The Impact of Emerging Technologies on Audiology and Speech-Language Pathology

L'impact des technologies nouvelles sur l'audiologie et l'orthophonie

Donald G. Jamieson
Hearing Health Care Research Unit
Department of Communicative Disorders, Elborn College
University of Western Ontario
London, Ontario

Abstract

The technological revolution is only now about to impact the professions of Audiology and Speech-Language Pathology. This revolution has wide-ranging implications for the clinical practice of Audiology and Speech-Language Pathology, including the scope and detail of practice, quality assurance, and productivity (and, as a consequence, the level of remuneration). Unfortunately, however, most clinicians in communicative disorders may be unaware of, and as yet quite poorly prepared to meet, the challenge of this revolution. This paper reviews the state of several important technologies that can be expected to impact the field of communicative disorders and discusses strategies that need to be developed within the profession to manage the technologies as they become available. The most important aspects of this management seem to be: (1) ensuring that technologies are appropriate to the task, and (2) ensuring that graduates and practicing clinicians are prepared to deal with the new technologies. The first aspect involves careful research involving both laboratory studies and clinical trials, together with an efficient, national/international information distribution system. In varying degrees, the second aspect requires changes in the mix of students entering communicative disorders programs, changes in university curricula and faculty complements, continuing education programs targeting specific technologies, and individual initiative on the part of practicing clinicians.

Résumé

La révolution technologique commence tout juste à faire sentir ses effets sur les professions de l'audiologie et de l'orthophonie. Cette révolution aura des répercussions majeures pour la pratique clinique de ces deux disciplines, en particulier le champ d'action et la routine quotidienne des professionnels, l'appréciation de la qualité et la productivité (et donc, le niveau de rémunération). Malheureusement, la plupart des cliniciens spécialisés dans les troubles de la communication ne sont pas au courant de ces questions et sont donc à présent très mal équipés pour faire face aux défis de cette révolution. Ce mémoire aborde l'état actuel de nombreuses technologies importantes qui devraient avoir un impact sur le domaine des troubles de la communication. Il propose également des stratégies qu'il faudrait adopter au sein de la profession pour tirer parti de ces technologies quand elles deviennent disponibles. Les principales recommandations proposées sont doubles: 1. veiller à ce que les technologies soient appropriées aux tâches exécutées et 2. veiller à ce que les cliniciens nouvellement diplômés et les professionnels déjà en exercice soient préparés à affronter les nouvelles technologies. Le premier aspect nécessite des recherches soigneuses (études en laboratoire et essais cliniques), ainsi qu'un système efficace national et international de diffusion des informations. Quant au second aspect, il requiert, à divers degrés, des changements sur le plan des exigences pour l'inscription aux programmes de troubles de la communication, des modifications touchant aux programmes d'enseignement universitaire et à la composition du corps enseignant, des programmes de formation continue soulignant des technologies spécifiques, ainsi que des intitiatives individuelles de la part des cliniciens en exercice.

Introduction

In science, business, and education, as well as in health care, the 1980s will be known as the decade in which it was first recognized widely that technology was changing everything. The most important technology of the 1980s was the almost universal application of microelectronics, making possible the personal computer and related products having intelligence.

The microelectronic technologies have reduced the size and expense of electronic products while increasing the speed, capacity, and reliability of those products. Some of the consequences of applying such technologies are therefore entirely predictable, at least in retrospect: Computing devices once filled rooms and applications once were so prohibitively expensive that they could only be done at the largest centres, and only then with a huge maintenance staff and budget. The same systems will now fit under an airplane seat, and the same (plus many much more powerful) applications are now done routinely on thousands of desktop systems requiring almost no maintenance. Other developments relevant to communicative disorders were less predictable. These include the development of: (1) inexpensive, very high-quality audio storage and playback systems, driven by the consumer market; (2) fast audio-signal processing algorithms; (3) fast, inexpensive, high-resolution color graphics displays; and (4) the behavioral technologies to begin to apply these sound processing and visual display capabilities.

Regretably, such technologies — both the microelectronic technologies and the behavioral technologies — as yet have had minimal impact on the practice of Audiology and Speech-Language Pathology. One colleague (Leeper, personal communication) recently surveyed some of our former students to get a picture of the extent to which practicing speech-language pathologists were making use of technology in their daily clinical practice. He reports that the only item identified as being in routine clinical use was a stopwatch!

A quick review of technological developments in the fields of Audiology and Speech-Language Pathology (based, for example, on reviews of the conference issue of *ASHA* [1989] versus the previous five to ten years) gives the immediate impression that this situation is changing fast. The journals and the displays at the American Speech and Hearing Association (ASHA) and the Canadian Association of Speech-Language Pathologists and Audiologists (CASLPA) conferences reveal that we are witnessing a virtual explosion in the development of technological applications for the field. The present paper will describe several aspects of the relevant, current technology and discuss some of the predictable changes about which this author is most confident, then provide some thoughts about how such technology should be used and some predictions about how technology will change the communicative disorders professions.

Point Of View

Technologies can be said to be required to the extent that they can *make a difference* in clinical service delivery. Moreover, however powerful and inexpensive it might be, the overall impact of technological change can be neutral or negative as easily as it can be beneficial. For these reasons, one needs to seek technologies that are not only new, but also *appropriate* for Audiology and Speech-Language Pathology. Appropriate technologies are those that are: (1) effective (and cost-effective); (2) mass-produced; (3) reliable; and (4) easy to use. All too often those seeking the cutting edge of technology find instead the bleeding edge.

Identifying appropriate technologies and developing effective strategies for managing those technologies are considered to be critically important, but all too frequently neglected, topics for professionals. However, the consequences of insufficient attention to technological issues can be awesome. One example within health care are neurologists who, as a group, in recent years have suffered a substantial erosion of their effective scope of practice because many of the diagnostic aspects of their practice having been overtaken by developments in radiology and imaging.

The Status of Relevant Technologies

Sound Input and Output

The most relevant technology for applications in Audiology and Speech-Language Pathology involves high-quality audio recording and output. Audio and speech signals must be easily calibrated and highly reproducible. Chamberlin (1985) reviews the spectacular developments in the field of digital sound processing up to 1985; subsequently there have been both important developments in technology and enormous cost reductions, so that in 1990, we are offered at least four mass-produced, inexpensive, and highly reliable audio alternatives: digital/analog conversion (DAC) boards that can store sounds on the disks of ordinary computers and then replay them as desired ($300 to $4,000); compact disc (CD) systems ($400 to $4,000); digital audio tape (DAT) systems ($1,000 and up); and video tape (VT) and disc (VD) systems ($400 and up).

Such approaches offer a signal-to-noise ratio in the range 72-96 dB (and beyond), with the cost efficiencies and high reliability associated with mass-produced microelectronics. There is an increasingly wide range of tests and procedures available for CD and VD, and such media are robust under reasonable conditions of use and multiple plays and offer both very large storage capacity and random access to any desired segment of the recording (i.e., any segment can be accessed as required and without any noticeable delay). On the other hand, DAC, VT, and DAT options are alone in permitting on-site recording of patient data and in supporting the development of new audio tests. Of the various audio output alternatives, the CD medium has found particular favour in recent years. As examples, CDs have been used as the basis for recording and widely distributing the entire National Bureau of Standards/DARPA speech database (Doddington et al., 1988); for recording clinical audiology tests to evaluate loudness tolerance (Moser et al., 1989); and to archive and widely distribute a large number of additional, public domain audiological test materials (Wilson, 1989).

Visual Display

The second aspect of technology for applications in Audiology and Speech-Language Pathology involves fast, high-quality visual displays. Until very recently, all but the most expensive computer visual displays were limited in several ways: (1) they had difficulty representing pictures and other graphical displays; (2) they were relatively slow so that you needed to wait patiently while the screen was painted; and (3) they were of limited resolution so that, for example, curves were obviously approximated by a jagged sequence of short lines and only a very limited number of points and colors could be presented on the screen.

Within the last two years, all these limitations have been removed for moderately priced systems. Contemporary displays now routinely present between a half-million and one million points on the screen at one time (e.g., 800 points by 600 points; 1024 by 768 points; or 1282 by 1024 points). Moreover, each point can be specified as any of a large number of colours (selections routinely vary from 256 on up to more than 2 million in many cases). Finally, most of these displays are fast, and some can even support real-time animation! The costs of these systems vary from a few hundred dollars (e.g., for 800 by 600 resolution, bundled with a new system) to thousands of dollars. In fact, the speed and resolution of such systems sufficiently approaches the limits of the human visual system, which suggests that future developments can be expected to focus primarily on cost reductions and increased ease of programming.

In addition to and complementing such computer displays are the video display technologies associated with video disc and the more familiar video tape. As noted previously, these media offer audio playback of excellent quality (and in the case of video tape, also offer audio recording). However, in addition they offer the possibility of recording and storing a very large number of high quality images and of playing these on command. Whenever real life scenes are to be depicted and when a large number of images must be available for presentation, these are the display technologies of choice. Video disc offers the additional advantage of supporting random access to images and scenes, plus a robust medium. Examples of applications include random access to a large number of computer-generated animated sequences to test young children (Wightman et al., 1989) and random access to a large number of speech sequences to assist in the evaluation of lip-read information (Boothroyd, 1987).

Signal Processing Applications

The impressive technical developments in the area of speech and audio signal processing are just now beginning to bear on applications in Audiology and Speech-Language Pathology. Examples of relevant signal processing applications include speech analysis, speech recognition, sound synthesis, and speech enhancement. Readers will be familiar with the modest use of at least some of these applications.

Speech analysis in its various forms is the application most familiar to present day communicative disorders clinics. Typically, several specialized devices are purchased, each of which measures a single aspect of speech. For example, in North America, Kay Elemetric's VisiPitch instrument, which estimates voice fundamental frequency and provides a simple visual display, appears to be the most widely purchased speech analysis device for speech clinics. But the purchase of single-purpose instruments is both costly and extremely limiting. Indeed, most of the vast (and rapidly growing) literature relating to speech analysis techniques has had no impact clinically because of this approach. Individual clinics have had limited resources to purchase such specialized systems, and with the limited market and cost of designing specialized equipment, manufacturers have had little inclination to increase the range of analyses available. Since the alternative analysis methods have their own advantages and disadvantages, depending on just what aspect of a speech sound you wish to measure, it is important that a range of analysis procedures is made available. In addition, the attention that manufacturers have given to the human factors aspects of systems has been very limited. One promising approach to applying the results of speech analysis clinically is the IBM Speech Viewer System (Thomas-Stonell, 1989). However, in this and in other systems, much more attention will need to be given to the type of information being conveyed to the clinician and/or the client, and to ways in which this information transfer can be improved. This last topic is addressed in a subsequent section.

With the recent development of inexpensive speech analysis systems that emphasize flexible software running on general purpose computers, such as CSRE (Jamieson, et al., 1989) and Micro Speech Laboratory (Dixon, 1989), a much wider variety of analysis approaches should become widely available soon. For example, the current version of the CSRE system offers four alternative spectral analysis procedures and two pitch estimation procedures in addition to speech capture, editing, replay, and synthesis. However, if CSRE and other related systems are to be used effectively, individual clinicians will need to improve their understanding of what different analysis approaches can offer so that they can make good choices when faced with a wide range of options. The reader is referred to Ryalls and Baum (1990; this issue) for a review of three systems and to Read et al. (1990) who provide a comprehensive review of eight of the more general-purpose (speech analysis) systems that are presently available.

Speech Synthesis

Speech synthesis offers at least two advantages to Speech-Language Pathology and Audiology. First, synthetic speech is both well specified and highly reproducible. Because the stimulus is well understood and is precisely replicated from test session to test session, the data collected are both more reliable and more easily interpreted. Secondly, speech synthesizers make it possible to store the codes for a very large number of utterances and to output the speech at will. Such coded speech can be in the form of control files for a parametric speech synthesizer, as with Klatt's (1980) synthesizer implemented in CSRE (Jamieson, et al., 1989). More often, the speech synthesis takes the form of the resynthesis of coded natural speech using linear predictive coding (LPC; e.g., Rabiner & Schafer, 1978). Either approach offers the possibility of very high quality speech output, so it remains a puzzle as to why the synthetic speech used in communication aids is so poor: Quality output has yet to be realized in most of the instruments available for augmentative/alternative communication applications, for example. However, an obvious prediction is that the augmentative/alternative communication devices will be forced to adopt these widely available techniques that permit very high quality synthesized speech to be used in other applications (e.g., Hunt, Zwierzynski, & Carr, 1989).

Speech Recognition

Research on speech recognition has made such remarkable progress that it is now possible to purchase general purpose systems for your microcomputer, priced in the low thousands of dollars, that can be trained to recognize words from a moderate vocabulary (500 to 2,000 words) from a single talker or a smaller number of words (10 to 100) from a variety of talkers. These systems are beginning to be applied in rehabilitation — for example, to control a robot to assist an individual who retains the capacity for speech but is otherwise immobilized. Within Speech-Language Pathology, a particularly interesting application is the use of an isolated word recognizer in a training situation in the ISTRA System (Kewley-Port & Watson, 1988). Briefly, in the ISTRA system, a clinician records and then selects the most acceptable utterances for a given set of targets from a given client. These utterances then are used to train the speech recognizer. During subsequent computer-based training sessions, the client attempts to produce the target utterance. For each attempt, the speech recognizer analyzes the utterance in relation to the client's own best productions and then provides feedback to indicate how closely the utterance approximated the target. It can be expected that as such technologies improve, the range of devices used to assist the speech-language pathologist in routine assessment and therapy will increase proportionally.

Signal Processing/Enhancement

Once an acoustic signal has been captured in digital (numerical) form within a computer, there are a host of operations that can be performed upon it. All of the familiar analog operations — filtering, amplifying, attenuating, ramping, and so forth — have a precise digital equivalent. In addition, it is relatively easy to develop a variety of novel applications in the digital domain that subsequently are applied either digitally or in a more traditional analog circuit. Audiologists are now beginning to see the results of such signal processing applications in the increasing numbers of hearing aids which offer adaptive, noise-reducing, and programmable features. Admittedly, the proven benefit of such features lags far behind the hype, but there is no question that signal processing applications are available that can enhance the signal-to-noise ratio in particular listening situations, and it seems apparent that such approaches will be applied to assist individuals with communicative disorders.

Behavioral Technologies

Much of the foregoing has described the available hard technologies that can be expected to be applied to applications in Speech-Language Pathology and Audiology. In fact, the clinical application of microelectronic technologies presently is more limited by what might be termed the *behavioral technologies*. I use this term to refer to the human factors aspects of technology. Some immediate examples would include: (1) specifying precisely how information should be displayed; (2) specifying the way each part of the system should be controlled by the user; (3) identifying just what measures should be taken for a given assessment, or in what sequence; and (4) prescribing and executing the most efficient habilitation/rehabilitation procedures for a given client and situation. Within each of these areas, much work is already underway so that some preliminary conclusions can be drawn. First, it is clear that in instances for which an optimal protocol can be identified for assessment or rehabilitation, it will be most efficient to implement this protocol in a computer rather than to attempt to have a human carry out the protocol. As one example, the considerable literature on optimal stopping rules for testing indicates that it is both possible and desirable to implement computer controlled testing to measure the signal level at which a given level of performance would be obtained (Cheesman, 1990; Jamieson, Dell'Orletta, & Ramji, 1988; Levitt, 1971). In several instances, such a stopping rule can be viewed as a formalization of what is sometimes referred to as clinical judgement, but without the occurrence of human errors. Using this approach, therefore, it is possible to obtain a measurement to a prespecified level of accuracy and confidence in the minimum amount of testing time. Moreover, under any given set of testing conditions, it is possible to do this in virtually every instance.

Along with the appropriate application of available hardware technologies, such behavioral technologies facilitate the collection of the most accurate measures possible per unit of time. Moreover, such efficient testing procedures can be implemented within simple, engaging, and even enjoyable tasks. As one example, Wightman et al. (1989) showed that reliable measures of complex auditory processing abilities could be obtained from young children by presenting the task in the form of a videogram, with animation sequences. As another example, following Rvachew and Jamieson (1989), McDougald, Jamieson, and Cheesman (1989) showed that the speech perception abilities of young, articulation disordered children could be tested quite readily with a computer-based task using cartoon figures. These approaches offer special promise in the assessment and rehabilitation of individuals from various special needs groups, for example, children, the multi-handicapped, the elderly, and children from other linguistic groups and cultures.

Implications Of Current Research

The results of contemporary basic research will certainly have a profound effect on the clinical practice of tomorrow in ways which are now almost completely unpredictable. As an example, one need only look at the consequences of the basic research on the influence of the human head, pinna, and ear canal on incident sound, which was undertaken more than a decade ago by Edgar Shaw at the National Research Council in Ottawa. Ultimately, this research, together with the availability of the required electronic and computing technology at reasonable cost, has driven the now widespread integration of probe-tube, real-ear measurement to improve the process by which hearing aids are prescribed and fitted. Research presently underway at the frontiers of auditory physiology, surgery, psychophysics, and acoustical engineering will certainly alter how Audiology and Speech-Language Pathology are practiced in the future.

Other Implications

The availability of new technologies raises a series of questions, going to the very heart of the practice of (and preparation for) Audiology and Speech-Language Pathology. Some of these questions are discussed below.

Access to the New Technologies

Changes in the technologies available to Audiology and Speech-Language Pathology will inevitably bring changes in professional practice. One reason is that in the early stage of any new technology opportunities are offered to several professional groups to use this technology in their work. Moreover, since no group will have been prepared to use the new technology, there is a limited basis upon which to argue that any particular group should have access to (or control over!) the technology. A few examples currently relevant to the communicative disorders professions are: evoked response testing, nasendoscopy, probe-tube measurement, evoked otoacoustic emission testing, the various vestibular tests, hearing aid prescription, and a wide range of speech, language, and hearing assessments. In each of these areas there is, or recently has been, a threat, in at least Canadian jurisdictions, that communicative disorders professionals may be either excluded from directly using such technologies or that the technologies would be made available to groups with very limited qualifications.

It would seem, therefore, that there are three aspects to gaining access to new technologies: (1) demonstrating that the technology is *required* to carry out one's professional responsibilities; (2) demonstrating both that one is *competent* to use (or supervise) the technology and that the others are not; and (3) gaining funds to *acquire* the technology. It can be argued that communicative disorders professionals have not done a particularly good job in any one of these domains to date.

Demonstrating Need

As noted above, technologies can be said to be required to the extent that they can make a difference in clinical service delivery. Framed in this way, a technology should be introduced to a clinical service delivery unit once research has shown that the technology is both clinically- and cost-effective. Increasingly, the health care system is responding to the unfortunate history of technological acquisition; it is being driven by the manufacturers and sellers of the technology and dominated by the medical decision makers rather than through systematic evaluations of the efficacy of the technology. In the future it will be important to have data demonstrating the efficacy of a technology. Thus, what audiologists and speech-language pathologists lack through their admittedly still limited access to the health care acquisition decision process, they can be expected to make up for by obtaining good data, derived from sound research, that demonstrates the clinical efficacy of particular technologies.

Demonstrating Competence

A larger problem, it seems, is that of demonstrating to the system that audiologists and speech-language pathologists are appropriately prepared to use (or supervise) the new technologies. In my experience, students in Audiology, while the more technologically experienced group of communicative disorders students, are still often computerphobic and require careful instruction to use new instruments. As such, they are poorly prepared to adapt to new ways and systems. There is little evidence that they change after they enter practice. There are now legendary reports of audiology clinics in which a new system has been purchased only to languish on a shelf for months or years until some more technologically literate audiologist retrieves it and puts it into use. In my experience, Speech-Language Pathology students are even less sophisticated with respect to equipment and its use, and they have little opportunity to gain experience after they graduate. This situation must change if the field is to take advantage of what will clearly be offered.

Changes in the Workplace

Increments to the technological basis of the practice of Audiology and Speech-Language Pathology will affect practice in at least three domains. First, the level of productivity that can be realized and may come to be expected will increase. Secondly, the type and amount of preparation required to undertake certain tasks will change so that audiologists and speech-language pathologists may not, in fact, be the best prepared to adopt and apply these technologies. Thirdly, partly as a consequence of the changes just identified, the scope and detail of practice can be expected to change substantially for both audiologists and speech-language pathologists.

Productivity Increases

Technical tools are essentially productivity tools: They increase the efficiency with which a task is done by letting you do a given set of tasks with more precision (accuracy) in less time and/or more easily. An obvious implication is that one individual can do more with such technology than without it. Given the dimensions of the unmet demand for communicative disorders services, any possible increment in the quantity of service delivery, while maintaining or extending current levels of quality, would clearly be welcome.

The challenge to the field, and a research problem that will remain open for years to come, is to identify the scale of the productivity increments offered by various technology options and the situations in which such increments are possible. However, because the technologies to enhance productivity are relatively inexpensive, while salaries are relatively high, administrators can be expected to welcome these technologies. In turn, it seems clear that significant increments in productivity could result in substantial increases in the amount professionals are paid for their services, provided that the situation is appropriately managed by the profession.

Preparation for the Technologies

With the new technology-based productivity tools comes the need for individuals trained to understand both the technologies and the possibilities for applying these technologies to meet real clinical needs. Presently, communicative disorders professionals seem to be the best prepared group to take control of these technologies, but this advantage is slight and it may be short lived. To ensure that the advantage is not lost, communicative disorders professionals must, as a group, acquire the requisite knowledge and skill base, and control the application of these technologies within their workplace. The alternative is that this knowledge/skill base will be left to paraprofessional technicians and/or to members of other professions. In this instance, others will control the technology and will reap the benefits of the productivity gains.

I believe that the present advantage held by professionals in communicative disorders is slight, because most audiologists and (to an even greater extent) speech-language pathologists are insufficiently sophisticated, technologically. Indeed, given the history of the field and the recent (and present) curriculum in the educational programs, it could not be otherwise. The question of how to address technology issues within educational programs is discussed below.

Scope and Detail of Practice

As in every other work environment, technological innovation will change the way professionals work, and it will challenge the existing status quo regarding how professionals and paraprofessionals carve out their respective scopes of practice. Technical change is unpredictable, and it presents specific challenges at unpredictable times. At the root of the challenge is the fact that new technology often either changes the level of skill required to obtain reproducible and reasonably defensible results or sufficiently changes the way in which tasks are done so that individuals may no longer be appropriately prepared to undertake these tasks.

One example of changes in requisite skill level is the development of expert systems that have been generalized to include the interpretation and preparation of reports based upon standardized tests. In some quarters, this has been viewed as a threat to psychologists and psychometrists, and (by generalization) to speech-language pathologists (e.g., Bales, 1989). Another example is the development of probe-tube measurement systems having built-in hearing aid prescription systems (e.g., Cole, 1989) that significantly facilitate the development of a precise (and reasonably accurate) hearing aid prescription for individual clients.

A contradictory but related example is the method of confirmation of hearing aid fit using probe-tube measurement systems that was once threatened (within the Ontario jurisdiction) with being classified as sufficiently invasive so that it fell within the scope of practice of Medicine, not Audiology. Another example is a new canal hearing aid, developed by Resound corporation, that requires the removal of tissue from the ear canal. Presumably physicians alone will be able to fit (prescribe? dispense?) this device, which is really just an advanced, canal hearing aid. Table 1 provides a partial list of technologies which presently impact communicative disor-

Table 1. Examples of specific technologies presently (or imminently) impacting the scope of practice in Audiology and Speech-Language Pathology.

Technological Challenge	Groups Involved
Automated Assessment	Teachers, Psychologists, Technicians, Psychometrists
Probe-tube Measurement	Dispensers, Technicians
Automated Hearing Aid Prescription and Fitting	Dispensers, Technicians
ABR Testing	Psychologists, Technicians, Physiologists
Automated Speech Training	Teachers, Technicians

ders, together with some examples of groups who may (or already do) see these tasks as a somewhat important part of their own scope of practice.

Preparation of Professionals

Although there are clear exceptions among individual practitioners, the university programs that educate professional audiologists and speech-language pathologists have done a poor job of preparing their graduates to deal with a technically sophisticated workplace. Part of the reason for this failure is that the individuals attracted to the field, including those who eventually become faculty members, traditionally have been generally prepared students with BA or BSc (or even undergraduate communicative disorders) degrees. Recognizing this fact, some universities (e.g., Purdue) have taken steps to encourage applications for admission from students with strong technical backgrounds.

Another reason is that the communicative disorders curricula have not provided for even a basic level of technical competence. Recognizing this deficiency, Western has introduced a new required course in instrumentation for our Audiology students beginning in 1990/91 (but no such course will be required for our Speech-Language Pathology students). Much more can be done to integrate computing and other technologies directly into individual courses, of course. However, this step will require a faculty that is more comfortable with computing and other equipment than many of the present university teachers in communicative disorders happen to be.

In addition, the professional associations have an important role to play (perhaps in concert with the universities) to encourage technical competence through continuing education programs. Moreover, there is considerable room for individual professionals to seek out courses offered by for-profit agencies, such as manufacturers and third-party vendors, as well as through formal continuing education.

Summary

The technological revolution is only now about to impact the professions of Audiology and Speech-Language Pathology. In the author's view, clinicians in these fields are, as yet, largely unaware of and poorly prepared to meet the challenge of this revolution. Strategies need to be developed to manage these technologies as they becomes available. Such management must include: (1) an improved evaluation process to ensure that technologies are appropriate to the task, and (2) an improved educational process to ensure that graduates and practicing clinicians are prepared to deal with the new technologies. Achieving these objectives involves careful research involving both laboratory studies and clinical trials, coupled with an efficient system to disseminate the results on a national/international scale. It also requires changes in the mix of students who enter communicative disorders programs, changes in university curricula, continuing education programs targeting specific technologies, and individual initiative on the part of practicing clinicians.

Author's Notes
1. I have spoken on the topic in various settings over the past few years, most recently in an invited talk at the October 1989 OSLA meeting in Toronto. The thoughts recorded here have benefited much from my collaboration and discussions with Meg Cheesman, J.P. Gagné, Anne Godden, Andy Leeper, Curtis Ponton, Mike Procter, Emmet Raftery, Ketan Ramji, Richard Seewald, and Fred Wightman.

2. Support for the preparation of the manuscript was provided by the Ontario Ministry of Health and by the University Research Incentive Fund. However, the opinions expressed here are not necessarily endorsed by either agency.

Address all correspondence to:
Donald G. Jamieson, Ph.D.
Hearing Health Care Research Unit
Department of Communicative Disorders, Elborn College
University of Western Ontario
London, Ontario
N6G 1H1

References

Bales, J. (1989). Computer is no threat to assessor. *The APA Monitor, 20*, 12.

Boothroyd, A. (1987). *Cuny topic-related sentence sets.* City University of New York, New York, N.Y., USA. (video disk).

Chamberlin, H. (1985). *Musical applications of microprocessors.* Berkeley, CA: Hayden.

Cheesman, M.F. (1990). Efficient and reliable estimation of speech reception. Manuscript under review.

Cole, W. (1989). Audioscan real-ear measurement system. Etymonic Design Incorporated, Dorchester, Ontario.

Dixon, C. (1989). Micro Speech Laboratory. Center for Speech Technology Research, University of Victoria, Victoria, B.C. (software/hardware system).

Doddington, G., Fisher, W., Goudie-Marshall, K., McDaniel, J., Pallet, D., Majurski, W., Garris, M., Hieronymus, J., Garofolo, J., Zue, Z., Seneff, S., Lamel, L., Leung, H., Isaacs, K., Cassel, R., Volaitis, L., & Bernstein, J. (1988). *DARPA TIMIT Acoustic Phonetic, Continuous Speech Database*, USA: Prototype, PDO (compact disc).

Huer, M.B. (1989). Acoustic tracking of articulation errors: [r]. *Journal of Speech and Hearing Disorders, 54*, 530-534.

Hunt, M., Zwierzynski, D.A., & Carr, R.C. (1989). Issues in high quality LPC analysis and synthesis. *Proceedings of European Conference on Speech Communication and Technology*, September 26-28, Paris, France, 1989.

Jamieson, D.G., Dell'Orletta, D., & Ramji, K. (1988). Towards the automated assessment of speech intelligibility: Some results from the amplification research group. *Human Communication Canada, 12*, 45-47.

Jamieson, D.G., Ramji, K., & Nearey, T.M. (1989). CSRE: The Canadian Speech Research Environment. *Canadian Acoustics, 17*, 23-35.

Kewley-Port, D., & Watson, J. (1988). ISTRA: The Indiana Speech Trainer. *Journal of Rehabilitation Research.*

Klatt, D. (1980). Software for a cascade/parallel synthesizer. *Journal of the Acoustical Society of America, 67*, 971-995.

Levitt, H. (1971). Transformed up-down methods in psychoacoustics. *Journal of the Acoustical Society of America, 49*, 467-477.

McDougald, D., Jamieson, D.G., & Cheesman, M.F. (1989). Perception and production of selected phonemes by children with functional articulation disorders. *Journal of Speech-Language Pathology and Audiology, 13(1)*, 63-64.

Moser, L., Kammermeier, A., & Nolte, D. (1989). *Welden Digital Audiometer Disc No. 7.* Augsburg, West Germany: Westra Electronic GMBY (compact disc).

Proctor, M., Ponton, C.W., & Jamieson, D.G. (1986). Programs to produce high-quality dichotic tapes for central auditory testing. *Computers in Biomedical Research, 19*, 508-519.

Rabiner, & Schafer (1978). *Digital Processing of Speech Signals.* Prentice-Hall.

Read, C., Buder, E.H., & Kent, R.D. (1990). Speech Analysis Systems: A survey. *Journal of Speech and Hearing Research, 33*, 363-374.

Rvachew, S., & Jamieson, D.G., (1989). Perception of voiceless fricatives by children with functional articulation disorders. *Journal of Speech and Hearing Disorders, 54(2)*, 193-208.

Ryalls, J., & Baum, S. (1990). Review of three software systems for speech analysis: CSpeech, BLISS, and CSRE. *Journal of Speech-Language Pathology & Audiology, 14*, 49-52.

Scharf, D.J., Ohde, R.N., & Lehman, M.E. (1988). Relationship between the discrimination of /w-r/ and /t-d/ continua and the identification of distorted /r/. *Journal of Speech and Hearing Research, 31*, 193-206.

Thomas-Stonell, N. (1989). Speechviewer review. *Journal of Speech-Language Pathology and Audiology, 13 (2)*, 59-60.

Watson, C.S., & Kewley-Port, D. (1989). Advances in computer-based speech training: Aids for the profoundly hearing impaired. *The Volta Review, 91*, 29-45.

Watson, C.S., Reed, D.J., Kewley-Port, D., & Maki, D. (1989). The Indiana Speech Training Aid (ISTRA): Comparisons between human and computer-based evaluation of speech quality. *Journal of Speech and Hearing Research, 32*, 245-251.

Wightman, F., Allen, P., Dolan, T., Kistler, D., & Jamieson, D.G. (1989). Temporal resolution in children. *Child Development, 60*, 611-624.

Wilson, R.H. (1989) *Speech recognition and identification materials, Disc 1.* Audiology Section, VA Medical Center, Department of Veterans Affairs, Long Beach, CA. (Compact Disc).