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# DAMPING THE HEARING AID FREQUENCY RESPONSE: EFFECTS ON SPEECH CLARITY AND PREFERRED LISTENING LEVEL

ROBYN M. COX CHRISTINE GILMORE
*Memphis State University, TN*

Damped hearing aid frequency responses were compared with undamped responses to determine the effect of response smoothing on speech clarity and on gain received when the hearing aid was adjusted to the preferred listening level (PLL). Damping elements were located in the hearing aid's earhook. Three commercially available hearing aids, two bandwidths, and two speech input levels were evaluated in a completely crossed experimental design. Data were collected using a paired comparison method and 10 hearing-impaired subjects. Results indicated that the undamped frequency responses were judged to produce more clear, pleasant, natural sounding speech than the damped responses ($p$ = .09). Although significant midfrequency peak reduction was achieved through earhook damping, the effects on gain at PLL were negligible.

Acoustical damping elements have been used in hearing aid transmission lines for many years. Until recently, the dampers available produced a rather unpredictable amount of reduction in resonance peaks and also tended to reduce high frequency amplification to some extent. As a result of these negative factors, dampers were often used only as a last resort: Their major function being to limit gain and saturation output to acceptably low levels.

A new generation of acoustical damping elements was introduced by Carlson and Mostardo (1976, U.S. Patent No. 3,930,560) with the development of a series of fused-mesh dampers that produced predictable amounts of peak reduction and had essentially no effect on high frequency amplification. Killion (1981) described a series of specially designed earmolds that incorporated combinations of stepped-diameter tubing and dampers strategically placed within the tubing. These earmolds, and their derivatives, became extensively employed in hearing aid fittings. However, clinical application of damped earmolds revealed several problems related to the placement of damping elements within the tubing: It was difficult to find and maintain the correct location of the dampers within the tubing and, once in place, they tended to become blocked with moisture. In due course, earmold damping elements were moved from the tubing to a location in the hearing aid earhook. Earhook dampers of the fused-mesh type have achieved wide acceptance and are vigorously promoted by many audiologists and hearing aid manufacturers for the purpose of smoothing the hearing aid's frequency response.

It has been suggested that a smoothed hearing aid frequency response results in better speech intelligibility and/or reproduction quality than an unsmoothed response (Dillon, 1983; Killion, 1982). This suggestion is based primarily on the notion that the prominent peak typically found at 1 kHz in undamped systems may result in (a) upward spread of masking effects, (b) emphasis of low frequency distortion products, and (c) generation of high frequency distortion products, especially in an extended bandwidth instrument or when the hearing aid is exposed to high level inputs (Gastmeier, 1981; Libby, 1979). Suppression of this peak by damping should reduce these effects and improve the overall fidelity of the system.

Several investigations may be cited in support of this hypothesis. Jerger and Thelin (1968), after investigating the effects of a variety of hearing aid characteristics, reported that response irregularity was the electroacoustic characteristic most closely related to synthetic sentence intelligibility for normal and hearing-impaired listeners. However, the relationship was much stronger for normal hearers than for the hearing impaired. Bucklein (1981), using normal hearers, found that frequency response peaks were much more detectable and objectionable in music, speech, and white noise than equally large valleys. He also reported that very narrow peaks of 5 dB were highly detectable in the 300–5000 Hz range and that a broad 25 dB peak at 1500 Hz produced a significant decrement in syllable intelligibility. Dillon and Macrae (1984) described three studies of the effects of response irregularities on the quality of continuous discourse, employing 5 to 7 normal hearers and 3 hearing-impaired subjects. They reported that a 6 dB $\frac{1}{3}$-octave wide peak at 1 kHz produced a very slight drop in speech quality whereas a 12-dB peak resulted in a strongly negative response. However, peaks and valleys of 6 to 12 dB at 2 kHz resulted in very small quality degradation. Finally, several investigators have used hearing-impaired subjects to compare a standard, undamped frequency response with a damped, broadband response (Cafarelli, 1981; Libby, 1981; Mertz, 1982; Sung & Sung, 1982). These studies have tended to indicate superiority for the damped, broadband response; however, the effects of bandwidth cannot be separated from those of damping.

It has also been suggested that a smoothed hearing aid response may allow the preferred listening level (PLL) to be established at a higher gain setting than an unsmoothed response (Dillon, 1983; Killion, 1982). It is assumed that the PLL for amplified speech is selected at a level that produces maximum intelligibility consistent

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with loudness comfort. If the frequency response contains significant peaks, the PLL setting may be dominated by the requirement to prevent loudness discomfort in peak regions even though this results in insufficient amplification at interpeak frequencies. It follows that if response peaks are reduced by damping, this would permit a higher gain setting before loudness discomfort becomes a factor. The result would be a PLL that provides significantly greater amplification across the entire frequency range. While this rationale applies to response peaks at all frequencies, the prominent peak at 1 kHz has been postulated to be a major culprit in limiting gain settings in PLL adjustments (Gastmeier, 1981; Libby, 1979).

At least two investigations have been reported that confirm the effect of frequency response peaks on loudness comfort levels (Byrne, Christen, & Dillon, 1981; Randolph, Bornstein, Giolas, & Maxon, 1981). Both studies used frequency response peaks that were considerably more pronounced than those found in a typical undamped hearing aid and both employed normal hearing subjects. Killion (1980) has suggested that the effects of smoothing on PLL may be even more marked for hearing-impaired persons than for normal hearers because of the reduced dynamic range of the hearing-impaired listener.

The studies cited above generally support the role of frequency response smoothing in improving speech perception and elevating gain at preferred listening levels, particularly for normal hearers. However, these investigations fall short of establishing the importance of smoothing effects in hearing aid use. No reports have been found of studies that (a) explored the effects of smoothing on typical hearing aid frequency responses, (b) separated the effects of smoothing from those of bandwidth, and (c) employed hearing-impaired subjects.

As a result of the above considerations, an investigation was performed in an attempt to define the role of frequency response smoothing as it is available in contemporary hearing aids. The research questions were:

1. Do hearing-impaired listeners prefer the speech intelligibility or quality of damped hearing aids over undamped hearing aids?
2. Is the preference for damped or undamped responses related to hearing aid bandwidth?
3. Is the preference for damped or undamped responses affected by the speech input level?
4. Does the PLL gain adjustment for damped responses result in greater amplification at off-peak frequencies than the PLL gain adjustment for undamped responses?

## METHOD

### *Subjects*

Ten individuals with bilateral sensorineural hearing impairment served as subjects. Ages ranged from 20 to 86, with a mean of 65 years. Hearing losses ranged from mild to severe with a mean three-frequency pure-tone average of 42 dB HL in the test ear. One subject had a rising audiogram (slope = −13 dB/octave), 4 subjects had essentially flat audiograms (slope 0–5 dB/octave), 4 subjects had gently sloping audiograms (slope 6–10 dB/octave), 1 subject had a steeply sloping hearing loss (slope = 12 dB/octave). Two subjects wore binaural hearing aids, 7 subjects used monaural amplification, 1 subject did not use a hearing aid. The test ear was randomly selected except in the two cases of asymmetrical hearing loss where the better ear was chosen. Four right and six left ears were used.

### *Test Stimuli*

The test stimulus was a 2.5 min continuous discourse passage, recorded in a sound treated room, spoken by a male talker whose speech contained no distinctive regional characteristics. The competing stimulus was a multivoice babble, edited to remove sections of unusually high or low intensity.

Two levels of continuous discourse were used: normal conversational level (55 dB Leq [Leq was defined as the A-weighted level of a continuous steady state sound with the same total acoustic energy as the continuous discourse passage]) and raised voice level (70 dB Leq) (Pearsons, Bennett, & Fidell, 1977). Speech-to-babble (S/B) ratios were adjusted for each subject.

### *Hearing Aids*

Three different pairs of commercially available postauricular hearing aids were used. Each aid incorporated: omni-directional, forward facing microphone; peak-clip limiting; undamped frequency response; high frequency average saturation sound pressure level of 123–129 dB SPL; high frequency average full on gain between 52 and 61 dB.

The two hearing aids of each pair were set to give identical undamped performance; high frequency average gain was 40 dB, tone controls were set to provide the widest frequency range. One aid in each pair was provided with a damped earhook incorporating one 680 ohm fused-mesh damping element in each end; the other instrument had an identical, but undamped, earhook. Figure 1 shows the HA-2 coupler frequency-gain functions for each damped/undamped pair. It will be noted that earhook damping substantially smoothed the frequency response of each hearing aid, reducing the resonance close to 1000 Hz by 8–10 dB and higher resonance peaks by a smaller amount.

Hearing aid bandwidth was varied through the use of two different earmold designs. The two earmolds were the undamped 6B0 and 6B10 designs described by Killion (1981). Relative to the 6B0 earmold, the 6B10 design

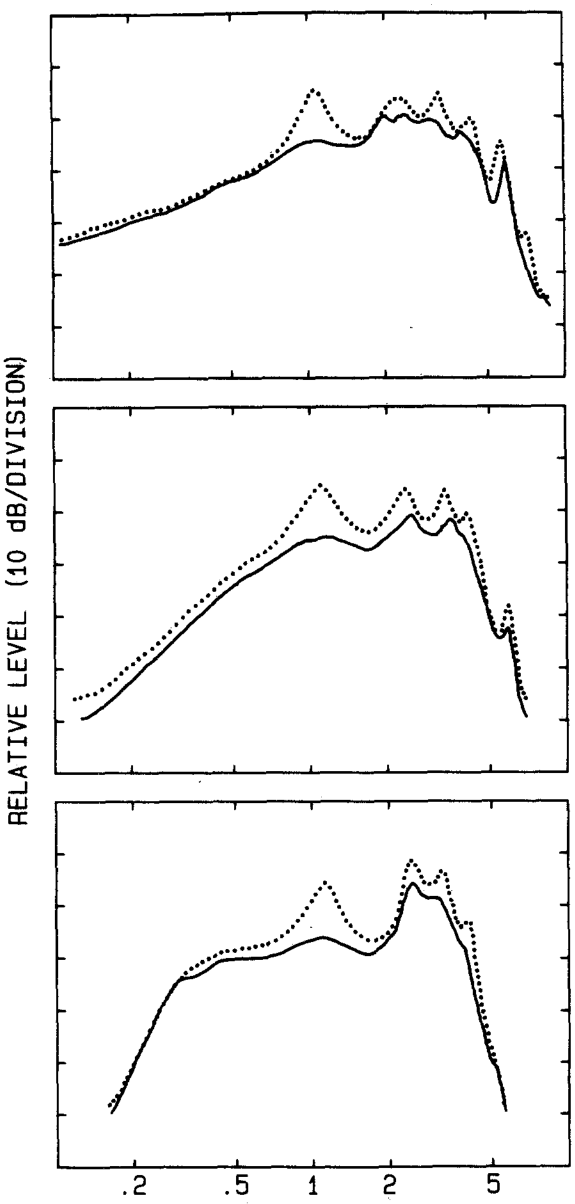


FIGURE 1. Damped (solid line) and undamped (dotted line) frequency responses for the three tested hearing aid pairs. Curves were measured in an HA-2 coupler with entrance via 25 mm of #13 tubing.

provided additional gain beginning at about 2500 Hz and increasing to a difference of 10 dB at 5000 Hz.

## *Instrumentation*

The test stimuli were replayed on a two-channel cassette deck (Onkyo TA-2080). The competing babble was attenuated (see Procedure, below), the two channels were then mixed and delivered to a $\frac{1}{3}$-octave-band equalizer (White, series 4000) that was adjusted to compensate for irregularities in the loudspeaker response. The compensated signal was amplified and delivered to the loudspeaker in an audiometric test room.

A pair of hearing aids (one damped, one undamped) was positioned in the audiometric test room 1 m from the loudspeaker. To assure that both instruments were receiving essentially the same input, the two microphones were placed symmetrically with respect to the loudspeaker axis and separated by 15 mm or less from each other. Each hearing aid output was directed, via either a 6B0 or 6B10 earmold, to a Zwislocki-type ear simulator coupler (Industrial Research Products, DB-100). The two coupler outputs were led outside the audiometric test room to a subject-controlled two-position switch box. The box also housed two unmarked attenuator knobs by which the subject could decrease the level in each channel independently over a range of 40 dB. The output from the switch box was directed to (a) a playback system, and (b) a 400-line spectrum analyzer set to the 10 kHz bandwidth (Hewlett-Packard model 3561A).

The playback system was designed to present a signal to the eardrum of the average subject that had essentially the same frequency response as the signal measured at the "eardrum" of the Zwislocki coupler. The features of this playback system have been described in detail by Cox and Studebaker (1980). It is composed of frequency response weighting elements (electronic and acoustic) in combination with a broad-band, miniature hearing aid receiver. The receiver's output was directed to the subject's ear canal using a compressible foam earplug that provided an excellent acoustic seal.

The head baffle effects for a 0° azimuth signal are small for a forward facing microphone hearing aid (Madaffari, 1974; Studebaker, Cox, & Formby, 1980). Consequently, the frequency response measured in the Zwislocki coupler was a close approximation of the frequency response that would have been measured there if the hearing aid and coupler had been placed on a Kemar manikin (Burkhard & Sachs, 1975). For purposes of discussion, it has been assumed that the coupler-measured response was identical to the in situ response.

The spectrum analyzer mentioned above was used to spectrally analyze, store, and process the coupler-measured amplified speech signals adjusted to the subject's PLLs in both damped and undamped conditions. In situ frequency responses (Figures 3–8) were derived by subtracting the long term average speech spectrum measured at the location of the hearing aid's microphone input from the amplified long term average speech spectrum measured at the Zwislocki coupler microphone.

## *Procedure*

The data were collected using a method of paired comparisons. This method has been shown to produce reliable and sensitive judgments of hearing aid-processed speech intelligibility and quality (Cox & Alexander, 1983; Studebaker, Bisset, VanOrt, & Hoffnung, 1982). Subjects were seated in a quiet room, holding the two-position switch box. Stimuli were presented monaurally with the opposite ear plugged. Prior to data collection, the speech-to-babble ratio (S/B) was adjusted, with the cooperation of the subject, to provide a slightly difficult listening task (75–100% estimated intelligibility for continuous speech). The chosen S/B ratios ranged from 5 dB to 0 dB with a mean value of 1.1 dB. Once chosen, the S/B ratio was held constant for a given subject across all conditions.

After S/B ratio adjustment, the subject was asked to manipulate the switch so as to listen alternately to each sample of the damped/undamped pair and to adjust the level of each sample to the PLL ("the level that you would prefer to use if you were listening to the TV or radio"). A bracketing method was used and adjustments continued until the subject reported that each sample of the pair was at his/her PLL and the two samples were equally loud. Each amplified speech spectrum (damped and undamped) was then spectrally analyzed and stored.

The subject then was asked to switch back and forth between the damped and undamped speech samples and to reach a decision regarding which sample sounded "the best—that is, the one with the most clear, pleasant, natural sounding speech." Subjects were allowed to listen to each sample as long or as frequently as they desired. In addition to choosing the preferred sample, the subject was asked to provide a rating to describe the perceived difference between the two samples. The ratings were: 5, very clear difference (one sample obviously better); 4, distinct difference (one sample definitely better after careful listening); 3, small difference (difficult decision, one sample slightly better); 2, barely detectable difference (very difficult decision, difference between samples barely noticeable); and 1, no difference (best choice possible, difference not really detectable).

Damped/undamped comparisons were made by each subject in each of 12 conditions (3 Hearing Aids × 2 Bandwidths × 2 Input Levels). Five consecutive trials were performed in each condition. Subjects were not informed that the same pair was being judged on these five trials. Thus, each subject yielded a total of 60 judgements. The presentation of hearing aid pair-bandwidth-speech level combinations was counterbalanced across subjects.

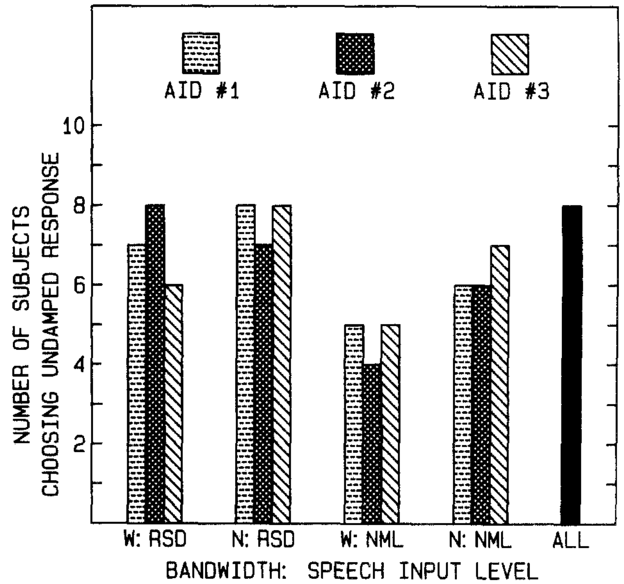


FIGURE 2. Number of subjects ($N$ = 10) who preferred the undamped frequency response in each of the 12 conditions. Data are shown for each hearing aid separately. W:RSD = wide bandwidth, raised voice level; N:RSD = normal bandwidth, raised voice level; W:NML = wide bandwidth, normal voice level; N:NML = normal bandwidth, normal voice level. The bar on the right gives the number of subjects who preferred the undamped responses in a majority of the conditions.

# RESULTS

## *Preference for Damped Versus Undamped Response*

Each damped/undamped comparison consisted of five trials. On each trial the subject indicated the response that provided the best speech signal. The response selected three or more times in five trials was judged to be preferred.

Figure 2 shows the outcome of the 120 comparisons (10 Subjects × 12 Conditions). The number of subjects choosing the undamped response in each condition is depicted. In addition, for each subject, the response chosen most often across the 12 conditions was judged to be that subject's preferred response overall. Figure 2 shows the number of subjects who displayed an overall preference for the undamped response: 8 of the 10 subjects preferred the undamped response overall, 2 subjects preferred the damped response. These results suggest a significant overall preference for the undamped frequency responses. There is a 9% probability that this was a chance outcome ($\chi^2$ test).

To determine whether the preference for damped or undamped response was different in any of the 12 tested combinations of hearing aid, bandwidth, and input level, a Cochran $Q$ test (Siegel, 1956, p. 161) was performed on the data. This test would yield a significant outcome if any condition(s) resulted in preference judgements that were significantly different from those in the other conditions (e.g., the data in Figure 2 seem to suggest that the damped response was preferred more often in the normal-input, wide-bandwidth conditions than in the other conditions). The outcome of the Cochran $Q$ test was nonsignificant; no unique conditions were identified. These data do not support a hypothesis that a smoothed frequency response is more beneficial for hearing aids with extended bandwidth, or for listening conditions where the hearing aid is exposed to high speech input levels, or for any of the other conditions tested.

On each trial, in addition to choosing the preferred response, the subject provided a rating for the amount of difference perceived between the damped and undamped response. Ratings ranged from 1 to 5; their verbal descriptors were given earlier. The overall difference rating for a given 5-trial comparison was derived by subtracting the sum of the ratings given to the nonpreferred response (for any trials on which it was selected) from the sum of the ratings given to the preferred response and dividing the result by 5. Overall difference ratings derived in this way could range from 0 to 5. An overall rating of less than 1 was interpreted as representing a negligible difference between the two responses whereas an overall rating of 5 was considered to indicate a very distinct advantage for the preferred response. Figure 3 summarizes the overall confidence ratings for the 120 comparisons. The figure reveals that most of the judgements, regardless of the preferred response, were accompanied by overall ratings that indicated small or very small differences between the two responses.

## *Effect of Damping on Gain at Preferred Listening Level*

Prior to each comparison, the subject adjusted the damped and undamped responses to be at the PLL and equally loud. The frequency responses were recorded at the selected levels in terms of the spectra generated at the simulated eardrum of a Zwislocki-type ear simulator. To examine the relationship between damped and undamped responses when both were set to the PLL, these data were averaged for each of the 12 conditions. Data for the first 8 subjects were used in this analysis: An instrumentation limitation prevented the participation of all 10 subjects. However, the data for the 2 omitted subjects were essentially identical to those submitted to averaging.

The results illustrated in Figure 4 are typical of the results for the three normal bandwidth, normal speech input level conditions. This figure shows the relative levels of the averaged damped and undamped frequency responses for one of the three hearing aids, measured in the Zwislocki coupler. The figure is interpreted as showing the relative damped and undamped frequency responses at the preferred listening levels at the eardrum of the average hearing-impaired listener. As expected, earhook damping resulted in considerable reduction in the height of the peak at about 900 Hz. Nevertheless, the damped frequency response was not set to a higher level overall than the undamped response. In fact, the spectrum levels of the two responses are very closely matched both below and above the damped frequency region.

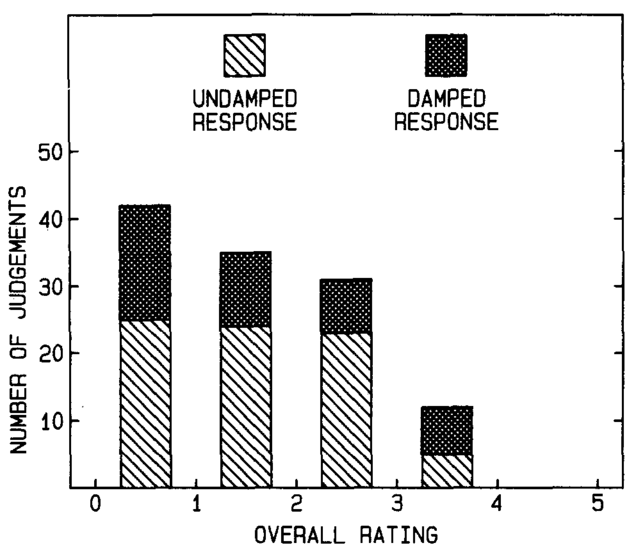


FIGURE 3. Distribution of overall ratings for all damped/undamped comparisons ($N$ = 120). An overall rating of <1 is indicative of a very small difference between the damped and undamped responses. An overall rating >4 would indicate a substantial advantage for the preferred response.

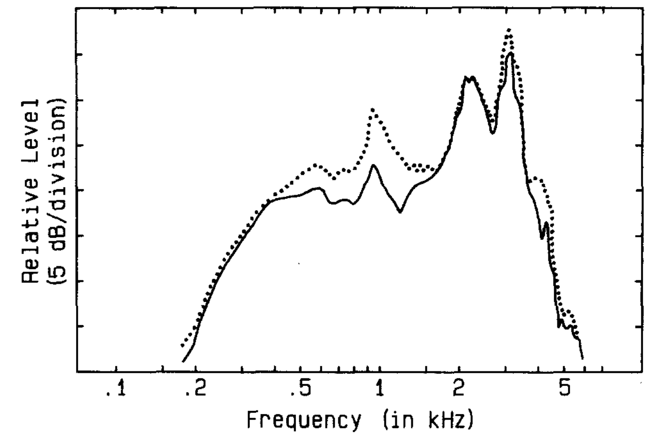


FIGURE 4. Damped (solid line) and undamped (dotted line) preferred listening levels for a typical normal bandwidth, normal speech input level condition. Shown are the Zwislocki coupler frequency responses for one of the three tested hearing aid pairs, averaged across 8 subjects.

The data displayed in Figure 5 are typical of the averaged results for the three wide bandwidth, normal speech input level conditions. In this hearing aid the midfrequency peak occurred at 1250 Hz and its reduction is clearly evident in the damped response. The averaged frequency responses at the preferred listening levels for the damped and undamped conditions resulted in very similar levels in the undamped frequency regions with the exception that the damped response gave about 2 dB more gain than the undamped response in the 3000–4000 Hz range.

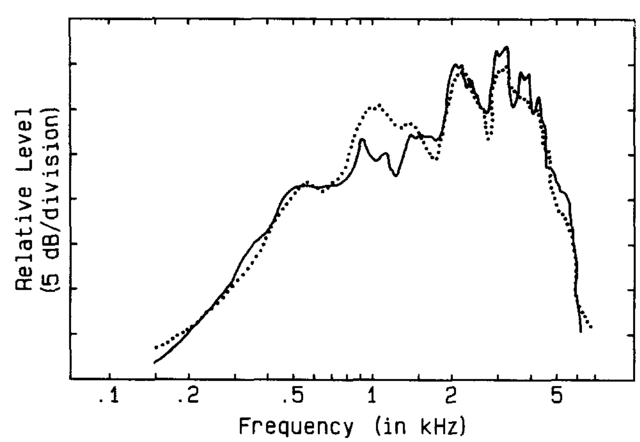


FIGURE 5. Damped (solid line) and undamped (dotted line) preferred listening levels for a typical wide bandwidth, normal speech input level condition. Shown are the Zwislocki coupler frequency responses for one of the three tested hearing aid pairs, averaged across 8 subjects.

Figure 6 illustrates results that are typical of the averaged damped and undamped frequency responses for the three normal bandwidth, high speech input level conditions. This hearing aid is the same one for which results are shown in Figure 4. A comparison of Figures 4 and 6 reveals that the high speech input level had a noteworthy effect on the hearing aid's frequency response, reducing its relative high frequency emphasis—presumably due to saturation for high-frequency speech peaks. Again, the effects of midfrequency damping can be seen in the reduction of the peak at 900 Hz in the damped response. The PLL adjustments resulted in the damped response being 1 to 2 dB higher in the low frequencies and 1 to 2 dB lower in the high frequencies than the undamped response.

The results in Figure 7 are typical of the averaged damped and undamped frequency responses for the three wide bandwidth, high speech input level conditions. Reduction in the height of the resonance near 1000 Hz is clearly seen in the damped response. The PLL adjustments resulted in the damped response being 1 to 2 dB higher in the low frequencies than the undamped response. The two averaged responses were at the same level in the high frequency region.

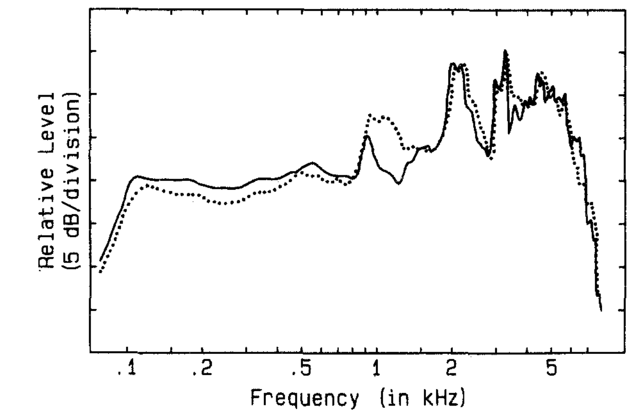


FIGURE 7. Damped (solid line) and undamped (dotted line) preferred listening levels for a typical wide bandwidth, raised speech input level condition. Shown are the Zwislocki coupler frequency responses for one of the three tested hearing aid pairs, averaged across 8 subjects.

## DISCUSSION

When evaluating speech reproduction, the hearing-impaired subjects tended to prefer the undamped frequency response over the damped response. Manipulation of hearing aid bandwidth and speech input level did not have a significant effect on this preference. It should be noted that most of the subjects in this investigation had flat or gently sloping audiometric configurations. It is possible that individuals with other audiometric configurations would give different results. However, in the present study, the 1 subject with a rising configuration and the 1 subject with a sharply sloping configuration both preferred the undamped response overall. This outcome suggests that the strong midfrequency resonance that occurs in undamped hearing aid frequency responses does not have the deleterious effects on speech clarity that have been postulated. This conclusion appears valid for hearing-impaired persons listening to everyday speech in the presence of a moderate level of speech babble.

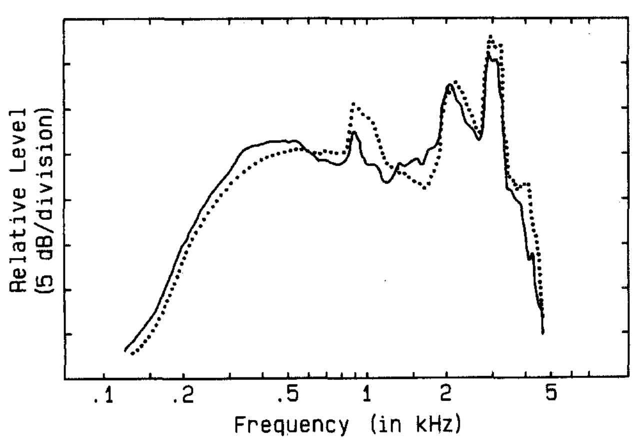


FIGURE 6. Damped (solid line) and undamped (dotted line) preferred listening levels for a typical normal bandwidth, raised speech input level condition. Shown are the Zwislocki coupler frequency responses for one of the three tested hearing aid pairs, averaged across 8 subjects.

This experimental result appears inconsistent with the results of the studies of response irregularities reviewed earlier (Bucklein, 1981; Dillon & Macrae, 1984; Jerger & Thelin, 1968). However, in all of these investigations, the relationship between frequency response irregularities and speech intelligibility or quality was established primarily using normal hearers. Jerger and Thelin tested hearing-impaired persons as well as normal hearers and noted that the relationship between response irregularities and speech intelligibility was much weaker in the hearing-impaired, particularly for persons with sloping hearing losses. Dillon and Macrae used 3 hearing-impaired subjects (in addition to 5 normal hearers): 2 were reported to give results similar to normals and 1 was essentially insensitive to response irregularities. These reports suggest that the effects of frequency response irregularities on speech perception are less for hearing-impaired listeners than for normal hearers: The results of the present study are consistent with this suggestion.

The data on relative preferred listening levels for damped and undamped responses (Figures 4–7) did not reveal the anticipated overall increase in gain at preferred listening level that has been postulated to accompany the frequency response smoothing resulting from earhook damping. On the contrary, damping had minimal effect on the spectrum levels of the amplified sound presented to the average eardrum beyond the limits of the damped midfrequency resonance.

Why did earhook damping have less effect on PLL than several writers (e.g., Gastmeier, 1981) have predicted? The results of this study suggest that this outcome may have been observed because earhook damping did not effectively reduce the peak(s) that played the dominant role in PLL selection.

When measured with a speech input at the simulated eardrum of the Zwislocki coupler (see Figures 4–7), all three hearing aids displayed considerable high frequency emphasis: The peaks in the 2 to 3 kHz region provided more gain in the ear canal than the peak in the 1 kHz region, even in the undamped conditions. This is a typical finding because most hearing aids are specifically designed to compensate for both insertion loss and high frequency sensory deficit. Furthermore, it should be noted that earhook damping was not very effective in reducing the 2 to 3 kHz peaks under the experimental conditions even though hearing aid test box measurements (Figure 1) suggested that these peaks would be reduced. The peak occurring at about 2300 Hz (due to a receiver resonance) was the least responsive to earhook damping when the hearing aids were exposed to a speech signal input.

Because the hearing aids produced their highest Zwislocki coupler gain in the 2 to 3 kHz range, it is not unreasonable to suppose that it was these frequency response peaks, not the lower peak around 1 kHz, that made the major contribution to the overall loudness of the amplified speech signal and therefore played a dominant role in the PLL adjustments. As a result, a modest frequency response change that did not affect the 2 to 3 kHz level (such as reduction at 1 kHz) would have a small effect on overall loudness and therefore would not be expected to have a significant impact on the PLL adjustment for that hearing aid. Examination of Figures 4 through 7 reveals that across all conditions the peaks in the 2 to 3 kHz region were adjusted to almost constant levels regardless of any damping effects in the midfrequency region. These data indicate that for typical contemporary hearing aids the midfrequency resonance has, in fact, considerably less importance in the PLL gain adjustment for speech signals than has been previously thought.

## *Preferred Listening Levels for Hearing Aid-Amplified Speech*

The data obtained in this investigation provided an opportunity to examine preferred listening levels chosen under several different conditions for hearing aid-amplified speech. One aspect of the rationale for recommending a smoothed hearing aid response rests on the assumption that the PLL is selected to provide maximum intelligibility consistent with loudness comfort. However, it is not known whether the preferred listening level for a given individual is equal to a constant loudness level across different listening conditions. In other words, does each listener have a single optimum loudness level for listening to amplified speech?

To investigate this question, the PLLs averaged across 8 subjects were compared across the two hearing aid bandwidth conditions and across the two speech input level conditions. Typical results are shown in Figures 8 and 9. Figure 8 illustrates the Zwislocki coupler-measured preferred listening levels for two different bandwidth conditions employing the same damped hearing aid and the same speech input levels. The dotted line indicates the normal bandwidth condition, the solid line indicates the wide bandwidth condition. Although the data collected in this study are not sufficient to permit definitive statements about the relative loudness levels of these two conditions, the relationship between the two frequency responses (dotted line higher in the low frequencies, solid line higher in the high frequencies) suggests that they have been adjusted to essentially equal loudness levels.

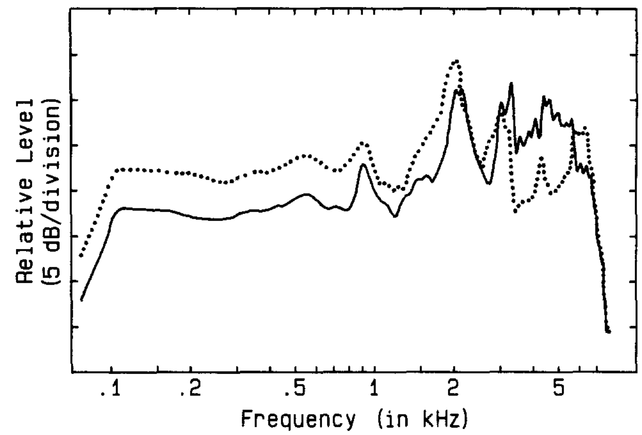


FIGURE 8. Averaged Zwislocki coupler-measured preferred listening levels for the same hearing aid in two different bandwidth conditions. Both conditions employed the same speech level. Dotted line = normal bandwidth; solid line = wide bandwidth.

Figure 9 is an illustration of the Zwislocki coupler-measured preferred listening levels for two different speech input level conditions employing the same undamped hearing aid and the same earmolds. The dotted line indicates the high input level condition, the solid line indicates the normal input level condition. The relationship between the two frequency responses illus-

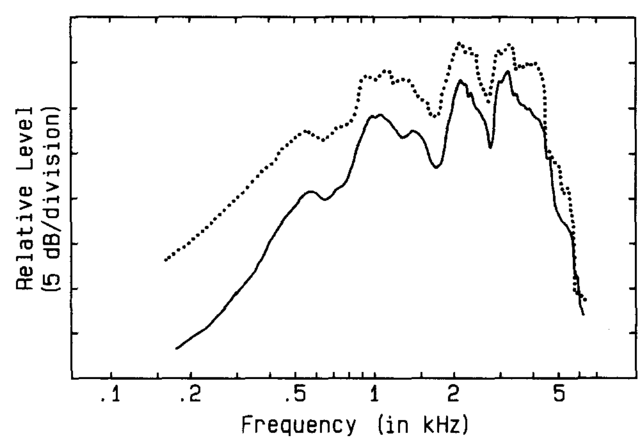


FIGURE 9. Averaged Zwislocki coupler-measured preferred listening levels for the same hearing aid in two different speech input level conditions. Both conditions employed the same bandwidth. Dotted line = raised speech input level; solid line = normal speech input level.

trates clearly that they were not adjusted to the same loudness level: The PLL for the high speech input level condition was a louder level than the PLL for the normal speech input level condition.

The comparisons shown in Figures 8 and 9 suggest that the preferred listening level for hearing aid-amplified speech was (a) at a constant loudness level across different hearing aid conditions for a constant speech input, and (b) not at a constant loudness level across different speech input conditions. In the present study quality judgements made by the authors suggested that the high speech input level resulted in poorer speech reproduction quality than the normal speech input level. Subjects selected a higher (louder) listening level for the poorer quality signal, presumably in an attempt to glean additional speech intelligibility cues. These observations have implications for hearing aid prescription schemes. Figure 8 suggests that the optimal gain at any frequency depends partially on hearing aid bandwidth. Figure 9 suggests that the optimal gain at any frequency depends partially on the quality of the amplified speech (differences in quality may result from different talkers and different S/B ratios as well as different speech input levels). Most hearing aid prescription schemes currently in use do not consider these issues.

## *Conclusion*

In general, the results of this investigation do not indicate that the frequency response smoothing obtained from earhook damping results in improved speech clarity or a more advantageous preferred listening level adjustment. However, the difference rating data shown in Figure 3 indicate that the perceived difference between damped and undamped responses was minimal. One may conclude that although the frequency response smoothing obtained from earhook damping may not have a salutary effect on speech intelligibility or quality, it apparently causes very little degradation in speech perception.

Earhook dampers may be employed for reasons that have not been addressed in this investigation. They have been used as a means to reduce acoustic feedback problems in hearing aid fittings and also to tailor the hearing aid's frequency response to conform with an amplification prescription. The results of this study should not be considered as suggesting that these applications of dampers are not valid.

## ACKNOWLEDGMENTS

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Requests for reprints should be sent to Robyn M. Cox, Memphis Speech and Hearing Center, 807 Jefferson Avenue, Memphis, TN 38105.