Letters to the Editor

Comment on “Consonant Perception in Quiet: Effect of Increasing the Consonant-Vowel Ratio with Compression Amplification”

To the Editor:

We recently read with great interest the article by Hickson and Byrne entitled “Consonant perception in quiet: effect of increasing the consonant-vowel ratio with compression amplification” (1997). The article represents a well-thought-out attempt to address a very complex question: Can increasing the CVR by compression increase speech intelligibility for hearing-impaired listeners? In reading the article, however, a number of issues came to mind that led us to question how the data should be interpreted. We would like to discuss some of these issues and would welcome any clarification that the authors might wish to provide.

One primary concern has to do with the high-pass response of the hearing aid used (Fig. 2) and whether filtering might have obscured larger differences in impaired NST scores between linear and compression conditions. An initial observation was that while the CVRs reported in Table 2 of the article were higher for compression than for linear amplification, the magnitude of the difference was quite small. In addition, there is a rather large discrepancy between CVRs reported under linear conditions (Table 6 and 7) and CVRs measured under unfiltered conditions (our own measurements). For example, the authors show CVRs for /af/ and /ip/ to be -5 and -10 dB, respectively, while our own measurements of these syllables (digitally recorded from the tape) reveal CVRs of -18 and -20 dB. This suggests that the high-pass characteristic of the hearing aid altered the natural CVRs of NST syllables, primarily by filtering out much of the vowel energy. This raises the question of whether the largely negative results might be explained by frequency response rather than by compression. Had a flat frequency response been used, it is likely that much more vowel energy would have been present, linear CVRs would have been much lower, and the effects of linear versus compression would have been more apparent, both with regard to CVRs and to NST scores.

Additional support for minimal compression was the finding that the smallest increases in vowel level were noted for /a/, while larger increases were found for the weaker vowels /i/ and /u/. This produced corresponding changes in CVRs. Data shown in Tables 6 and 7 suggest that /a/ may have been the only vowel above the compression threshold. If true, the effect of compression per se has not been adequately tested due to the high-pass filter characteristic.

A second issue is more of a curiosity but may also be related to filtering. Table 2 shows that the mean consonant and vowel levels were approximately 12 dB and 9 dB higher, respectively, with compression than with linear amplification. This is puzzling, since the two amplifiers were set to produce equivalent output with a static 75 dB, 1600 Hz input (Fig. 1). For a circuit with a 50-msec release time, one would expect a dynamic signal (speech) presented through the compression amplifier to be less than or equal to the level through the linear amplifier, but in fact the reverse occurred. One possible explanation for this result is that energy below 1600 Hz, which was attenuated by high-pass filtering, was given more gain. In other words, the compression amplifier was frequently operating to the left of the 75-dB crossover point shown in Figure 1.

A third observation was the strong correlation between the severity of the loss and NST performance with linear amplification. The authors reported no significant differences in performance between two audiometric subgroups and yet Figure 4 shows that seven of eight subjects in the more severe group performed better with linear amplification. These subjects all had 4-kHz thresholds at or above 60 dB, suggesting inner hair cell involvement, while each of the seven listeners in the milder group had 4-kHz thresholds of 60 dB or less. It would be of interest to know the results had the data from the two audiometric groups not been pooled, as this may have an important influence on the appropriateness of linear versus non-linear amplification for impaired listeners.

One final point that we wish to make is simply to reiterate that the hearing aid used had an infinite compression ratio combined with a low compression threshold. Such a fitting would rarely be used clinically (as noted by the authors) as it would create considerable distortion. It should also be noted that results would likely vary with the time constants of the circuit, which are known to affect compression characteristics for time varying signals like speech.

We hope that this letter generates a lively discussion of an interesting subject. The topic is certainly complex, and we suspect that clarification
and further discussion would be welcomed by many readers.

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Reply to Fortune and Scheller

To the Editor:

We thank Todd Fortune and Tom Scheller for their comments on our recent article. The topic of compression amplification is a complex one that merits considerable further discussion. The Fortune and Scheller letter is a timely caution against overgeneralizing the findings of any particular study to apply to systems or subject groups that may differ significantly from those studied. In particular, the letter stresses the important point that the effects of compression interact with those of frequency response.

The major concern expressed is that filtering may have “obscured” larger differences between the linear and compression conditions. We think this choice of expression, given its negative connotations, is unfortunate and unwarranted, although it is certainly true that the filtering reduced the CVR differences between conditions and that the choice of a flat linear response may well have shown greater advantages for compression. We chose a high-pass response because that is appropriate for subjects such as ours who had moderate hearing losses sloping, on average, from about 15 dB at 500 Hz to about 60 dB at 4000 Hz. In our view, the most relevant clinical question is not whether compression per se can be beneficial, but whether it confers any advantage over an optimally fitted linear system. High-frequency emphasis and compression are both means of improving the audibility of soft sounds, especially for people with high-frequency hearing losses; the question is whether high-frequency emphasis plus compression is any better or worse than high-frequency emphasis alone. It would have been unrealistic to use a flat frequency response as a reference because that would be inappropriate for subjects’ hearing losses and would not normally be fitted in such cases.

In addition, Fortune and Scheller queried the CVR values obtained in our experiment and questioned whether or not the vowels or consonants were in compression at all. If the vowel sounds had been below the compression threshold, it would be expected, on the basis of the input/output graph, that the difference between vowel levels for the compression and linear modes would have been approximately 14 dB. It can be seen in Tables 6 and 7 that the values for syllables containing /a/ and /i/ are below this level. Thus, it may be that the aid was not in compression for the syllables containing /u/ only. In general, CVR values depend on the frequency response of the aid and on the compression characteristics. The differences between CVR values obtained for linear and compression modes in our experiment were governed by the compression characteristics (since the frequency responses were very similar).

If a lower compression threshold had been used, the level of the vowel sound /u/ could have altered more. Acoustic analysis of the kind undertaken in our study is very useful for determining the complex effects of amplification on the speech signal.

Fortune and Scheller raise an interesting point about the possible relationship between severity of hearing loss and NST performance. Subjects 1, 3, 6, 7, 11, 12, and 13 had an average hearing loss from 250 to 4000 Hz of between 32 and 40 dB. The mean score of these subjects was higher with linear amplification (70.84%) than with compression (66.07%); however, this difference was not significant (t[6] = 0.91, p = .39). Similarly, the mean scores for the remaining subjects who had an average hearing loss of 29 dB or less did not differ for linear (74.53%) and compression (72.68%)(t[7] = 0.73, p = .491). It must be pointed out, however, that these findings are based on a small group of subjects with similar hearing impairments. We agree that this issue warrants further investigation.

To return to the main point of this discussion, the major conclusion of our article could be restated as follows: when syllabic compression is added to suitable frequency response shaping, resulting in a further increase in consonant-to-vowel ratio, the effect on speech intelligibility may be detrimental. This does not mean that compression cannot be beneficial but only that, under some conditions, some types of compression may have a negative effect. We think it is important for clinicians to be aware of this possibility. The Fortune and Scheller letter is a timely reminder that the findings of this study, or any other, should not be generalized beyond the conditions that were studied and that the effects of frequency response shaping and compression need to be considered jointly when fitting hearing aids.

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