This special issue of the Journal presents the results of original research on various aspects of digital hearing aids. Introductory articles set the foci for the scientific papers which follow in four subject-related sections. A bibliographic section, containing the results of literature and patent searches for material related to digital hearing aids, is the final component of this special report.

INTRODUCTION

The first introductory article, by Neuman, provides an overview of the clinical implications for future applications of digital technology. It addresses the growing use of computer applications in Audiology, the implications for clinical practice, and the issues to be considered with the pending introduction of practical, wearable digital hearing aids. The second article, by Levitt, provides an historical review of the various types of digital hearing aids and their development, followed by a brief primer on the digitization process and basic methods of digital signal processing.

SECTION I.
DIGITAL HEARING AIDS

This section, devoted to the development of digital hearing aids, begins with a paper by Studebaker, Sherbecoe, and Matesich describing the implementation of a specific method of digital signal processing that is particularly well suited for digital hearing aids. The next paper, by Levitt et al., traces the development of a digital master hearing aid through a series of experiments concerned with the application of adaptive paired-comparison testing to the prescriptive fitting of hearing aids. The third paper, by Engebretson, Morley, and Popelka, describes a digital hearing aid, associated audiometric equipment, and the computer-based method of hearing aid prescription developed at the Central Institute for the Deaf.

SECTION II.
NOISE REDUCTION

The series of articles on noise reduction begins with a review paper by Chabries et al. on two-channel adaptive noise cancellation. A companion paper, by Brey et al., provides evaluative data on this form of noise reduction with both normal-hearing and hearing-impaired listeners. There are, however, practical constraints to the implementation of two-channel adaptive noise cancellation in a wearable hearing aid. The paper by Schwander and Levitt provides experimental data on the effectiveness of this technique when both microphones are mounted on a moving head (as would be the case in a practical hearing aid). The paper by Weiss reports on the effects of filter length, reverberation time, and number of noise sources on the improvement in signal-to-noise ratio produced by this form of adaptive noise cancellation.

More advanced forms of noise reduction using multimicrophone inputs and providing improved signal-to-noise ratios are described in the next two papers. Peterson et al. report on a multimicrophone adaptive beamforming system with extremely good directional properties (for eliminating noise coming from directions other than that of the signal). Chazan, Medan, and Shvadron describe an adaptive algorithm for noise...
reduction using information obtained during pauses in the speech using a multimicrophone array.

Noise reduction using a single microphone input is very attractive for hearing aid applications because of its practical convenience. In the paper by Graupe, Grosspietsch, and Basseas, a single-microphone self-adaptive filter is described with supporting evaluative data. This adaptive filter already has been reduced to chip form for use in conventional hearing aids. The final paper in this section, by Neuman and Schwander, provides evaluative data on a method of filtering for noise reduction that would be relatively easy to implement in a single-microphone hearing aid.

SECTION III.
SPEECH PROCESSING
HEARING AIDS

This group of papers deals with experimental forms of speech processing. It begins with a paper by Villchur on multiband amplitude compression for profound hearing impairment. It is followed by the paper of Bustamante and Braida on multiband compression limiting, a variation of multiband amplitude compression which has not been previously explored. The third paper in this series, by Yund, Simon, and Efron, deals with a multiband compression system based on a refined psychoacoustic model of the listener's signal-processing capabilities. In the next paper, by Moore, a two-channel amplitude compression system that has yielded relatively good results is described. There is growing use of two-channel amplification, and several hearing aids are now being manufactured that incorporate some form of two-channel compression amplification. In the final paper dealing specifically with amplitude compression, Haggard et al. describe a novel form of signal processing in which the spectral tilt of the speech signal is compressed.

The remaining papers in this group deal with methods of speech-cue enhancement and the perceptual effects of this form of speech processing. Revoile et al. describe ongoing research related to the amplification of burst/murmur cues for improving the perception of voiced final stop consonants. In the paper by Guelke, a technique for improving the perception of fricative sounds is described. It should be noted that this technique was developed by Guelke some time ago, and there is now renewed interest in this form of speech-cue enhancement because of the greater signal-processing capabilities of modern hearing aids.

The next two papers in Section III deal with perceptual studies relevant to forms of speech processing for speech-cue enhancements. The paper by Montgomery et al. is concerned with the effect of increasing the consonant/vowel intensity ratio on the loudness of speech. The variations in intensity between vowels and consonants in normal speech can, in many cases, exceed the dynamic range of the impaired auditory system. There is thus great interest in methods for, and the effects of, reducing the intensity differences between consonants and vowels. The paper by Turner, Holte, and Relkin is concerned with the discrimination of spectral shapes by normal-hearing and hearing-impaired listeners. In order to
develop more effective speech-processing hearing aids it is important to know which changes in spectral shape are likely to be discriminable.

The last paper in the group dealing with new forms of speech processing, by Rosen et al., describes the development and evaluation of a fundamentally different type of hearing aid, which is designed for those profoundly hearing-impaired persons for whom conventional amplification is of little practical benefit. In this hearing aid, the voice fundamental frequency is extracted and delivered auditorially as a means for improving lipreading ability.

The final group of papers relate to selected issues of measurement that are relevant to (but not restricted to) digital hearing aids. The paper by Levitt describes a method for measuring both the amplitude and phase characteristics of a hearing aid in situ using the cancellation technique. The method can also be applied to calibrating nonconventional transducers using electrical or vibrational methods of stimulating the cochlea. The second paper, by Kates, is concerned with a general index for evaluating hearing aids and other speech communication systems. The index proposed is the short-time articulation index that can take into account time-varying changes in the speech transmission channel. An index of this type would appear to be an appropriate tool for the analysis of multiband amplitude compression hearing aids.

The next two papers deal with the problem of distortion. Since new forms of distortion, particularly nonlinear distortions, are likely to be encountered with digital hearing aids, it is important to develop the techniques for measuring and evaluating nonlinear distortion in hearing aids. The paper by Williamson, Cummins, and Hecox describes a general technique for detecting and measuring nonlinear distortion in hearing aids. The following paper, by Levitt et al., is concerned with the development of a general distortion index that could be used to quantify both linear and nonlinear forms of distortion in hearing aids.

Completing this special issue of the Journal are listings of periodicals and patents that pertain to digital hearing aids and related instrumentation. This information should be of interest to all concerned with the further development of digital hearing aids and/or advanced signal-processing hearing aids.