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Unilateral Auditory Temporal Resolution Deficit: A Case Study

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Abstract

An adult with a unilateral precipitous severe high-frequency hearing loss displayed a selective auditory temporal resolution deficit in the poorer ear despite excellent word recognition ability in quiet bilaterally. Word recognition performance was inferior in interrupted noise, reverberation, and time-compression conditions when stimuli were presented to the hearing-impaired ear and compared with performance for stimuli presented to the normal-hearing ear or that of normal-hearing listeners. It was suggested that a restricted listening bandwidth was responsible for the performance decrement on the tasks involving temporal resolution. This case illustrates the importance of employing temporal resolution tasks in an audiologic test battery. Such assessment tools may reveal deficits that otherwise may go unnoticed in light of excellent word recognition in quiet.

Educational Objectives: After reading this article the reader will be able to (1) appreciate the effect of high-frequency hearing loss on temporal resolution and (2) realize the importance of utilizing temporal resolution tasks in an audiologic test battery.

Key Words: Hearing Loss, Speech Recognition, Temporal Resolution.

By comparison of word recognition performance in listening conditions involving interrupted and continuous noise masking, Stuart, Phillips, and colleagues have revealed deficits in auditory temporal resolution in various groups of listeners. They have independently demonstrated that listeners with noise-induced hearing loss (Phillips, Rappaport, & Gulliver, 1994), older listeners with presbycusis (Stuart & Phillips, 1996), and normal-hearing listeners with a simulated high-frequency hearing loss (Stuart, Phillips, & Green, 1995) exhibit a selective performance deficit for the interrupted noise condition. The deficit is demonstrated by way of a significantly smaller release from masking than normal-hearing listeners. The performance detriment encountered in the interrupted noise condition led them to conclude that the auditory systems of these listeners must have poor temporal resolution. This reasoning stemmed from the fact that the difference between the continuous and interrupted maskers lies in their temporal and not spectral structure. Failure of the auditory system to take advantage of the time structure of the interrupted masker is a temporal problem, according to this viewpoint.

Stuart and Phillips (1998a) along with others (Bacon & Viemeister, 1985; Buus & Florentine, 1985; Moore, Glasberg, Donaldson, McPherson, Plack, 1989; Shailer & Moore, 1987) have hypothesized that a restricted listening bandwidth is one factor that contributes to the poor performance of listeners with high frequency hearing loss on temporal resolution tasks. The high-frequency cochlear loss creates a loss of audibility and a loss in temporal resolving capacity. Temporal resolution

capacity suffers because it is thought to be mediated through low frequency auditory channels that, although function normally, have inherently poorer frequency resolution than high frequency auditory channels.

Stuart & Phillips (1998b) recently demonstrated the generality of the hypothesis that listeners with restricted high-frequency listening have temporal resolution deficits regardless of the temporal resolution task. Recognition of time-compressed or reverberated words by normal-hearing listeners with and without a simulated high-frequency hearing loss was explored. Performance decreased significantly as a function of increasing time-compression, reverberation, and with the simulated hearing loss ($p < .05$). More important, a statistically significant interaction between conditions of time-compression ratio and reverberation time with the simulated high-frequency hearing loss condition was found ($p < .05$). This finding of an interactive as opposed to a simple additive effect of multiple distortions of the speech on word recognition performance suggested to the authors that loss of audibility alone could not account for decrements in word recognition performance with time altered speech. It was speculated that the interaction effect for combined acoustic distortions was a consequence of the functional loss of the high-frequency region of the cochlea.

A further exploration of this theme is presented in this report. An adult with a unilateral precipitous severe high-frequency hearing loss displayed a selective auditory temporal resolution deficit for stimuli presented to the poorer ear relative

to the normal ear and a control group of normal-hearing listeners despite excellent word recognition ability in quiet bilaterally.

Method

Patient

A 21 year-old female university student presented clinically. She reported a unilateral hearing loss since childhood and complained of occasional listening difficulties in background noise. The presumed etiology of the hearing loss was a viral infection suffered at eleven years of age. All other history was insignificant.

A double wall sound-treated audiometric suite (Industrial Acoustics Corporation), meeting specifications for permissible ambient noise (American National Standards Institute, 1991), served as the test environment. She presented with normal hearing sensitivity in the right ear and a precipitous severe high-frequency sensorineural hearing loss in the left ear. Her audiogram is displayed in Figure 1. Her speech recognition thresholds (SRTs) were 5 dB HL (American National Standards Institute, 1996) bilaterally. Word recognition was excellent: 100% and 92% for the right and left ear, respectively. Otoscopy was unremarkable bilaterally. Middle ear function was normal bilaterally (American Speech-Language-Hearing Association, 1990). Acoustic reflexes were present in the right ear with ipsilateral presentation of pure-tone stimuli from 500 Hz to 4000 Hz in octave steps. Acoustic reflexes were present in the left ear with ipsilateral presentation of pure-tone stimuli at 500 Hz and 1000 Hz but absent at 2000 Hz and 4000 Hz.

Auditory Temporal Resolution Assessment

Recorded stimuli were routed from a compact disc player (Sony Model CDP-CE 415) to a clinical audiometer (Grason Stadler GSI 61 Model 1761-9780XXE) and presented monaurally through an insert earphone (Etymotic Research Model ER-3A). Stimuli were presented at 30 dB SL re her respective SRTs.

To assess auditory temporal resolution capacity, we employed word recognition in continuous and interrupted noise and with temporally distorted words (i.e., time-compression and reverberation). The test stimuli consisted of compact disc recordings of 50 monosyllabic word lists of the Northwestern University Auditory Test No. 6 (NU-6). NU-6 stimuli that were compressed 45% and 65% were obtained from lists five to eight of the *Tonal and Speech Materials for Auditory Perceptual Assessment, Disc 1.0* compact disc (Department of Veterans Affairs, 1992). Uncompressed NU-6 stimuli lists one to four were obtained from the *Speech Recognition and Identification Materials, Disc 1.1* compact disc (Department of Veterans Affairs, 1991). For reverberant listening, the recorded stimuli were routed from the same compact disc player through a multi-effect digital signal processor. Reverberation times were set to either 1.75 or 2.25 s. The word recognition in continuous and interrupted noise was assessed at seven signal-to-noise ratios using custom made compact disc recordings of the NU-6 stimuli (see Stuart & Phillips, 1996).

Results

The patient's scores for each task are presented in Figures 2 and 3. Several pertinent observations can be made. First, word recognition performance in quiet

was excellent and essentially equivalent between the two ears (100% vs. 92%; see 0.0s reverberation and 0% time-compression in Figure 3). Second, word recognition performance was superior in conditions of competing noise; 45% and 65% time-compression; and 1.75 and 2.25 s reverberation when stimuli were presented to the better ear. What is interesting to note is that performance for stimuli presented to the hearing-impaired ear in the continuous noise, although inferior to performance for stimuli presented to the normal-hearing ear, was normal/borderline normal. Finally, performance detriments were exacerbated in all temporal resolution tasks (i.e. interrupted noise, reverberation, and time-compression) when stimuli were presented to the hearing-impaired ear.

Discussion

The performance of the patient was consistent with that of normal-hearing control listeners when stimuli were delivered to the normal-hearing ear. Of particular interest to us was that performance on all temporal resolution tasks (i.e. interrupted noise, reverberation, and time-compression) was inferior when stimuli were presented to the hearing-impaired ear of the patient. This occurred in spite of the fact that word recognition performance in quiet was excellent and essentially equivalent between the two ears. We suggest that a restricted listening bandwidth, as a consequence of the functional loss of the high-frequency region of the cochlea, was responsible for the performance detriment on the tasks evaluating temporal resolution performance. The hearing deficit impairs not only audibility but also temporal resolution capacity.

The proposed mechanism for temporal resolution detriments among listeners with high-frequency hearing loss is two-fold (Stuart & Phillips, 1998a): The first point concerns poor audibility and poorer frequency resolution in the impaired region of the cochlea. This factor can also be associated with the poorer performance in continuous noise albeit normal/borderline normal. The second factor is the functional loss of the high-frequency auditory channels that have the best temporal resolution. Consequently hearing is confined to low-frequency auditory channels with normal temporal resolution that is poorer than that of high-frequency auditory channels. We emphasize that poorer-than-normal perceptual advantages realized under interrupted masking in these listeners does not in itself specify which of many available “temporal processes” in the low-frequency channels might be inherently poor (c.f. Moore, 1993, 1997; Phillips, 1995), only that the deficit is necessarily temporal in nature.

We suggest that this case is relevant for two reasons. First, it displays the importance of utilizing temporal resolution tasks in an audiologic test battery. The employment of such assessment tools may reveal deficits that otherwise may go unnoticed in light of excellent word recognition in quiet. Second it may help to understand a patient’s complaints about the inadequacy of hearing aid performance in difficult listening situations. That is to say, in fitting hearing aids we are often concerned only with the spectral dimensions of one’s hearing loss and not the implications of the hearing loss on temporal processing. Although the hearing aids address the restoration of lost spectral cues they can not compensate for deficits in

processing as a consequence of a restricted listening bandwidth and listening at a reduced sensation level (Stuart & Phillips, 1997). Employing word recognition in temporally complex backgrounds may help illuminate patient's complaints of listening difficulties in reverberant conditions or in backgrounds of competing noise that fluctuates.

References

- American National Standards Institute (1996). *Specification for audiometers*. (ANSI S3.6-1996). New York: ANSI.
- American National Standards Institute (1991). *Permissible ambient noise levels for audiometric test rooms*. (ANSI S3.1-1991). New York: ANSI.
- American Speech-Language-Hearing Association (1990). Guidelines for screening for hearing impairments and middle ear disorders. *Asha* 32 (Suppl. 2): 17-24.
- Bacon, S.P., & Viemeister, N.F. (1985). Temporal modulation transfer functions in normal-hearing and hearing-impaired listeners. *Audiology*, 24, 117-134.
- Buus, S., & Florentine, M. (1985). Gap detection in normal and impaired listeners: The effect of level and frequency. In A. Michelsen (Ed.), *Time resolution in auditory systems* (pp. 159-179). Berlin: Springer-Verlag.
- Department of Veterans Affairs (1991). *Speech recognition and identification materials, Disc 1.1* [CD]. Long Beach, CA: Auditory Research Laboratory VA Medical Center.
- Department of Veterans Affairs (1992). *Tonal and speech materials for auditory perceptual assessment, Disc 1.0* [CD]. Long Beach, CA: Auditory Research Laboratory VA Medical Center.
- Moore, B.C.J. (1993). Temporal analysis in normal and impaired hearing. In P. Tallal, A.M. Galaburda, R.R. Llinás, & C. von Euler (Eds.), *Temporal information processing in the nervous system: Special reference to dyslexia and dysphasia: Vol.*

682. *Annals of the New York Academy of Sciences* (pp. 119-136). New York: New York Academy of Sciences.
- Moore, B.C.J. (1997). *An introduction to the psychology of hearing* (4th ed.). London: Academic Press.
- Moore, B.C.J., Glasberg, B.R., Donaldson, E., McPherson, T., & Plack, C.J. (1989). Detection of temporal gaps in sinusoids by normally hearing and hearing-impaired subjects. *Journal of the Acoustical Society of America*, *85*, 1266-1275.
- Phillips, D.P. (1995). Central auditory processing: A view from auditory neuroscience. *The American Journal of Otology*, *16*, 338-352.
- Phillips, D.P., Rappaport, J.M., & Gulliver, J.M. (1994). Impaired word recognition in noise by patients with noise-induced cochlear hearing loss: Contribution of a temporal resolution defect. *The American Journal of Otology*, *15*, 679-686.
- Plack, C.J., & Moore, B.C.J. (1990). Temporal window shape as a function of frequency and level. *Journal of the Acoustical Society of America*, *87*, 2178-2187.
- Shailer, M.J., & Moore, B.C.J. (1987). Gap detection and the auditory filter: Phase effects using sinusoidal stimuli. *Journal of the Acoustical Society of America*, *81*, 1110-1117.
- Stuart, A., & Phillips, D.P. (1996). Word recognition in continuous and interrupted broadband noise by young normal-hearing, older normal-hearing, and presbycusis listeners. *Ear and Hearing*, *17*, 478-489.

Stuart, A., & Phillips, D.P. (1997). Word recognition in continuous noise, interrupted noise, and in quiet by normal-hearing listeners at two sensation levels.

Scandinavian Audiology, 26, 112-116.

Stuart, A., & Phillips, D.P. (1998a). Deficits in auditory temporal resolution revealed by a comparison of word recognition under interrupted and continuous noise masking. *Seminars in Hearing, 19*, 333-344.

Stuart, A., & Phillips, D.P. (1998b). Recognition of temporally distorted words by listeners with and without a simulated hearing loss. *Journal of the American Academy of Audiology, 9*, 199-208.

Stuart, A., Phillips, D.P., & Green, W.B. (1995). Word recognition performance in continuous and interrupted noise by normal-hearing and simulated hearing-impaired listeners. *American Journal of Otology, 16*, 658-663.

Author Note

Presented in part at the 1998 American Speech-Language-Hearing Association Annual Convention, San Antonio, TX, November 20, 1998.

Continuing Education

1. Temporal resolution capacity may be revealed by word recognition performance in condition(s) of:
 - a. Interrupted noise
 - b. Time-compression
 - c. Reverberation
 - d. All of the above
 - e. None of the above

2. The difference between continuous and interrupted noise maskers employed in this study is in their:
 - a. Audibility
 - b. Spectral structure
 - c. Temporal structure
 - d. All of the above
 - e. None of the above

3. The patient presented in this report displayed equivalent word recognition performance between ears when stimuli were presented in:
 - a. Quiet
 - b. Continuous noise
 - c. Interrupted noise

- d. Time-compression
 - e. Reverberation
4. The proposed mechanism for temporal resolution detriments among listeners with high-frequency hearing loss:
- a. Poor audibility
 - b. Poorer frequency resolution in the impaired region of the cochlea
 - c. Functional loss of the high-frequency auditory channels that have the best temporal resolution
 - d. All of the above
 - e. None of the above
5. This case presentation is relevant because:
- a. It highlights the importance of utilizing temporal resolution tasks in an audiologic test battery
 - b. It helps illuminate patient's complaints of listening difficulties in reverberant conditions or in backgrounds of competing noise that fluctuates
 - c. It may help to understand a patient's complaints about the inadequacy of hearing aid performance in difficult listening situations
 - d. All of the above
 - e. None of the above

Key

1. D
2. C
3. A
4. D
5. D

Figure Caption

Figure 1. The patient's pure tone audiogram.

Figure 2. Word recognition performance in continuous and interrupted noise as a function of signal-to-noise ratio. Circles and crosses represent the right and left ear, respectively. Broken lines display plus/minus two standard deviations from the mean from a normative normal-hearing group ($n = 12$).

Figure 3. Word recognition performance as a function of reverberation time and time-compression. Circles and crosses represent the right and left ear, respectively. Broken lines display plus/minus two standard deviations from the mean from a normative normal-hearing group ($n = 12$).