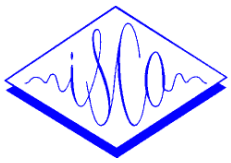

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THE IMPACT OF TECHNOLOGY ON SPEECH REHABILITATION

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ABSTRACT

The impact of technology on speech rehabilitation is examined from an historical perspective. The electronic era brought with it a prolific number of developments. Many of the devices developed during this period were initially designed as speech-reception aids but proved to be more successful as aids for speech production. The computer era brought with it not only significant advances in speech rehabilitation technology but, more importantly, it has changed our way of thinking about the rehabilitation process.

Two major milestones standout in the application of technology to speech rehabilitation. The first was the introduction of electronic technology, the second was the application of computers to the rehabilitation process.

Although several ingenious instruments for speech analysis and/or speech training were developed during the nineteenth century, these devices were not widely used and had little impact on speech rehabilitation. It should also be noted that most of these devices were not developed for speech training specifically, but were rather adaptations of instruments developed for scientific or commercial applications. One example is the flame manometer which measured the flow and oxygen content of air and, as such, could be used to provide a visual representation of the strength of speech sounds. Another example is the phonograph which was initially designed for business applications (as a dictaphone) but soon found widespread application as a new medium of entertainment. The phonograph also provided scientists with a powerful new tool for studying speech sounds. In addition, the phonograph opened up new possibilities for speech rehabilitation, and it has been used extensively for pronunciation training, although this application was mostly in the context of second language learning.

The electronic era brought with it several major developments, the most important of which was the electronic hearing aid. A related development of great consequence was the introduction of electronic test instruments for the evaluation of hearing, speech reception and speech production. Three other significant developments during this period were the invention of the tactual vocoder, the Visible Speech Translator and electronic means of recoding speech signals, such as frequency transposition.

Each of the above inventions was designed primarily as a means of improving speech reception for hearing impaired individuals. In some cases, the device was successful in its intended application. The hearing aid, for example, has improved the speech reception capabilities of millions of hearing-impaired people and is now the most widely used of all electronic sensory aids. The hearing aid has also been found to be of considerable value in speech rehabilitation of severely and profoundly hearing-impaired individuals.

In other cases, such as for tactual aids of various kinds, the device was found to be only moderately useful in terms of its intended application as a speech reception aid; i.e., these devices were typically found to be of some value as supplements to lipreading. In contrast, all of the early investigations of tactual aids found these devices to have potential value as speech-training aids. A similar result was obtained with frequency transposition. Although early evaluations of frequency-transposing hearing aids were disappointing in terms of their value as speech reception aids, certain forms of frequency transposition were nevertheless found to be of practical benefit for speech training.

The experimental evaluation of the Visual Speech Translator and other visual speech displays showed a similar pattern of results. In terms of its intended application, the Visible Speech Translator and other speech displays were not very successful. However, these instruments were found to be useful as speech-training aids. Further, as a research tool, the sound spectrograph (the key component of the Visible Speech Translator) has been an enormous success and has given rise to new ways of thinking about the speech signal which, in turn, has lead to the development of practical methods of speech synthesis. These techniques are now widely used in speech rehabilitation.

The use of digital techniques in speech rehabilitation began with the use of a general purpose laboratory computer for speech training. The use of a computer offered many advantages over traditional electronic techniques. The computer, because of its programmability, could incorporate a wide range of speech training devices in a single unit. That is, the computer would do what any conventional electronic speech training aid could do, but more efficiently. More importantly, the computerized speech-training system could do things beyond the capabilities of conventional electronic devices. In particular, computer systems could be programmed not only to be easy to use (i.e., user friendly) but also to provide the teacher with helpful information on training strategies and methods of evaluation.

Several other important advantages of computer-based systems should be noted. Modern computers have the capability of storing and retrieving large quantities of information rapidly and efficiently. It is thus possible to record and store speech produced by the student during the course of training. Since students in training show a high degree of variability in the quality of their speech productions, the good utterances that have been stored can be used to provide the student with an achievable goal to aim for during training. These recorded utterances can be played to the student either auditorially or with a visual display showing the appropriate articulatory movements. Recordings of improperly produced utterances can be used to determine the nature of the speech problem and displayed to the student to illustrate which problems to avoid.

The capability of monitoring a student's speech productions objectively and unobtrusively during training can add considerably to the effectiveness of a well organized speech-training program. A systematic speech training program beginning with basic speech skills to which more advanced speech skills are added incrementally can produce significant improvements in speech production skills. The logistics of maintaining such a speech training program, however, are not trivial. A significant portion of the teacher's time is taken up in maintaining records of each student's progress. Further, much of the evaluative data obtained on each student is based on subjective judgment. This can cause serious problems if a student is judged as having acquired one or more basic skills, and at a later stage, when the student is attempting to acquire more advanced skills, it is discovered that these early subjective assessments

were incorrect and the student has to either start again, or worse, to unlearn incorrect speech habits resulting from this early misdiagnosis.

Objective measures of speech production ability can do much to avoid the above problems. Computer-based systems not only facilitate the use of objective measurement within the framework of a practical speech-training program, but these measurements can be obtained efficiently and unobtrusively; i.e., by the press of a designated key on the computer while the training session is in progress.

Perhaps the most important advantage of digital technology is that it has changed our thinking with respect to speech rehabilitation. Speech synthesizers, for example, have provided a completely new approach to the rehabilitation of individuals with severe speech impairments. Using speech synthesis as a means of communication, a limiting factor has been found to be the speed with which a human being can enter the symbols needed to synthesize speech. This has lead to the development of speech synthesis systems which attempt to predict, on the basis of linguistic and statistical constraints, which symbols are likely to be entered next thereby simplifying the task for the user and speeding up the communication process. The development of systems that both predict and synthesize speech signals requires a much broader approach to speech rehabilitation; one that takes into account not only the traditional issues involved in speech rehabilitation but also the cognitive and motor capabilities of the user and the extent to which the user can make use of advanced technology.

The immense popularity of video games is having a profound effect on the younger generation. Many children have developed unusual capabilities in terms of human-machine interaction that adults cannot match. This has come about largely because of their early and extensive exposure to this technology. An obvious way of harnessing this technology for speech rehabilitation is to develop video games that elicit speech productions by the user and, in the context of the game, systematically improve the quality of the user's speech skills. This has been done using computer-based speech training systems although, as yet, video speech games have yet to be developed which have attained the popularity and intense loyalty exhibited by devotees of the more successful video games.

The development of computer-based games for speech training requires not only a deeper understanding of the differences between normal and pathological speech, but also a good understanding of the psychology of game playing and why certain games are extremely popular and are played intensively for long periods of time while other games rapidly lose the player's interest. It would have been a particularly insightful researcher to have predicted, before the advent of computer-based speech-training systems, that considerations such as these would be a factor in developing more effective methods of speech rehabilitation.

Another significant development that has influenced our thinking is that of computer simulation. The use of digital techniques for speech analysis are obvious. These techniques are not only considerably more precise than older traditional techniques, but the analysis procedures could also be automated thereby providing a means for obtaining substantial amounts of precise information with relatively little effort. The use of computer simulation, however, provides information of a different type. In order to simulate a given form of pathological speech properly it is necessary to have an accurate, quantitive model of the speech mechanism and the effect of the pathology on that mechanism. The emphasis is thus on modelling the speech mechanism accurately and this

activity has generated significant new insights with respect to the nature of speech pathologies and its impact on speech production.

An additional advantage of computer simulation is that the effects of different intervention strategies can be investigated by manipulating the parameters of the computer stimulated speech. One such study has demonstrated how this approach can be used to develop training strategies for improving timing in the speech of deaf children. The result of this investigation showed that maintaining the normal ratio between stressed and unstressed syllables was important for intelligibility, but that shortening vowel durations in order to approximate those of normal speech was not particularly helpful. This result was not quite what was expected and it affected our thinking with respect to developing a speech-training curriculum for improving rhythm and timing in the speech of deaf children.

The use of advanced technology for speech rehabilitation has not always been successful and it is instructive to compare those applications which have been successful and those which have not. Initially, the attitude of many engineers in developing technology for speech rehabilitation has been to simply hand over new devices to the rehabilitation professional and to expect immediate positive benefits to emerge. This approach has not worked primarily because most of the early technological devices were not easy to use and effective methods of intervention for these devices were not obvious. A much more productive approach is to develop new technology as part of an integrated rehabilitation program in which both rehabilitation strategies and the associated technology are developed symbiotically. In developing an improved speech-training system, for example, it is encumbent on the research team not only to develop improved hardware but also to develop an appropriate speech-training curriculum to be used with the system.

Finally, of the many systems for speech rehabilitation that have been developed over the years, the most successful ones have been both reliable and easy to use. Although the technology itself may be exceedingly complex, simplicity in the hands of the user is the hallmark of success.