SPEECH TRAINING DEVICES FOR PROFOUNDLY DEAF CHILDREN

Lynne E. Bernstein, James B. Ferguson III and Moise H. Goldstein, Jr.

Department of Electrical Engineering and Computer Science
Johns Hopkins University
Baltimore, Maryland, U.S.A.

ABSTRACT

Prelingually, profoundly deaf children have great difficulty achieving intelligible speech. Even after intensive therapy, their speech is deficient in voice pitch, rhythm, stress and intonation, as well as segmental phonetic characteristics. To facilitate the speech training of these children, we are developing two interrelated personal computer (PC) based systems: a school system and a home system. In the school system, speech production is monitored by microphone, electroglottograph, and pneumotachograph. The home system uses only microphone input. Both systems use video displays for providing feedback and reinforcement. The school system allows diagnosis, training by game playing, and specification of games to be played on the home system. The home system provides directed speech practice between therapy sessions.

PROJECT GOALS

Speech training of prelingually, profoundly deaf children in typical preschool programs and in elementary schools for the deaf is in one-on-one sessions with a specialist. Speech and language training is required, because these functions will not develop spontaneously in such children [1]. However, even with therapy, these children typically make little progress. Even though speech production may improve during a training session, improvement typically does not carry over to the next session. We believe that this poor progress is due to the short training periods in school, the lack of adequate analysis and training tools in the hands of therapists, and inadequate opportunities for guided practice by the child outside of the therapy sessions. In order to help ameliorate these problems, we are developing two PC-based, interrelated speech training systems, one for use by a specialist in a school or clinic, the other for the deaf child's home.

Speech can be described in terms of its phonetic and prosodic characteristics. The profoundly deaf speaker is likely to be deficient in the production of both types of characteristics. The prosodic characteristics are closely related to fundamental aspects of speech physiology and without control over prosody, even correctly articulated phonetic segments can be unintelligible [2][3][4]. For this reason, many current training programs begin with work on prosodic characteristics [4][5]. In the first year of our project, just complete at this time, a sequence of games for training certain prosodic characteristics of speech (i.e., sustained voicing, intensity, and isolated syllables produced on one breath) have been developed and are described below.

Present development is focused on voice pitch, its control, and detection of abnormal speech physiology. Research at Gallaudet College has demonstrated the usefulness of the electroglottograph (EGG) and the pneumotachograph (PTG) in diagnosing problems in voice production of deaf college students [6][7]. The EGG provides a monitor of the opening and closing of the vocal folds, while the PTG monitors the volume velocity of expiration. These two signals in conjunction with the acoustic signal of vocalization can provide significant diagnostic power to detect abnormalities in voicing production.

PC-BASED SYSTEMS

Figure 1 shows the configuration of the school system. The home system is simpler, having only the microphone input and using an IBM PC/XT. Both the home and school system make use of high resolution color graphics and a digital signal processing board employing the Texas Instruments TMS320 chip.

 CH2243-4/86/0000-0633 $1.00

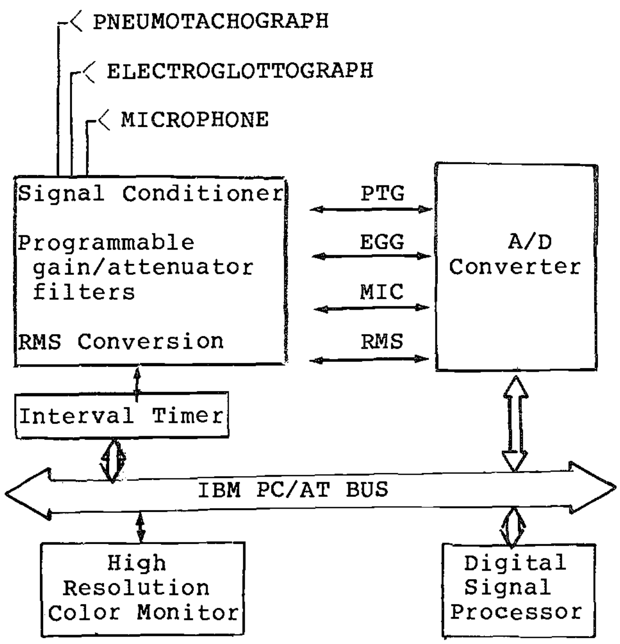

Figure 1. System configuration.
Line connections indicate analog signals.
Bar connections indicate digital I/O.

Hardware development has included design of an analog preprocessor. Programmable preamplifiers and filters allow flexible conditioning of the input signals. A data acquisition board follows with A/D conversion and data acquisition all under program control.

The major engineering task in realizing the system has been software development. Most of the software has been written in the C programming language. The overall aim of the engineering design is to have a very flexible system, yet one that is easy for therapists and students to use. These aims have been met largely through extensive software control and through menus by which the user selects functions or games and sets parameters.

SPEECH TRAINING GAMES

The following is a brief description of some of the training games that have been written and are now in use.

Sustained Vocalization

The goal of the sustained vocalization game is to train the child to produce sustained voicing for 2, 3, 4, 5, or 6 s. Each duration can be presented as a separate level of the game. The vocalization required of the child is typically a vowel or consonant-vowel syllable that the child can already produce relatively easily. Figure 2 shows the monitor following 4 trials of the game. The game is voice activated, and a color bar is filled during the duration of the child's vocalization. If that vocalization is the required length, one of a set of animated images is presented. Vocalizations that are intermittent or too short are not followed by animation. Required duration can be changed at any point in the program.

Repeated Short Vocalizations

The goal of this game is to produce in one breath a specified number (i.e., 1-15) of short isolated syllables. Usually one consonant-vowel combination will be chosen for repetition. The number of syllables and the rate of production (1, 2, or 3 syllables per s) can be independently specified by the user. Figure 3a and 3b shows two graphics from the game. The game employs graphics of bird "foot prints" to represent the sequence of target syllables. After each production of an isolated syllable, a foot print changes color, starting from the left of the screen and moving right. At the same time, a graphic of a bird is moved along above the foot prints (Figure 3a). An animated worm moves across the screen beneath the foot prints at the specified rate of syllable production. If the child successfully completes the specified number of isolated syllables before the worm reaches the end of the line of tracks, the bird picks up the worm and flies across the screen (Figure 3b). No animation follows an inadequate attempt. Especially important for this exercise is that the child is required to interrupt voicing between each syllabic articulatory maneuver. Ongoing voicing without interruption will not move the bird across the screen.

Immediate Feedback for Intensity Changes

This exercise introduces the child to a perceptual loudness scale that is mapped onto a vertical bar composed of three different color blocks. As the child vocalizes into a microphone, the image of a balloon rises or falls in real time next to the vertical bar. The scale is divided into regions for quiet voice, conversational voice, and loud voice.

Intensity Game with Star or Score Feedback

Once the child understands the loudness scale, a game is available to work further on the control of intensity. On a random basis, a target intensity level is indicated, and the child must attempt to produce that level. A pointing hand indicates the target level, and after the child vocalizes a balloon rises to the level that was achieved. Figure 4 shows a graphic of the balloon at the level specified by the pointing hand. Correct response results in receiving a star or a numerical score, depending on the version of the game being run. In this game, the balloon does not rise to the intensity level achieved until 2 s of speech have been sampled. In this way, the child cannot use immediate feedback to adjust vocalization to the required intensity.

Intensity Game with Limited Feedback

In the games described above, a visual scale or display provides a direct analog to the child's vocilizations. One goal of speech training is that the child achieve vocal control independent of such feedback. A game was written to provide limited delayed feedback for control of vocal intensity. In this game, the color of blinking balloons held by a clown is used to signal the required loudness of vocalization. Trials are voice activated and sampling continues for 2 s. Success results in a star appearing over the balloon associated with the particular trial. Figure 5 is a graphic taken during the course of the game. Incorrect vocalization results in no change in the display, and the next balloon in the sequence begins to blink.

DISCUSSION

A fundamental aspect of the project from the beginning has been the participation of specialists in speech training, and profoundly deaf children. Our system is now being used at the Kendall Elementary School of Gallaudet College and also in the laboratory at Johns Hopkins University. These games have received enthusiastic response from children ages 3-5 and 9-11 years.

One of the constant issues raised in the process of developing these systems is the effect of isolating specific speech characteristics for training. When, for example, training is focused on control of intensity, children's voice fundamental frequency tends to co-vary, as does voice quality. Further, it is possible for a speaker to achieve specific acoustic characteristics using abnormal vocal maneuvers. For example, as a child attempts to increase vocal intensity, he may produce breathy or harsh voice that may result from inadequate approximation of the vocal folds. The dilemma is to provide specific training in a particular voice or phonetic characteristic without inadvertently giving experience and reinforcement for inadequate or abnormal performance of another characteristic. The resolution to this dilemma at this time seems to be multifold. Inclusion of tools for diagnosis and games using the EGG and PTG can help to correct abnormal physiology that might nevertheless result in partially adequate acoustic signals. Another partial solution is to produce a large number of games and/or diagnostic tools that depend on a wide variety of speech characteristics, both in isolation and combination. Of prime importance is the intervention of the individual who works with the child. This person must make judgments about the appropriate points at which to introduce and withdraw training exercises. Our system is intended to be a significant aid to the speech-language pathologist or speech therapist working with deaf children.

ACKNOWLEDGEMENTS

This work is an Orphan Product Development Study supported by NIH/NINCDS (N01 NS-4-2372). Dr. James Mahshie has provided considerable input to this project in all its stages. Our appreciation is extended to Ms. Betty Waddy-Smith, speech-language pathologist, and Ms. Diane Vari, speech therapist, and the deaf children in this project. Also, thanks are due to Mr. Silvio P. Eberhardt for his help in preparing this paper.

REFERENCES

[1] S. P. Quigley. "Effects of early hearing impairment on normal language development." In F. N. Martin (Ed.), Pediatric Audiology. Englewood Cliffs, NJ: Prentice-Hall, 1978.

[2] K.N. Stevens, R. S. Nickerson and M.H. Rollins. "On describing the suprasegmental properties of the speech of deaf children." Bolt, Beranek and Newman Report 3955, 1978.

[3] J. M. Pickett. The Sounds of Speech Communication. Baltimore, MD: University Park Press, 1980.

[4] D. Ling. Speech and the Hearing-Impaired Child: Theory and Practice. Washington, D.C.: The Alexander Graham Bell Association for the Deaf, Inc., 1976.

[5] D. Ling. "Speech development in hearing-impaired children." Journal of Communication Disorders, 1978, 11, 119-124.

[6] A. Hasegawa, J. Mahshie, E. Herbert and J. M. Pickett. "Electroglottographic, aerodynamic and acoustic study of normal and breathy phonation." Journal of the Acoustical Society of America, 1984, 76, S58(Abstract).

[7] J. Mahshie, A. Hasegawa, M. Mars, E. Herbert and F. Brandt. "Voice fundamental frequency training of hearing impaired speakers." Journal of the Acoustical Society, 1983, 73,

S15 (Abstract).

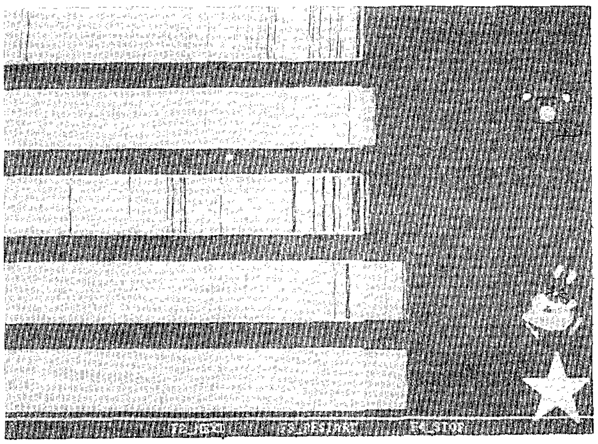

Figure 2. Graphic from sustained vocalization game. White bars represent duration of voicing.

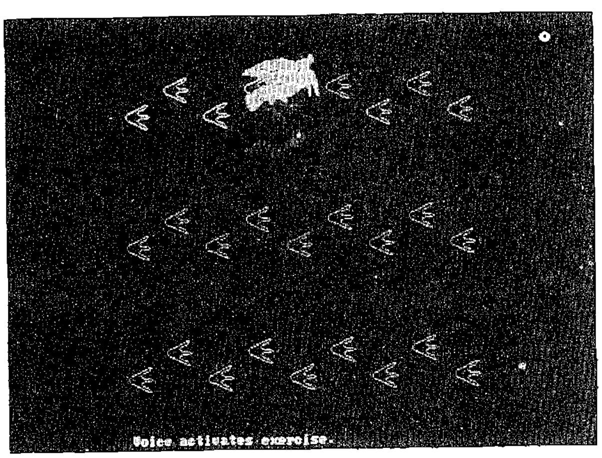

Figure 3a. Graphic from repeated short vocalization game. Bird moves one foot print for every syllable vocalized.

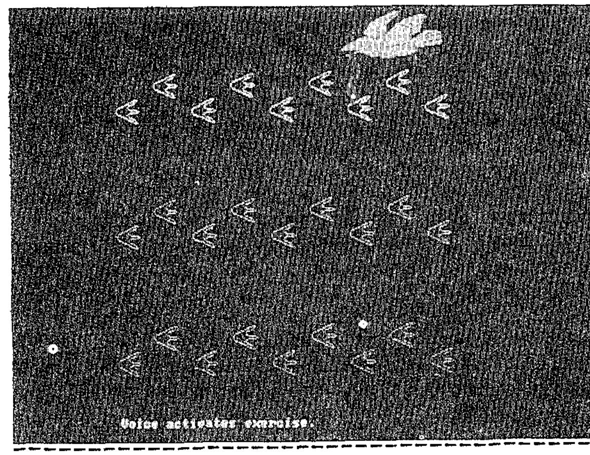

Figure 3b. Graphic from repeated short vocalization game. Following successful sequence, bird flies across screen.

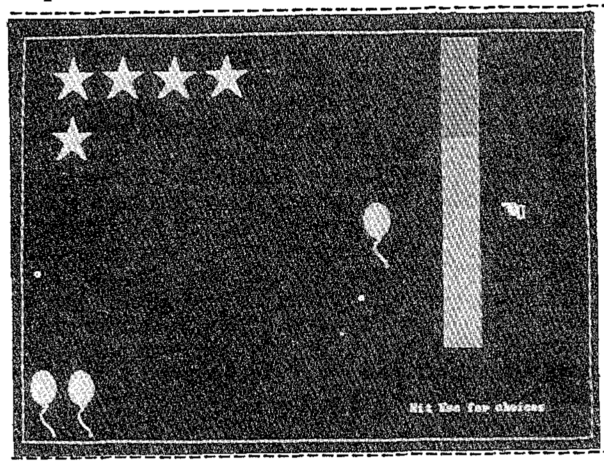

Figure 4. Graphic from intensity game with feedback. Child must make balloon rise to the level indicated by the hand on the right of the screen.

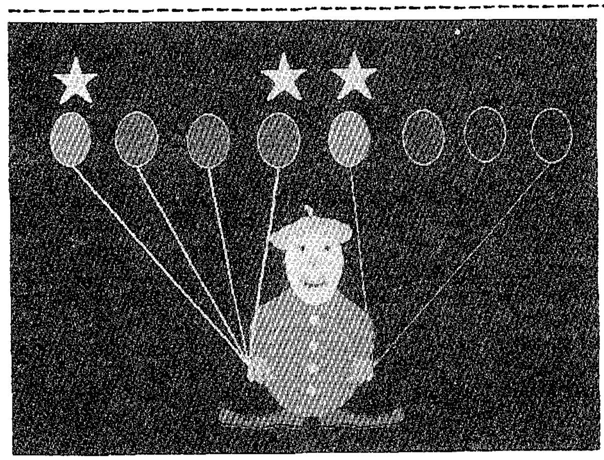

Figure 5. Graphic from intensity game with limited feedback. Child must produce intensity levels coded by the color of the balloons.