hearing."* **Proceedings of the 3rd International Congress on Acoustics**, p. 655 - 657

ongoing support and training. This report focuses on provision of a training program for a client fitted with hearing aids using frequency transposition, and highlights the value of such support.

SUBJECT

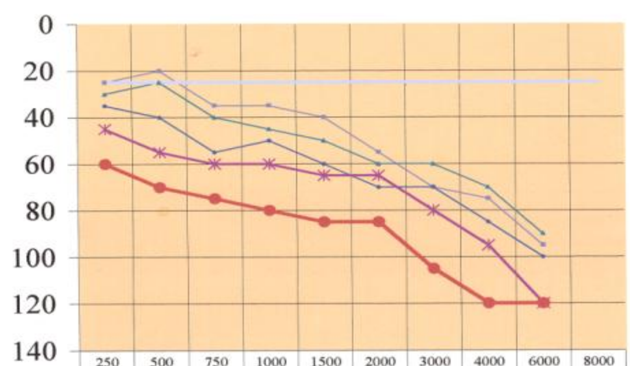
The subject of this report is a 55-year-old man with a progressive hearing loss. Serial audiograms over a period of 10 years are presented in Figure 1. The subject was fitted with binaural Widex Inteo hearing

Left ear



	250	500	750	1000	1500	2000	3000	4000	6000	
Dec-97	10	20	35	30	30	45	65	75	105	
Jul-99	10	25	40	45	45	55	65	70	105	
Feb-00	15	35	45	45	50	50	65	70	100	
Sep-02	30	50	50	65	65	65	80	85	120	
Aug-07	35	60	65	70	70	75	85	105	100	
Normal	25	25	25	25	25	25	25	25	25	25

Right ear



	250	500	750	1000	1500	2000	3000	4000	6000	8000
Dec-97	25	20	35	35	40	55	70	75	95	
Jul-99	30	25	40	45	50	60	60	70	90	
Feb-00	35	40	55	50	60	70	70	85	100	
Sep-02	45	55	60	60	65	65	80	95	120	
Aug-07	60	70	75	80	85	85	105	120	120	
Normal	25	25	25	25	25	25	25	25	25	25

Figure 1 The subject's audiometric thresholds in the left and right ears over the period December 1997 – August 2007.

aids in 2007, and one of the programs selected was for the Audibility Extender, which uses Linear Frequency Transposition to lower high frequency speech information into the user's audible range. Despite being considered a good candidate for this setting, he had rejected its use, and reported that he found it unsuitable for his listening needs. The subject was offered training in the use of the Audibility Extender setting, and reluctantly agreed to attend for several 1:1 training sessions. He reported that he wanted training, but couldn't see the value of its being conducted using the Audibility Extender setting, as he didn't like the sound of the shifted consonants.

TRAINING

The subject attended weekly training sessions over a period of three months. Each session was around 60 – 90 minutes in duration. The training initially focused on analytic training exercises to reintroduce the "sound" of the high frequency consonants. Most of the analytic training materials were taken from "Analytika,"[8] which contains over 600 lists contrasting vowels and consonants in real word pairs. The contrasts presented included:

		INITIAL			FINAL	
Closed-set Presence/Absence exercises in both the word initial and word final positions. Examples of these exercises are shown to the right.	sin	vs.	in	peace	vs.	pea
	say	vs.	A	pits	vs.	pit
	chat	vs.	at	each	vs.	E
	charm	vs.	arm	arch	vs.	are

		INITIAL			FINAL	
Later analytic training focused on closed-set materials contrasting the high frequency consonants in both the word initial and word final positions. Examples of these contrasts are shown to the right.	sin	vs.	tin	peace	vs.	Pete
	shin	vs.	chin	swish	vs.	switch
	sore	vs.	shore	mass	vs.	mash

Other contrasts presented included consonantal blends such as beat/beats/beach, and mat/mats/match. All training lists were presented twice using the "normal" (no frequency shifting) position and the Audibility Extender (AE) position. The order of presentation was varied from list to list to minimize possible learning and familiarization effects. After each list was presented, the subject was asked to rate the degree of difficulty and effort involved in the task. Over time, it became apparent that the subject found the AE setting much easier, and he reported that he was also more confident in his responses when using this setting.

During the training sessions, some time was set aside to discuss the importance of the high frequency consonants in speech perception and production, and these discussions served to emphasize for the subject *why* this set of speech sounds was so important for overall speech understanding.

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[8] Plant, G. 2008. **Analytika**. MED-EL, Innsbruck

The training materials also included sets of sentences, which were presented the "normal" and AE positions. In most cases, the scores obtained were very similar, but the subject commented that the task seemed easier in the AE position – "I didn't have to work so hard!" In the latter sessions, Speech Tracking was used to provide practice in perception of connected speech in quiet and in a noise background. When Speech Tracking presented in a noise background, the subject again commented that he found the task easier using the AE position.

One of the outcomes of the training program was that within a few weeks, the subject reported that AE had become his preferred setting, and he was using it at almost all times. He further commented that he now much preferred the sound of the AE setting over that of the aids in the "normal" position. When asked whether he thought the training program had been a factor in AE becoming his setting of choice, he replied that he had given up on the setting prior to the training program, and would *never* have used it without the program.

TESTING

Testing was conducted contrasting the subject's performance in the AE and "normal" (N) settings. The tests used and the results of the testing are described below.

Monosyllabic word lists made up of voiceless consonants and vowels/diphthongs with high second formant (F2) frequencies. These 50-item lists were taken from "Adult EARS" a comprehensive test program, which the author is currently developing for use with adults fitted with cochlear implants and/or hearing aids.

Two lists were administered live-voice via audition alone, with List 1 presented using the N setting, and List 2 using the AE setting. Five weeks later, the lists were re-administered, but, in this test session, List 1was presented in the AE position and List 2 in the N position. The results obtained for this testing are presented in Table 1.

		NORMAL (N)	AUDIBILITY EXTENDER (AE)	DIFFERENCE (AE – N)
LIST 1	(50 items)	52%	64%	12
LIST 2	(50 items)	50%	68%	18
MEAN	(100 items)	51%	66% (significant at 5% level)[9]	15

Table 1 The subject's scores for two 50-item monosyllabic word lists made up of voiceless consonants and vowels with high F2's. The lists were presented with the subject using the N and AE settings on his hearing aids.

[9] Carney, E. and Schlauch, R.S. 2007. *"Critical difference table for word recognition testing derived using computer simulation."* **Journal of Speech, Language and Hearing Research**, 1203 - 1209

Two additional 50-item word lists containing items made up of voiceless consonants and vowels with high F2's were also presented in the two conditions. In Session 1, List 1 was presented using the AE position, while List 2 was presented using the "normal" position. In Session 2, one week later, the presentation settings were reversed. The results of this testing are shown in Table 2.

		NORMAL (N)	AUDIBILITY EXTENDER (AE)	DIFFERENCE (AE – N)
LIST 3	(50 items)	34%	50%	16
LIST 4	(50 items)	32%	48%	16
MEAN	(100 items)	33%	49% (significant at 5% level)[10]	16

Table 2 The subject's scores for two 50-item monosyllabic word lists made up of voiceless consonants and vowels with high F2's. The lists were presented with the subject using the N and AE settings on his hearing aids.

In order to ensure that the AE position was not having a negative effect on the subject's performance with low frequency consonants, an additional two monosyllabic word lists made up of voiced consonants and vowels with low second formants (F2) were presented in the two conditions – AE and N. The procedure used was that adopted for the high frequency word lists with a period of one week between the presentations. The results of this testing are shown in Table 3.

		NORMAL (N)	AUDIBILITY EXTENDER (AE)	DIFFERENCE (AE – N)
LIST 1	(50 items)	84%	92%	8
LIST 2	(50 items)	90%	94%	4
MEAN	(100 items)	87%	93%	6

Table 3 The subject's scores for two 50-item monosyllabic word lists made up of voiced consonants and vowels with low F2's. The lists were presented with the subject using the N and AE settings on his hearing aids.

DISCUSSION

By the end of the training period, AE was the *only* setting that the subject was using. He reported that he found it best in all situations. When asked if he felt that he would have used the AE setting without training, his answer was unequivocal; he had already stopped using it prior to training, and he would not have used it without the training program. He felt that training had highlighted the importance of high frequency sounds, and made him aware of the advantages of the AE setting. These had been explained to him previously, but he needed to directly experience the difference in a structured setting. He noted that use of the AE setting meant that he required less effort . The scores were sometimes very similar in

[10] Ibid

the two positions, but he “didn’t have to work so hard” in the AE position. The subject also noted that on occasions in N setting he used silence as the cue to high frequency consonants – “If I don’t hear anything it must be [s]!” – but recognized that this strategy would have very limited use in real-life situations. Twelve months after the completion of the training program, the subject was contacted and asked which program(s) he was now using. He responded that the AE program remained his setting of choice, and he used it on all occasions.

The results of testing with the “high frequency” monosyllabic word lists showed superior performance across all four lists when the subject was using his hearing aids in the AE position. These scores were not, however, statistically significant. When the scores obtained for the combined lists, that is, 100 items, the scores obtained for the AE setting for Lists 1 & 2 and Lists 3 & 4 were significantly better than those obtained when using the N position. Testing with low frequency words also indicated that the use of the AE setting did not lead to a decline in performance with these materials. Although the difference between scores in the AE and N settings was not statistically significant, performance in the AE setting was slightly higher.

Finally, the benefits of the use of the AE setting may be even more marked for children with congenital or early onset hearing losses. The subject of the present study acquired his hearing loss as an adult, and could “fall back” on his linguistic knowledge to “fill in gaps” in the auditory signal. It does not follow that children with a congenital or early onset hearing loss will acquire such knowledge if they lack reliable access to the high frequency speech signal. This is an area that warrants further study