

Using a Voice Synthesizer to Increase Reading
Comprehension Levels of Learning Disabled Adults:
Implications for Training

by

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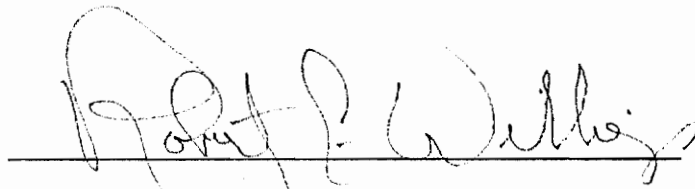
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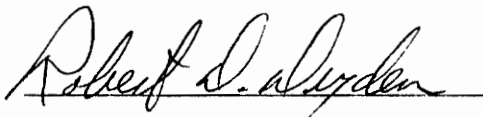
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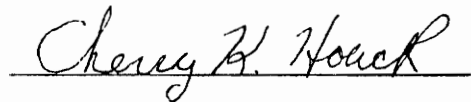
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Barbara H. Glickstein

Committee Chairman: Robert C. Williges
Industrial Engineering and Operations Research

(ABSTRACT)

Research efforts to determine the needs of special populations has increased in the field of human factors. The majority of these efforts are focused on the physically disabled. Little attention has been paid to the learning disabled, and specifically, the learning disabled adult. A single factor between subject design was utilized to evaluate the effectiveness of using a voice synthesizer to increase reading comprehension levels of learning disabled adults. The independent variable was presentation mode. The Passage Comprehension subtest of the Woodcock Reading Mastery Tests-Revised was presented via the computer. Subjects were required to complete the test under one of two

conditions:

with voice feedback or without voice feedback.

Dependent measures included total correct answers and reaction time. Also, using a seven-point Likert scale, subjective data regarding various aspects of the voice synthesizer was collected. The Passage Comprehension subtest of the Woodcock-Johnson Psycho-Educational Battery-Revised was also administered to each subject by the experimenter. Comparisons of total scores were then made between the different administration formats. Analysis of the data was conducted using ANOVAs and t-tests. Results indicated no significant differences. Such results were attributed to the small sample size, the subject's potential familiarity with the type of test administered, and compensation skills already developed and maintained by the learning disabled subject. It was concluded that additional research was needed in order to understand the effects of using a voice synthesizer to increase reading comprehension levels and in adapting training programs in industry for the learning disabled.

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INTRODUCTION

The rise in computer technology and the increase in human factors research in the area of special populations has provided support for those with special needs in a variety of ways. Computerized speech has proven successful as an aid to the nonvocal physically disabled through the development of a "talking wheelchair" (Bell, 1979); the blind and visually impaired via "talking books" (Mills, 1988); and those with cognitive and speech difficulties through the many computer programs which employ computerized speech (Stoughton, 1983). While research continues to grow and expand to support special populations, research pertaining to those with learning disabilities remains virtually untouched in the field of human factors.

Understanding the user with a learning disability is often difficult due to the heterogeneity of this population and the invisible nature of the user's problems. Since one can not "see" the disability as with a physically disabled person, the learning disabled adult is often met with limited career choices due to a lack of understanding of the nature of their problem, and subsequently, how the employer might help to meet their needs (Hoffman, Sheldon, Minskoff, Sautter, Steidle, Baker, Bailey, and Echols, 1987).

One of the more widely recognized and researched

learning disabilities is reading disabilities. Published literature suggests that the use of computers can aid in increasing reading comprehension. In addition, it is suggested that multisensory approaches to teaching the learning disabled have been successful by providing a variety of potentially non-dysfunctional avenues through which information can be obtained (Lovitt, 1989).

Although evidence indicates that learning disabilities persist into adulthood, most studies focus on learning disabled children. Furthermore, research on the use of a voice synthesizer is lacking. The lack of research on learning disabled adults and the increasing evidence that such disabilities persist into adulthood provided a strong impetus for conducting this study. The success of this research could provide implications for modifying industrial training programs which in turn could widen the opportunities for the adult with a learning disability.

Experimental Overview

A single factor between subjects design was used to examine the effectiveness of using a voice synthesizer to increase the reading comprehension levels of learning disabled adults. The independent variable was presentation mode (with and without voice feedback). The dependent variables included total scores achieved on a standardized

reading comprehension test and reaction time. Additional data were collected in order to make comparisons between manual and computer administration of a reading comprehension test.

Subjective measures regarding the synthesized speech were also assessed. Analysis of the data was conducted using a single factor analysis of variance (ANOVA) and t-tests.

Purpose of Study

The purpose of this study was to evaluate the effectiveness of the voice synthesizer on the reading comprehension levels of learning disabled adults. The researcher sought to determine whether, in administering the Passage Comprehension Subtest of the Woodcock Reading Mastery Test-Revised (WRMT-R) (Woodcock, 1987), those subjects who are provided with voice feedback score more correct answers and respond more quickly to questions presented on a cathode ray tube (CRT) than those who are not provided voice feedback.

The users' attitude regarding the voice synthesizer, the intelligibility of the speech, and its potential usefulness in a job situation, was also evaluated. The results indicate that additional research and understanding is needed before beginning to adapt training programs in industry.

LITERATURE REVIEW

To meet the needs of any user, one must first understand these needs. The following section offers an initial introduction to who the learning disabled adult is, and why it is important to address this population. Focus is on specific reading disabilities with special attention to comprehension difficulties. A basis for using a multisensory approach to address these difficulties is illustrated through studies which have incorporated both visual and auditory stimuli. Finally, the nature of and support for using a voice synthesizer is presented.

Learning Disabled Adults

The term "learning disability" is often misunderstood and misused. Many people assume that "learning disability" is synonymous with "mentally retarded." This assumption is incorrect. A number of definitions of learning disability are put forth by various organizations and individuals. The most commonly accepted definition is the one endorsed by the federal government.

'Specific learning disability' means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include children who have learning problems which are primarily the result of visual, hearing, or motor handicaps,

of mental retardation, of emotional disturbance, or of environmental, cultural, or economic disadvantage (Federal Register, December 29, 1977, p. 65083).

This definition emphasizes that the disorder is in one or more of the basic psychological processes involved in understanding or in using language and, is the primary characteristic of the learning difficulty. Note that this definition does not include adults. Other definitions, such as those proposed by the National Joint Committee for Learning Disabilities (NJCLD) and the Association for Children and Adults with Learning Disabilities (ACALD) seek to specifically include the adult population in their definitions and emphasize that the disability is a life long condition (Hallahan and Kauffman, 1988).

While children with learning disabilities have been the usual focus of research in this area, recent studies have supported the NJCLD and ACALD definitions, indicating that such disabilities continue into adulthood. Indeed, many adults with learning disabilities continue to have problems which affect their vocational competence and employment opportunities (Buchanan and Wolf, 1986; Polloway, Smith and Patton, 1988). Geib, Guzzardi and Genova (1981) note that while the law has helped to identify increasing numbers of learning disabled children, many adults who previously may not have been identified as learning disabled are now being identified as indeed, having such problems. The authors go

on to explain that even if such adults have gained the skills for employment, they may encounter difficulty, even job loss, particularly if directives are written and paper work is required.

In a survey of 33 learning disabled adults, Buchanan and Wolf (1986) found only three percent of this group held professional jobs. The majority, (39.4%), were students, with the next highest percentage (18.2%) reporting employment in semi-skilled positions. Hoffman, et al. (1987), in sampling 381 persons with learning disabilities from Pennsylvania, West Virginia and Virginia, stated that "[o]verall, the typical learning disabled adult could be characterized as an unemployed, unmarried 23-year-old white male ... who had graduated from high school, had received some form of specialized education, had previously been labeled learning disabled, and was being supported by his parents" (p. 43). Clearly, there is a necessary concern for the fate of the learning disabled adult.

In providing guidance for addressing the needs of learning disabled adults, Gray (1981) emphasizes that compensation for the disability must be a focus of provisional services. Such a focus should make use of devices, strategies and techniques that are necessary to compensate for deficit skills.

Such techniques may include the use of audio and/or video sources rather than print; taping test responses; dictating written reports, letters, or projects which s/he wants to function (p. 430).

Gray goes on to state that the

'read - nothing' syndrome, always inappropriate, especially inappropriate for adults. More productive is the development of skills which will allow the LD adult to cope in the desired environments in spite of skill deficits (p. 430).

A major, if not critical, issue faced by the learning disabled adult is employers' attitudes. People often find it difficult to understand and empathize with the learning disabled individual due to the invisible nature of the disability. Often this lack of understanding leads to false expectations and negative stereotypes. It is therefore understandable why the learning disabled adult might question how much to tell an employer about his or her disability (Zambrano, 1988). In a study conducted by Mansoff, Sautter, Hoffmann and Hawks (1985), the researchers found that employers often had negative attitudes toward hiring the learning disabled. In general, employers were willing to help handicapped workers as long as they carried their own loads and did not introduce their personal problems into the workplace. However, a small percentage admitted that they would fire an employee AFTER finding out that they had a learning disability. Such attitudes must be addressed not only by increasing the

employer's understanding of the capabilities of the learning disabled, but by providing employers and the learning disabled employee, techniques and devices to make adaptations in the workplace. The voice synthesizer is a device which may allow wider access to jobs that are currently unavailable to the LD adult.

Specific Reading Disability

As indicated by the federal definition, learning disabilities can be manifested by difficulties in a variety of areas, most notably reading. While reading disabilities can be due to a number of factors (physical, neurological psychological, socioeconomic and educational) (Lovitt, 1989), it is beyond the scope of this paper to present such a discussion. The focus of this research relates specifically to those persons whose reading difficulties are due to a visual processing problem. As such, the following section presents information pertaining to the process of reading and the nature of comprehension difficulties.

Process of Reading. Several paradigms exist in explaining learning disabilities in general. To date, theories presented through the information processing paradigm have provided the basis for explaining the reading process and offering suggestions for increasing the abilities of the learning disabled. The information

processing paradigm assumes that the mind may be viewed as a limited capacity symbol manipulator, analogous to a modern computer. Like a computer, humans process information using elaborate "programs". Information is analyzed and synthesized in sequential steps (Parrill-Burnstein, 1981; Swanson, 1987; Torgeson, 1986).

A model of human information processing is shown in Figure 1 (Wickens, 1984). This model illustrates the flow of input from a stimulus to the short-term memory store. Wickens describes this store as a central mechanism within each sensory system, (or modality), that prolongs a representation of the physical stimulus for a short period of time after the stimulus has physically terminated. It requires no conscious effort, preserves most of the physical details of the stimulus, and is rapidly decaying, the particular time of the decay varying somewhat between the type of sensory store. Thus, the stimulus image is preserved briefly and without attention. The higher centers of the nervous system then process the conscious perception of the stimulus. The incoming information is matched to a unique neural code that was previously learned and stored in the brain resulting in a perceptual decision in which the physical stimulus is assigned to a single perceptual category.

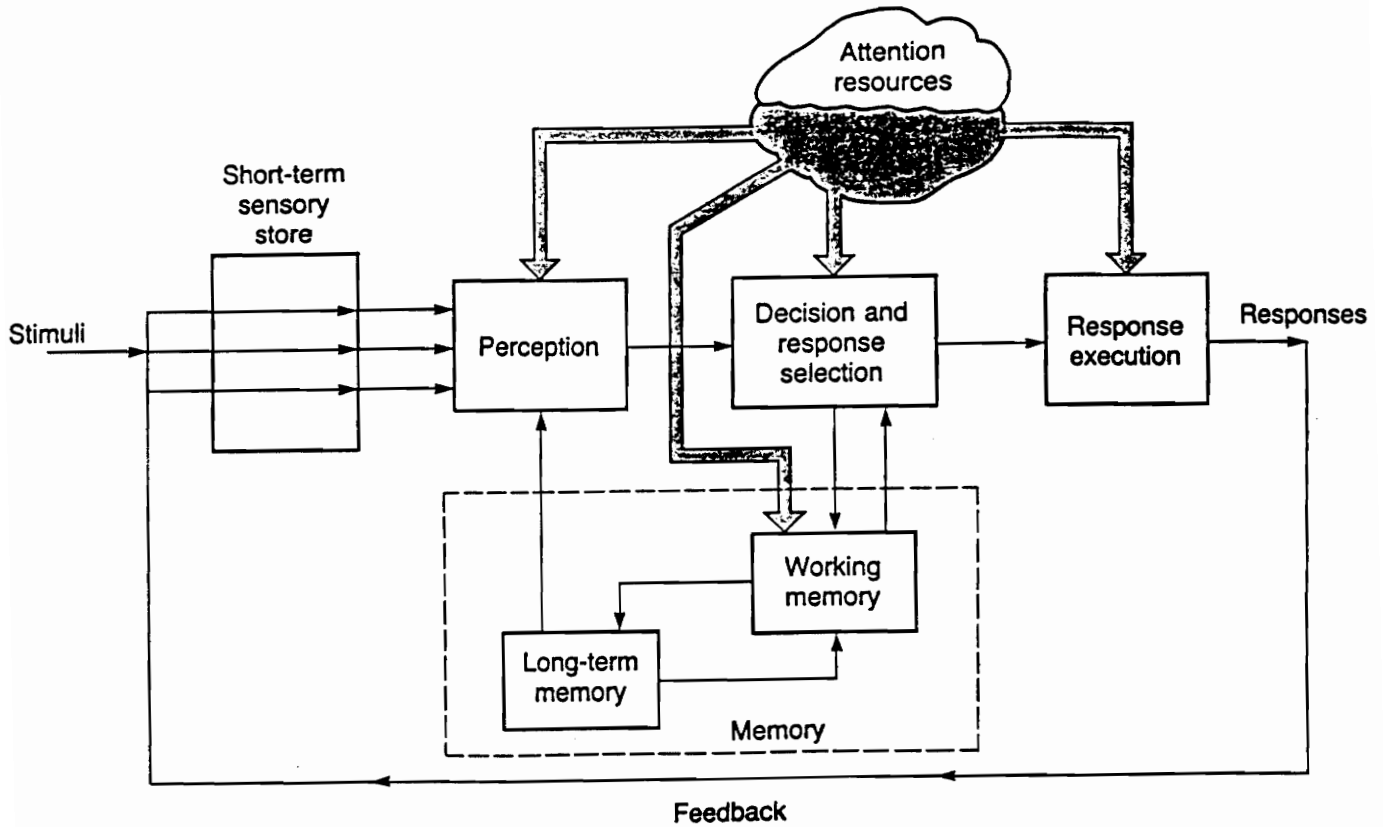


Figure 1. A Model of Human Information Processing. Adapted from Wickens, C. D. (1984). Engineering psychology and human performance. Glenview, Illinois: Scott, Foresman and Company.

Following the perceptual categorization of the physical stimulus, a decision must be made as to what to do with the information - to store it in memory and/or to generate a response. If a response is executed, some type of feedback is often provided to aid in monitoring the consequences of the response. (While feedback is often thought of in terms of a visual feedback loop, other modalities may provide such loops as well.)

Finally, the model takes into account the fact that the different stages of processing compete for various amounts of a limited attention resources. Thus, if one stage requires more of this resource, less will be available for other processes, whose performance may therefore deteriorate. However, learning and practice decrease the demand for the limited supply of attentional resources.

In applying this model to the reading process, the physical stimulus to be perceived becomes the viewed printed material. The perception of printed material is hierarchical in nature, such that when we read and understand the meaning of a sentence we must in the process analyze its constituent words. For the learning disabled, even if the initial association is made, attentional demands may be such that other stages in the information processing model may deteriorate due to the lack of resources. As can

be seen from Figure 1, there are many avenues during which problems can arise and make the reading process difficult.

Comprehension Difficulties. To understand reading difficulties the first step must be to start at the beginning of the information processing model and attempt to understand the initial perception and categorization of the information. Snider and Tarver (1987) stress this point in researching the effect of early reading failure on acquisition of knowledge among students with learning disabilities. The researchers detail Chall's stages of reading development which are as follows: initial decoding, fluency, reading for meaning, relationships and viewpoints, and synthesis. The authors emphasize the sequential nature of this development by explaining that skills and knowledge learned in later stages can only be increased by building upon skills learned in previous stages. Thus, in relating such learning to the model again, knowledge of the individual's ability to perceive the information must be understood and emphasized first. If the print (stimulus) is not effectively entered and perceptually categorized, then the potential for incorrect or confusing outputs are increased. To aid the learning disabled, methods for understanding how information can best be presented must therefore be researched and tested. Such research has been

conducted in the area of multisensory instructional techniques.

The study and use of multisensory techniques address the need for identifying better ways of increasing correct inputs and categorization, and thus aid the comprehension abilities of the learning disabled. Multisensory techniques are based on the fact that individuals learn and process information using different sensory modalities. It is believed that a multisensory approach will aid in the comprehension of the displayed information by increasing the amount of sensory stimuli received and thus the amount of information received (Reilly and Barber-Smith, 1982; Schiffman, Tobin, and Buchanan, 1982).

While there are many methods of introducing multisensory techniques into reading instruction, most include at a minimum, the incorporation of some auditory stimulus to enhance the visual scene. Research has been conducted in efforts to understand whether or not such an enhancement aids the learning disabled person's ability to read. One way of incorporating an auditory stimulus is to have the student verbalize the words which are being read.

In facilitating the use of the auditory channel as well as the visual channel, researchers have also attempted to use tape recordings of the material to be read and learned.

Results of these studies provided support for such a multisensory technique. Subjects had increased achievement scores, and recall of textbook information and reading passages was also facilitated by the use of the tape recorded material (Mosby, 1979; Sawyer and Kosoff, 1981; Wiseman, Hartwell and Hannafin, 1980).

Bowman and Davey (1986) studied the effects of using the auditory channel via an audiotape in addition to the visual mode, in researching the comprehension-monitoring behavior of the learning disabled. They studied the effects of two presentation modes - verbalization and listening - on the comprehension-monitoring behaviors of learning disabled adolescents. Four modes of comprehension monitoring tasks were presented: oral reading, oral reading/listening, silent reading, and silent reading/listening. Results indicated that a multimodal presentation of information does not assist, and may even interfere, with the student's comprehension monitoring and processing.

In a similar study, Holmes (1985) also found that listening to text via an audiotape while silently reading resulted in lower comprehension scores than silent reading alone. Holmes, however, also took into account the situational context in oral reading and compared oral reading to an audience and oral reading to oneself, however

silent reading under either condition still resulted in better performance than oral reading. Finally, a study on the effects of the rate of acquisition of information under three listening conditions, (expanded, which was 0.5 times the normal rate, normal (125 wpm), and compressed, which was 1.5 times the normal rate), revealed no significant differences between the scores of subjects in each of the three conditions (D'Alonzo and Zucker, 1982).

As can be seen from the studies presented, results have proven inconsistent. This inconsistency in findings between studies leads one to conclude that further research is required to improve our understanding of how the needs of the learning disabled might best be met. In addition, a method which can be incorporated into the workplace must be considered in conjunction with increasing comprehension such that a wider range of opportunities can be made available to the learning disabled adult.

Use of the Voice Synthesizer

The use of a voice synthesizer involves the understanding of how computers generate speech and the application of this technology in providing a mode for aiding reading comprehension in learning disabled adults. This section presents an understanding of synthesized speech technology and the application of voice synthesis as a multisensory

approach to aiding the learning disabled.

Synthesized Speech Technology. Speech synthesis is an auditory display which is made to be characteristic of the human voice. Computer generated speech may be accomplished by several methods. These methods include digitized speech, synthesis by analysis, and synthesis by rule. Digitized speech involves the process of recording human speech digitally and then transforming it into a more compressed data format. Human speech is sampled very rapidly (up to 8000 times per second) and information about each sample is stored for later decoding back to speech. While this process provides high quality speech generation, it requires massive amounts of storage capability (Sanders and McCormick, 1987).

Synthesis by analysis methods use an electronic model to produce speech sounds in order to simulate the human vocal mechanism. The speech waveform is analyzed and only the parameters needed to direct the model are encoded (Sanders and McCormick, 1987). The analog-to-digital conversion is conducted generally at a rate of 96K bits per second (8000, 12-bit samples per second). Digital speech analysis algorithms are then used to compute the synthesizer parameters. Coding techniques can generally reduce the bit rate to the range of 1,200 to 2,400 bits for each second of

speech (Michaelis and Wiggins, 1982). While less storage requirements are demanded in comparison to digitized speech, still, as with digitized speech, messages can be formed only with words or phrases that were previously encoded and stored. Another disadvantage to analysis synthesis is that messages composed of concatenated words and phrases can sound very awkward and unnatural. This is due to a lack of coarticulation, the natural blending and modification of sounds caused by words and phonemes that precede and follow a particular sound (Sanders and McCormick, 1987).

The method of generating speech by rule uses stored dictionaries of elementary speech segments and sets of rules for combining them and for stressing particular sounds or words that produce the prosody (rhythm) of speech (Sanders and McCormick, 1987). There are several advantages of synthesis-by-rule systems over synthesis by analysis or digitized methods. One such advantage includes the possibility of very large vocabularies with relatively small amounts of computer memory. Another advantage is that speech may be generated from more easily interpreted inputs such as text or phonemes. Thus, the human speaker is not relied upon to provide new vocabularies and the appropriate parameters for speech production can be provided at the time of synthesis (Michaelis and Wiggins, 1982). The

disadvantage to synthesis by rule systems is that the voice quality is usually not as good as that produced by other methods.

Evaluation of Synthesized Speech. Speech synthesizers are evaluated along two parameters: intelligibility and naturalness. Intelligibility is defined as the percentage of speech units correctly recognized by a human listener out of a set of units. Naturalness refers to a listener's judgment of the degree to which the speech sounds as though it were spoken by a human (Simpson, McCauley, Roland, Ruth, and Williges, 1985). As reported by Cooper (1987), most studies show that synthetic speech is generally less easy to understand than natural speech. This lower intelligibility may result in the listener not hearing or accurately remembering the information presented by the synthetic speech, or the additional effort required to understand synthetic speech interfered with the ability to carry out other necessary tasks at the same time.

It has been suggested by a number of researchers that the difficulty in understanding synthetic speech as compared to natural speech is due to encoding processes rather than actual retention (Nusbaum and Pisoni, 1984; Waterworth and Thomas, 1985). Implications from these studies suggested the need to also consider the role of contextual clues and

training. Merva and Williges (1987), in studying the effects of context clues on intelligibility, found that the more context clues that were provided, the less transcription errors subjects committed.

Many researchers have shown the positive effects of training on the intelligibility of synthetic speech. Studies of training using isolated words versus training with sentences indicated that the latter aids in the intelligibility of both isolated words and sentences, while the former only increases the intelligibility of isolated words (Greenspan, Nusbaum, and Pisoni, 1988).

Rosson (1985) found that subjects who were exposed to specific synthetic phonemes were not only better able to identify them during testing, but they were also better able to identify completely new sounds produced by the same voice. Schwab, Nusbaum and Pisoni (1985) also found that moderate training with low-intelligibility synthetic speech could improve word recognition of novel stimuli. Training consisted of the presentation of words in isolation, words in fluent meaningful sentences, and words in fluent semantically anomalous sentences. Immediate feedback was provided following this presentation. Subjects who were trained under these conditions had significantly better results than those who received training on the same tasks

with natural speech, and those who received no training. In addition, a six-month follow-up study indicated that training effects persisted for those subjects trained with synthetic speech.

With regard to naturalness, people generally comment that synthetic speech sounds "unnatural." Thomas and Rosson (1984) found that the two most common classes of complaints regarding sample applications of synthetic speech to subjects were the lack of natural prosody, and the perception that the synthesizer sounded "nasal." The researchers conducted an experiment to determine if prenasalization of vowels prior to a nasal consonant would make the synthetic speech sound more intelligible or natural. Results indicated a significant effect on naturalness. The listeners preferred nasalized vowels relative to other contexts. No effects of nasalization on intelligibility were found.

Simpson et al. (1985) notes that intelligibility and naturalness are not as highly correlated with each other as they are with speech rate. Speech rate is the number of words spoken per minute. Slowiaczek and Nusbaum (1985) reported a speaking rate of about 150 words per minute (wpm) as optimal for perception of synthetic speech. Merva and Williges (1987), also found that transcription accuracy was

best for messages spoken at 150 or 180 wpm. Intelligibility decreased when messages were spoken at a speech rate of 210 wpm. Wu (1989) reported optimal speech rates as low as 120 wpm.

Finally, consideration must be taken regarding the fact that not all speech synthesizers are the same. As discussed previously, in general, digitized speech synthesizers are more intelligible than rule-based synthesizers. However, rule-based synthesizers are made more attractive by their unlimited vocabulary size and versatility in creating synthetic speech. Among the rule-based synthesizers, Digital Equipment Corporation DECTalk has been found to be significantly more intelligible than other commercially available rule-based synthesizers (Manous, Pisoni, Dedina, and Nusbaum, 1985). Logan, Pisoni, and Greene (1985) compared the intelligibility of eight text-to-speech systems and found the overall performance of DECTalk-Paul to be equivalent to natural speech, but only in terms of performance on initial consonants. In an evaluation of DECTalk version 1.8, Greene, Manous and Pisoni (1984) found DECTalk's Perfect Paul voice to be substantially better than other systems that had been evaluated in the Speech Research Laboratory at Indiana University over the last five years. These systems included the Speech Plus Prose 2000, the

MITalk system, and Votrax Type'N'Talk.

The studies cited in this section thus far have all employed subjects with no learning disabilities. Studies of the effects of aurally presented information in educating the learning disabled have focused primarily on children (D'Alonzo and Zucker, 1982; Reilly and Barber-Smith, 1982). While the use of voice synthesis to educate the learning disabled has been proposed (Chadwick and Watson, 1986; Dobbins and Bickel, 1982; Schiffman, et al., 1982), few studies have specifically addressed its use in increasing reading comprehension of the adult learning disabled. Voice synthesis for learning disabled persons with reading difficulties provides a modality which serves not only to increase the amount of sensory stimuli, but presents information through a modality that is not dysfunctional.

Meeting a Multisensory Approach. In keeping with the theories of multisensory techniques for instructing the learning disabled, researchers have begun to explore the effects of incorporating computerized speech into computer aided instruction. For example, Jones, Torgesen, and Sexton (1987) found that decoding fluency in learning disabled children was substantially improved by use of computer-aided practice. The researchers evaluated the use of the Hint and Hint I Program, which provides practice in recognizing and

analyzing words varying in medial vowels and vowel combinations. What is of particular interest in this study, with regard to the incorporation of multisensory methods into computer-aided instruction, is the ability to introduce digitized speech through this program. The use of digitized speech was incorporated in the presentation of different vowel sounds. As can be seen in this study, the use of computers does not have to limit the instructional ability to increase the modalities through which information can be presented.

Cumming and McCorrison (1981) evaluated the intelligibility of computer speech for use with computer aided instruction for young, non-LD children. They compared normal speech, Supertalker (a device used widely with Apple microcomputers), and Codec speech (a device used for use in the telephone system), and found the Supertalker speech gave distinctly worse performance than the Normal speech while the Codec speech was determined to be adequate for use with beginning readers.

Helsel-Dewert and Van Den Meiracker (1987) found comparable results in a study which evaluated the intelligibility of synthetic speech to learning handicapped children. One group of children was initially exposed to synthetic speech for 20 minutes every day for 10 weeks,

while another group had limited or no exposure. When children were later asked to identify stimulus words presented by a taped voice and a speech synthesizer, results indicated that the synthesized speech was more difficult to understand. While the group which had extended exposure to synthetic speech performed significantly better than the nonexposure group, these children were still unable to identify one-third of the words presented by the speech synthesizer.

Several cautions must be noted regarding the results of the above studies utilizing the speech output devices. One important note is that the devices which were used in the studies were of low quality (low sampling rates, for example), and would not produce the sound quality that might be achieved by a higher quality device. In addition, Helsel-Dewert and Van Den Meiracker point out two limitations in their study: words were presented in an isolated, rather than meaningful context, and the type of practice children had during their initial exposure to the synthesizer (words presented in isolation for 20 minutes a day over 10 weeks). Presenting words in context, comparing massed versus distributed practice, and use of higher quality speech output devices may provide significant improvements to the understandability of synthetic speech

and further aid to the learning disabled.

A study conducted by Olson, Foltz, and Wise (1986) did consider the limitations mentioned in the above study. In this study the text-to-speech synthesizer used was DECTalk, a higher quality synthesizer than that used in the previous study. In this study the subjects, 8 to 12 year-old reading disabled children, were provided with a meaningful context which, as the researchers stated, may have played a supporting role for word identification. While intelligibility of the synthesized speech was less than that of natural speech, the deficit was small and did not appear to be a significant problem when the subjects received feedback in text. During the experiment subjects touched unfamiliar words in stories presented on the computer display and received speech feedback to help develop word decoding skills. A word recognition test was presented at the end of each story and at the end of the experimental session. The results indicated that subjects were able to learn and comprehend a higher percentage of words under conditions which employed speech feedback.

As with studies involving other methods of auditory stimuli, results of research conducted with computers using speech feedback has also proven to be mixed. Still, the technology is relatively new and holds both many drawbacks

as well as encouragement for continued study. One particular advantage in using computerized speech, cited by Blanchard et al. (1987), is that such devices make it possible for even nonreaders to communicate and learn from a computer. Computers provide learning disabled students with the opportunity to develop and learn along with their normal peers. It is a step towards helping the learning disabled build self-esteem, as well as their reading abilities.

One may speculate, based on the literature, that in industry use of a voice synthesizer may provide a means for the learning disabled adult to learn tasks via a method suitable to meet their particular needs. In addition to addressing the reading comprehension levels of learning disabled adults, results from this study may also provide implications for use of the voice synthesizer in computer managed instruction. The voice synthesizer could be employed in administering tests of performance standards, and the computer in scoring such tests. This would free the instructor from more administrative tasks, and provide him or her with additional opportunity to aid students on a more personal level or to accomplish tasks he or she was not otherwise able to complete.

The use of this mode may not only decrease instructor time, but can provide a discreet method of instruction which

would allow for the learning disabled to fit into the "normal" population. The voice synthesizer is a training aid which can be used effectively for all employees. By using this method for all trainees, the learning disabled adult is not made to feel different or odd, and employee satisfaction is increased.

Learning disabilities exist in adulthood. Employers not only need to be made aware of the nature of those with reading disabilities, but need to be provided with adequate methods to aid such employees. In order to identify such aids research must continue in the area of increasing comprehension levels of reading disabled adults. While results of studies using multisensory techniques have been mixed, and studies which have employed the use of a voice synthesizer with the learning disabled population have been limited, some studies have provided positive results. For example, the study conducted by Olson, Foltz and Wise (1986) which employed the use of a voice synthesizer did provide significant results in support of its use. Given the lack of research in this area and the increasing identification of adults with learning disabilities, research must continue to identify methods and techniques which may be of some aid. The voice synthesizer provides a multisensory technique which may prove to be beneficial in doing just that.

Thus, the purpose of this study was to evaluate the effectiveness of using a voice synthesizer on the reading comprehension levels of learning disabled adults with the anticipation that significant results could provide implications for adapting training programs in industry to more appropriately meet the needs of this population.

METHOD

Experimental Design

The study was conducted using a single factor between subjects design. The Passage Comprehension subtest of the Woodcock Reading Mastery Tests-Revised (WRMT-R) was administered to each subject via the computer. The independent variable was presentation mode and each subject was randomly assigned to one of two conditions: with voice feedback or without voice feedback. The dependent measures included number of correct responses and reaction time (i.e., the amount of time it took the subject to answer each question). Figure 2 depicts the experimental design. It was hypothesized that subjects who received the voice feedback would answer significantly more questions correctly, and would take significantly less time to answer questions than those subjects who did not receive voice feedback.

In addition to studying the effects of the voice

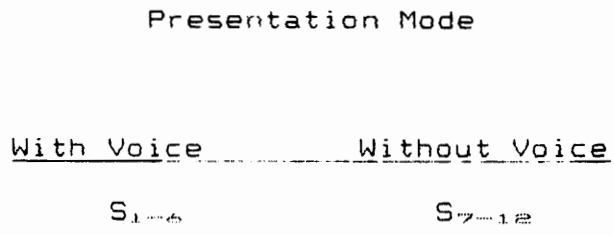


Figure 2. Experimental Design

synthesizer, the experiment was designed so that additional information could be gathered regarding the effects of test administration format, namely computer versus manual administration (administration by the experimenter). In order to avoid learning biases by having subjects complete the same test twice, the Passage Comprehension subtest of the Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R) was utilized during the manual administration format. The correlation between the WJ-R and WRMT-R is between 0.6 and 0.7 (Woodcock, 1987). The WJ-R was administered to each subject by the experimenter. Comparisons were then made between the computer and manual administration formats based on number of correct responses.

Subjects

In order to maintain confidentiality, subjects were solicited via the Assistant Dean of Students, Disabled Special Services at Virginia Polytechnic Institute and State University and a like representative from the Counseling Center at Radford University. Letters of solicitation (Appendix A) were mailed to the learning disabled student population at these institutions and in addition to noting that the results may be potentiall be personally beneficial to the subject, the subject was also informed of a monetary

benefit (\$5.00 per hour) of participating in the study. Prospective subjects were required to contact the investigator in order to participate.

A total of 37 letters were mailed to full-time undergraduate students at each university. Fourteen responses were received (37.8%). Two students were from Radford and 12 were from Virginia Tech. Of the two subjects from Radford, one did not meet selection criteria and due to equipment failure a complete set of data could not be collected for the other subject. Thus, the 12 subjects participating in the study were all students at Virginia Tech.

Eight males and four females participated in the study. It is important to point out that students with learning disabilities must still meet the same admission standards as any other student at Virginia Tech. It was reported by the Virginia Tech Admissions Office that the middle 50% of 1989 incoming freshman had SAT scores of 1020 to 1110. In addition, Virginia Tech is a comprehensive, competitive university which attracts a high level of achievers.

Subjects were selected based on the following criteria:

- presence of a reading disability as identified by the Assistant Dean of Students, Disabled Special Services at Virginia Tech,

- absence of any listening comprehension problems as evidenced by a score of 29 or higher on the Listening Comprehension subtest of the Woodcock-Johnson Psycho-Educational Battery-Revised,

- minimum exposure to computers as evidenced by a "yes" answer to item 4 on the background questionnaire and,

- aged 18 to 25 and enrolled in a university program.

Analysis of the background questionnaire (Appendix B) indicated that all subjects characterized themselves as having learning difficulties in the area of reading, many of whom stated reversing letters, incorrect additions or deletions in sentences, and memory as specific problems. Subjects varied in age from 18 years to 25 years ($X=21.25$), and in grade from 13.7 years to 16.8 years ($X=15.5$). All subjects when asked questions regarding what types of difficulties they had and in what school subjects indicated language problems - particularly reading and subjects which required a lot of reading, and writing, such as English. In addition, five subjects identified having difficulty in courses which involved math (such as chemistry and accounting). With regard to aids, eight of the subjects stated that they took advantage of extended test times, the remaining four indicated using such aids as the computer, the Virginia Tech Writing Center, Franklin Speller, and

making additional comments to the teacher after at the end of an exam.

Career goals and majors varied between subjects. Five of the subjects were majoring in some type of engineering curriculum and intended on either working as an engineer, or continuing their education through graduate school. Other majors included communication, psychology, chemistry, history, computer science and financial management. Finally, with regard to having used a voice synthesizer, over half of the subjects (67%) had listened to a voice synthesizer as part of some demonstration or experimentation, however, none of the subjects had ever used it for any gainful purpose. All subjects felt that access to a computer on the job would be a definite aid in helping them to do their job. While some felt that the computer could be helpful in learning to do their job, overall, subjects felt that even if a computer was used in training, some form of additional human instruction would be desirable. Table 1 provides details of subject characteristics based on data solicited via the background questionnaire.

Materials and Apparatus

Listening comprehension measure. The Listening Comprehension subtest of the WJ-R measures the ability to

Table 1. Background Questionnaire Data

SUBJECT GRADE NUMBER LEVEL	QUESTION NUMBER				
	1	2	3	4	5
1 13.7 1st grade	(a) languages (b) generally, no problems	(a) writing center (b) generally no problems	(a) everyday (b) games, writing, programs (c) parents, high sch., college	(a) Never Used (b) N/A (c) N/A (d) N/A (e) N/A	
2 13.8 9th grade	(a) math, languages (b) directions, counting money	(a) calculator, Franklin speller (b) avoid potential problem situations	(a) two days/week (b) word processing, games (c) parents, high sch., self	(a) Never Used (b) N/A (c) N/A (d) N/A (e) N/A	
3 16.8 4th grade	(a) English, classes with a lot of reading (b) directions	(a) extended test times, tutors spell check (b) avoid potential problem situations	(a) three days/week (b) writing, games, programs (c) college class	(a) Never Used (b) N/A (c) N/A (d) N/A (e) N/A	
4 14.8 freshman in college	(a) English (b) no problems	(a) spell checker, extended test times, avoid potential problem situations (b) carry a pocket spell checker	(a) everyday (b) use at work to input and manipulate information (c) parent	(a) summer 1989 (b) demonstration (c) don't know (d) N/A (e) spoke slowly	
5 16.8 3rd grade	(a) English (b) no real problems	(a) extended test times, try to make relationships (b) post-it notes	(a) once a week (b) writing, spreadsheets, statistics (c) parents, high school	(a) Never Used (b) N/A (c) N/A (d) N/A (e) N/A	
6 14.8 3rd grade	(a) English, any course in which a lot of reading is required (b) no real problems	(a) use a computer to write (b) use environmental clues	(a) everyday (b) word processing, drawing (c) parents, self	(a) 1988 (b) demonstration (c) don't know (d) speech not clear (e) N/A	

Table 1. Background Questionnaire Data (cont'd.)

SUBJECT NUMBER	QUESTION NUMBER				
	6	7	8	9	10
1	(a) elem. sch., college (b) reading, class lectures (c) help in retention of trivial facts (d) Not difficult (e) N/A	mechanical engineering	work as an engineer, write technical papers	access to word processors, especially w/spell checker	if lesson < 30-40 minutes voice - N/A
2	(a) used books on tape (b) classes, foreign language (c) can rewind if miss something, read more slowly; cannot highlight points (d) not really, didn't use a lot (e) N/A	communication for film English minor	create, produce films	plan on being own boss; would like help with editing and finances	helpful in writing; don't have much patience to learn from them; don't know enough about them
3	(a) Never Used (b) N/A (c) N/A (d) N/A (e) N/A	electrical engineering	graduate school, or work as an engineer	access to a computer	not sure, best way is to have somebody demonstrate; easier to listen to something than to just read it
4	(a) spring semester 1990 (b) tape recorded lectures (c) helpful in reviewing notes (d) not difficult (e) tape recorder has better ability to speed up speech without much distortion	psychology	graduate school	have someone write for me	tutorials are helpful; best way to learn is through demonstrations; voice not helpful, tend to input additional words when listening
5	(a) freshman year in college (b) tried taping lectures (c) not helpful, too much background noise (d) not difficult, but not worth using due to noise (e) N/A	financial management	insurance agent	need someone to do paperwork computer access, quiet work place	having someone available to ask questions, provide demonstration
6	(a) grade school (b) provided by teacher (c) don't remember (d) don't remember (e) N/A	civil engineering	work as a civil engineer with the government, or a consulting firm	computer access, minimize amount of writing required	would be helpful in allowing me to concentrate more on what I'm doing than on how to do it

Table 1. Background Questionnaire Data (cont'd.)

SUBJECT NUMBER	GRADE LEVEL	QUESTION NUMBER				
		1	2	3	4	5
7	15.8 college junior	(a) English, any subject in which a paper is req'd (b) not really, have a tendency to get bored, and not pay attention	(a) Writing Center, extended test time (b) avoid potential problem situations	(a) once a month (b) games, word processing (c) parents, computer course in college	(a) used at home (b) demonstration (c) Apple (d) don't remember (e) speech not very clear, monotonic	
8	15.8 5th grade	(a) reading/writing affects all classes (b) not really	(a) write comments to teacher after writing a paper (b) can't think of anything	(a) 1-2 hours/week (b) word processing, problem solving (c) college courses	(a) 1988 (b) recreational (c) don't know (d) N/A (e) pronunciation "off"	
9	16.8 1st grade	(a) engineering courses (b) memory problems at times, usually not too many problems	(a) extended test time, tutors read aloud to self, rewrite important information (b) avoid potential problem situations	(a) 2-3 hours/week (b) word processing, problem solving, programming (c) high school course, also had a computer at home	(a) 1987 (b) demonstration (c) don't know (d) N/A (e) N/A	
10	14.7 fall 1987	(a) geology, economics, some accounting, where a lot of reading is involved (b) not really, some memory	(a) extended test time, relate information to known facts (b) try to make relationships	(a) three days/week (b) word processing, games, programming (c) high school computer class	(a) 1987 (b) demonstration (c) don't know (d) N/A (e) at first difficult to understand	
11	15.8 kindergarten	(a) history, chemistry, note-taking in any class (b) some listening difficulty esp. with long lists of instructions	(a) extended test time, reread, highlight, write, tape record lectures, use other student's notes (b) don't really use any	(a) two - three days/week (b) word processing, games, spreadsheets (c) mostly self-taught, with help from friends	(a) 1988 (b) demonstration (c) don't know (d) N/A (e) N/A	
12	16.8 7th grade	(a) any subject where under pressure to write; math (b) left and right directions	(a) extended test time, try looking at things from a different angle, record lectures, use other student's notes (b) most of the same things as use in school	(a) 1-2 hours/day (b) word processing, desk-top publishing, programming (c) in middle/high school, neighbors had a computer	(a) 1984 (b) experimentation (c) don't know (d) N/A (e) speech was slow	

Table 1. Background Questionnaire Data (cont'd.)

SUBJECT NUMBER	QUESTIONNUMBER				
	6	7	8	9	10
7	(a) spring 1990 (b) recording lectures (c) helped to reinforce notes (d) easy to use, time consuming (e) can't really compare in terms of learning	chemistry/pharmacy	pharmacy school	access to computer, assistance in writing skills	helpful in producing graphics voice may be helpful by reinforcing words on screen
8	(a) Never Used (b) N/A (c) N/A (d) N/A (e) N/A	civil engineering	graduate school, or work as an environmental or construction engineer	computer access, a good secretary	prefer hands on and to have demonstration
9	(a) 1988-1990 (b) recording class lectures (c) easier to fill in gaps in notes, aid in outlining notes helped reinforce notes (d) time consuming (e) synthetic speech more difficult to understand	industrial engineering	graduate school, in the area of manufacturing	access to computer, provide deadlines, provide clear explanations	can't really see how it would fit into my job., might start with a tutorial, then put it aside
10	(a) 1985 (high school) (b) used to learn a foreign lang. management (c) helpful in understanding pronunciation of words (d) difficult - speech to slow (e) computer seemed inhuman	business - finance and management	something that involves the public	use of signs, pictures patience	depends on type of work; helpful in retail business, not helpful in crisis centers speaking helps reinforce reading
11	(a) spring 1990 (b) tape recorded History class (c) helpful in filling in gaps in notes, reinforcing notes. (d) time consuming (e) N/A	history	graduate school, would like to teach at college level	access to computer, someone to proofread work	depends on type of work; helpful to have simulations, not helpful if trying to study something
12	(a) college (b) tape recorded class lectures (c) helpful in refreshing memory before an exam. (d) time consuming (e) tape recorded speech sounded more natural	computer science	work using my computer background, system management or production development	access to computer for writing papers, extra time to complete paperwork, don't require compilation of a lot of numbers	helpful in illustrating what to expect, esp. if provide graphics in terms of reading, may slow me down

listen to a short tape recorded passage and supply the single word missing at the end of the passage. This test was used to screen out persons who may have difficulty in understanding information which is presented orally.

Reading comprehension measures. The WJ-R is a comprehensive set of individually administered tests which measure cognitive abilities, scholastic aptitudes and achievements. The tests were normed on a national sample of subjects ranging in age from 24 months to 95 years. These norms include college and university students. The Passage Comprehension subtest of the WJ-R uses a cloze procedure to assess a person's skill in understanding written material (Woodcock and Johnson, 1989). (For a more detailed description of the entire test, the reader is referred to Woodcock and Johnson, 1989.)

The WRMT-R is a diagnostic battery which measures various aspects of reading ability. The Passage Comprehension subtest of the WRMT-R was used as the measure of reading comprehension during the experimental sessions. This test provided a direct measure of reading comprehension which had already been proven as a valid and reliable measure. In addition, the norms used for standardization included the adult population.

The WRMT-R consists of six individually administered tests used to assess the development of readiness skills, basic reading skills, and reading comprehension skills in students from kindergartners to college seniors, and in adults up to 75 years of age. There are two alternate forms of the test, G and H. Since the reliability of the two forms have shown them to be equivalent, Form G, which was readily available, was selected to be used in the study. The Passage Comprehension subtest was administered during the study as the measure of reading comprehension. (For a more detailed description of the entire test, the reader is referred to Woodcock 1987.)

Voice synthesizer. DECTalk (version 1.8) was used as the voice synthesizer in the study as it was also readily available. DECTalk is a rule-based text to speech system manufactured by Digital Equipment Corporation. The voice that was used in the study was Perfect Paul due to its higher intelligibility over the other voice options. The voice was set at the default parameters. Words and sentences were transmitted to the DECTalk system in exactly the same way as they appeared on the display with one exception. The "blank" presented in the sentence for which the subject must provide a response, was spoken by the system as "blank". For example, given the following item:

Here are the letters in the alphabet.

_____ their names out loud.

The item appeared on the screen as it is shown above. The subject, under the "with voice" condition was able to read the item on the screen and also heard the item spoken as:

Here are the letters in the alphabet.

"Blank" their names out loud.

Minor adjustments, such as adding a comma to insert appropriate pauses were also made. The speech rate was set at the default rate of 180 words per minute. Due to its availability, a VAX 11/750 computer manufactured by Digital Equipment Corporation (DEC) was used to record transactions made between the experimenter and the system thus measuring the number of errors a subject made. In addition, reaction time was measured as the time from the initial presentation of a question item to the subject, to the time at which a correct/incorrect menu item selection was made by the experimenter. Information was displayed using a DEC VT-200 terminal. The experiment was conducted in real time. The experimenter recorded the verbal answers of the subjects as well as indicated whether the answer was correct or incorrect. A Realistic tape recorder was used to record the verbal responses of the subjects.

Questionnaires. Two questionnaires were administered as part of the study. The first questionnaire, shown in Appendix B, was used to collect background data regarding the subject's learning disability and computer experience. Additional information regarding the subject's age, educational level, and career goals were collected.

The second questionnaire, shown in Appendix C, utilized a seven-point Likert scale in order to collect data regarding the subject's attitude towards using the computer and the voice synthesizer.

Procedure

Informed consent (Appendix D) was obtained prior to the screening process due to the personal nature of the data being collected. The informed consent form as well as other instructions for the study were provided to the subject in a written format as well as read aloud by the experimenter. After obtaining informed consent, subjects were provided a brief set of instructions (Appendix E) for the screening procedure. Subjects were then screened in order to determine if they met the selection criteria. Using the background questionnaire, the experimenter solicited and documented the potential subject's answers. Following this discussion, the Listening Comprehension subtest was administered. Subjects who scored a minimum of 29 items

correct (out of 38 total items) on the Listening Comprehension test, and met additional criteria as evidenced through the background questionnaire, were selected for participation. (A total of 29 items correct corresponded to an age equivalent of 18.6, and a grade equivalent of 12.4, both of which were felt to be the minimum level at which a subject should be performing, given that this is approximately the corresponding age and grade level of entering college freshman, and upon graduation from high school society typically considers one an "adult".)

Following the screening procedure, the subject was provided an introduction to the study (Appendix F) which described the two parts of the study. After the introduction the subject was administered either the WJ-R or the WRMT-R (either under the with voice, or the without voice condition). The order of the administration of these tests was counterbalanced in order to control for systematic biases. Instructions were provided for both the computer administration (Appendix G) and the manual administration (Appendix H) prior to the commencement of the session.

During the manual administration of the WJ-R written instructions were provided to the subject as well as read aloud by the experimenter prior to the administration of the test. The subject was then instructed to read each item to

him/herself and to tell the experimenter one word which best filled in the blank. Responses were provided orally and were recorded as correct or incorrect by the experimenter.

During the computer administration of the WRMT-R another set of written instructions were provided to the subject. These instructions were also read aloud by the experimenter. Furthermore, in order to familiarize each subject with the synthesized speech, the written form of the instructions were presented on the computer screen and via the voice synthesizer.

During the experiment subjects were seated at a table with a computer terminal and microphone placed in front of them. The experimenter was seated in the same room as the subject behind a divider, such that the experimenter was not in view of the subject. In this way the subject was provided the security of knowing someone was in the room in case something unexpected should happen, yet by being out of sight, the experimenter did not distract the subject from his/her task. A computer terminal and keyboard were located at the experimenter's station. A tape recorder was also located at this station in order to record subject's verbal responses.

In both the with and without voice conditions subjects were provided a visual stimulus through the presentation of

questions on the screen, and provided answers by speaking into a microphone. After the subject indicated that the instructions were understood, the experimenter began the administration of the test from the experimenter's station. The items in the test appeared on the screen as they would if the test were being administered manually. That is, if three items were presented on a page at one time in the test manual, so they would appear on the subject's screen. The subject answered one item at a time and at his or her own pace.

The presentation of each screen of questions was controlled by the experimenter. Under the with voice condition, the verbal presentation of each question was also controlled by the experimenter. After each verbal response made by the subject, the experimenter recorded the correctness of the response and the actual answer given by selecting from a menu displayed on the experimenter's computer screen. This menu consisted of four options. These options allowed the experimenter to identify subject responses as correct or incorrect. In addition, the other two options allowed the experimenter to prompt the subject if a response had not been provided within 30 seconds, or if a query regarding the subject's response was necessary. The experimenter typed in the subject's final response and then

either presented the next question, or signaled to end the session. The procedure was exactly the same for both conditions, with one exception. The voice synthesizer was turned down during the "without voice" condition. If the selection of a menu option required the voice, the synthesizer was turned up to a designated level in order for the subject to hear the prompt. Following the spoken message, the synthesizer was again turned down.

All subjects began with item 29. This item is the recommended starting level for grades 6 to 10. It is a level at which all subjects should be able to correctly answer initial questions and gain some initial self-confidence. Questions continued to be presented until all had been answered. The termination of the session was signaled by both a displayed message on the screen and voice output for all subjects. Following the administration of the WRMT-R, the subject was asked to complete the attitudinal questionnaire.

The final step in the experiment consisted of a debriefing session in which the participant was thanked for their participation, and any remaining questions were answered. Payment for the subject's participation was also rendered at this time.

RESULTS

Performance Measures

In order to make comparisons between manual and computer administered scores, as well as to maintain consistency with other statistical tests, all total scores were converted to normal curve equivalents ($X=50$, $SD=21.06$). This conversion was made following the accepted procedures outlined in the WJ-R and WRMT-R manuals. Also, subjects were renumbered according to condition assigned in order to more easily identify which subject received which condition. For example, subjects who received the computer administration with voice feedback first, and the manual administration second, were numbered 1 through 3. This numbering therefore, in no way reflects the assignment of condition, or order of administration of the computer versus manual test.

The mean scores for subjects on the WRMT-R were as follows: $X_{with}=65.3$, $X_{without}=65.0$. The mean reaction times for subjects on the WRMT-R were $X_{with}=30.9$ seconds $X_{without}=31.6$ seconds. The mean scores for subjects on the WJ-R were $X_{with}=63.2$, $X_{without}=56.5$. A single factor analysis of variance (ANOVA) was conducted to analyze the effects of the voice synthesizer on the number of correct answers and reaction time. The results of both the ANOVA for scores and ANOVA for reaction time were not significant.

Tables 2 and 3 illustrate the ANOVA summary tables for the analysis of scores and reaction time, respectively. In comparing scores between administration formats, a t-test revealed no significant differences. Finally, in order to determine if order had a significant effect on format, a two factor between subject ANOVA was conducted for the variables computer x order, and manual x order. Results were not significant for either analysis. The ANOVA summary tables for Computer x Order and Manual x Order are shown in Tables 4 and 5, respectively.

While all analyses were conducted at the $p < .05$ level, it was further noted that even at a higher alpha level, ($p < .03$), results were still not significant.

Subjective Measures

Comparisons were made between subgroups (voice vs. no voice) of responses for each of the 5 items in the attitudinal questionnaire. Results of t-tests for each item indicated no significant differences between subgroups. While not statistically significant, many subjects did provide verbal comments indicating their preference for a faster speech rate and a voice that sounded more natural. In addition, analysis of the background questionnaire indicated that all subjects felt that a computer would be helpful on the job. Half of the subjects also felt that

Table 2. ANOVA Summary Table - Scores

<u>Source</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Presentation Mode (P)	1	0.750	0.750	0.00
Subjects/P	10	2122.167	212.217	
Total	11	2122.917		

Table 3. ANOVA Summary Table - Reaction Time

<u>Source</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Presentation Mode (P)	1	1.233	1.233	0.01
Subjects/P	10	1448.568	144.857	
Total	11	1449.801		

Table 4. ANOVA Summary Table - Computer x Order

<u>Source</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Computer Administration (C)	1	0.333	0.333	0.00
Order (O)	1	243.000	243.000	1.23
Computer x Order (CO)	1	280.333	280.333	1.42
Subjects/CO	8	1587.000	197.250	
Total	11	2101.666		

Table 5. ANOVA Summary Table - Manual x Order

<u>Source</u>	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Manual Administration (M)	1	133.333	133.333	1.27
Order (O)	1	8.333	8.333	0.08
Manual x Order (MO)	1	12.000	12.000	0.11
Subjects/MO	8	840.000	105.000	
Total	11	993.666		

while a computer may be beneficial in training, they would still prefer to have some human instruction in addition to the use of the computer.

DISCUSSION

While the results of this study were not significant with regard to the statistical tests conducted, several reasons may account for these results. Furthermore, it is imperative to consider the subjective comments made by the subjects in this study in order to consider completely the impact this study may have on future research as well as on implications for adapting training programs in industry.

Interpretation of Results

The results of this study are in contrast to those of Olson, Foltz and Wise (1987) in which subjects performed better under conditions which employed speech feedback. One difference between the studies is that in the above study subjects had an additional sensory input from the use of a mouse or lightpen. Subjects in the present study had no tactile manipulation available to them. Another potential contributor to the lack of significant results in this study is the small sample size. The smaller the sample size, the larger the population differences must be in order to achieve significant results. In addition to the sample size, one might also consider the actual task to be

accomplished. The test which was selected, while being a standardized comprehension measure, is a task with which subjects may already have been quite familiar with given the process of identification of a learning disability. Subjects are quite often required to go through similar batteries during their identification and assessment of achievement throughout their school lives. Finally, it is important to consider that most studies have been conducted with children and employ a learning task (Cumming and McCarriston, 1981; Jones, Torgesen, and Sexton, 1987). As the learning disabled child grows, many coping mechanisms may be learned or unconsciously used in comprehending written material. For example, one subject stated that when trying to understand something new, she tried to relate the new material to something that was already familiar. This "technique" may be used for words and phrases as well as for concepts. Thus, when a subject reads an item, rather than paying attention to the voice synthesizer, the subject may have been unconsciously using his/her own mechanisms to decode and understand the sentence. It could be possible that given the older population of subjects in this study such strategies were used, thus influencing the outcome of the scores and reaction times.

With specific regard to the voice synthesizer several

subjects indicated through comments made to the experimenter, that the speech rate was slow or not quite intelligible. In the study conducted by Helsel-Dewert and Van Den Meiracker (1987) it is noted that learning disabled subjects who had extended exposure to synthetic speech correctly identified a significantly higher percentage of words than those with a limited exposure. Thus, it could be that additional training in understanding the synthetic speech was needed. Researchers have found that training does aid in the intelligibility of synthetic speech. Results of these studies indicate that training using sentences rather than isolated words (Greenspan, Nusbaum and Pisoni, 1988). Helsel-Dewert and Van Den Meiracker (1987) found that learning handicapped children who were exposed to synthetic speech for 20 minutes every day for 10 weeks had higher performance measures than those who had limited exposure or no exposure at all.

In addressing the lack of differences between groups with respect to reaction time, this variable may have been affected by the requirement that the experimenter input the answer, and thus had some control over time. It was therefore possible for the experimenter to get ahead or behind the subject when he or she decided to change an answer. For example, if a subject provided an initial

answer and then decided to change it, there was a potential for the experimenter to have already entered the initial response and tell the system to present the next question, thus recording the end/start time for the initial response and not the actual response given. Such subtle occurrences over the total 40 item test may have influenced the reaction time results. In future studies, it would be advisable to develop a more flexible system to avoid such concerns.

As discussed in the beginning of this section, the familiarity with this type of test as well as the small sample size may have affected the results, especially with regard to comparisons made between format (computer versus manual administration).

Future Research and Adaptation for Training

Statistical results of the study indicate acceptance of the null hypothesis - no significant differences between those who received voice feedback and those who did not receive voice feedback exists. These results suggest that additional research in this area may not be necessary. However, subjective comments made by the participants in conjunction with the interpretation of the results discussed above suggest that continued research on the effects of using a voice synthesizer to aid reading comprehension levels of learning disabled adults, and the implications

which could be provided for adapting training programs may still be necessary and could still prove beneficial.

With regard to future studies several considerations should be made. First, a larger sample size should be used in future studies of a similar purpose. Given that the means were almost exactly the same for the two groups, an extremely large sample size, (somewhere in the 100's) would be necessary for conducting a similar study. A power analysis should be considered to determine the number of subjects needed for future studies. The IQ of subjects should also be considered. As in this study, it could be that subjects were at a higher level of the continuum and thus were able to achieve higher scores regardless of their learning disability. Persons with lower IQs may be aided by the voice synthesizer to a greater degree than those with higher IQs and future studies might address this issue. Furthermore, different types of reading material and the purpose for reading should be investigated. While this study employed the use of a standardized test in which the subject was required to comprehend only one sentence and without much context, very different results might be expected when reading is conducted for a different purpose, (such as for enjoyment, or to learn an actual task), or presented in a different format.

Subjective comments also suggest that future research of such factors as different speech rates and an option to have certain words or phrases repeated may also provide valuable insights. It would also be beneficial to develop the computer program such that the test could be administered by a stand alone system - without the aid of the experimenter. Finally, comparisons of performance measures between digitized and synthesized speech may also provide useful information. For example, if digitized speech provides a more quality speech sound, one might question whether digitized speech is more intelligible than synthetic speech to the learning disabled adult. One might ask does the quality of digitized speech prove to be less distracting, and thus more useful in aiding comprehension, than synthetic speech. Differences in subjective reactions would be important for even if a method appears to be helpful statistically, it must still be well received by its users if it is to actually be used.

Subjective comments clearly suggested the desire to incorporate hands on training and demonstrations with the use of a computer. Woodward, Carnine and Gersten (1988) found a combination of structured teaching and computer simulation was effective in teaching learning disabled high school students factual-level knowledge, as well as higher

cognitive skills. Such research suggests that a single method of training may not be sufficient. Rather, some combination of methods may be more appropriate. Thus, future research could also be conducted using some combined method of the voice synthesizer and other types of training.

The above limitations of the study can not be interpreted singularly. Future studies should attempt to address several factors in parallel. Of the above noted factors, the most important which need to be addressed include a larger sample size and careful consideration of sample characteristics. Subjects in this study may have been the "survivors" of their disability and would get to the top based on their own initiative and self-determination. It would be well worth studying subjects who were not from a university setting, who may want to go into a professional job, but feel they lack the needed resources to help them perform well in this type of position.

A second major factor which would seem to require more immediate attention is the use of a procedural task requiring the use of motor skills, rather than a strict reading comprehension measure, such as used in this study. This type of task would provide a more concrete and observable measure of comprehension since performance is based on the correct completion of the task. Also, since a

large majority of learning disabled adults work at semi-skilled jobs, many of which would incorporate motor skill tasks, significant results may prove beneficial to a larger portion of the learning disabled population.

Finally, a third factor which should be incorporated into near-term studies is the development of a more flexible system to measure reaction time. The system should be programmed so that the experimenter has no control over the amount of time it takes the subject to complete a task. One method would be to simply allow the subject to indicate when he/she has begun/completed the task by pressing a button, or key. With respect to adapting training programs in industry additional research needs to be conducted to identify more specific needs of the learning disabled adult with regard to the use of synthesized speech to increase comprehension. Such research might include an actual motor task in which the subject must learn and perform, as well as looking at different types of training methods for understanding the voice synthesizer (comparing massed versus distributed training). The importance of conducting additional studies is supported by the 100% agreement of subjects that computer access would be an important tool in aiding them on the job. Just how such a tool can be made most beneficial can only be identified through continued research.

CONCLUSION

The purpose of this study was to determine the effectiveness of using a voice synthesizer to aid the reading comprehension levels of learning disabled adults. While the results were not statistically significant, subjective comments made by participants, limitations of the study, as well as research on the positive effects of computers on persons with learning disabilities, support continued efforts to understand this area. With the increase in learning disabled college students, results from continued research and understanding can provide hope for widening job opportunities for a deserved population.

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APPENDICES

APPENDIX A. SOLICITATION OF SUBJECTS

800L Foxridge Apts.
Blacksburg, VA 24060
April 8, 1990

Dear Student,

I am a graduate student in Human Factors, a Department in Industrial Engineering and Operations Research. I am looking for students with learning disabilities to participate in a study. This study involves the use of a computer which speaks. Participants will be paid \$5.00 per hour. The entire study will take approximately 1 hour. All information which you provide will be kept strictly confidential.

The results of this study may help you while you are still in college by providing a better way to study for exams. It may also help you when you look for a job by providing information which may change the way you learn to work on the job. However, your support and participation is needed.

If you are interested in participating, or have additional questions please contact me at 231-9093, or Mr. Wayne Speer at 231-9093.

Thank you for your interest and your participation.

Sincerely,

Barbara Glickstein

APPENDIX B. BACKGROUND QUESTIONNAIRE

Subject # _____ Date _____

Name _____ Age _____

University _____ Grade _____

1. When were you diagnosed as having a learning disability?

2. Describe the kinds of difficulties you have.
 - a. Does the difficulty cause you problems in any subjects? If so, which subjects?
 - b. Does the difficulty cause you problems outside of school? If so, in what areas?

3. Do you use special aids or adaptations? If so, :
 - a. What aids/adaptations (or compensations) do you use to help you in school?
 - b. What kinds of aids/adaptations (or compensations) do you use to help you outside of school? (for example, at home, at work, etc.)

4. Have you ever used a computer? If yes :
 - a. How often do you use a computer?
 - b. For what purposes do you use a computer?
 - c. How did you learn to use a computer?

5. Have you ever used a computer with speech generation? If so,
 - a. When did you use this computer?
 - b. For what purposes did you use this computer?
 - c. What kind of computer/speech generator did you use?
 - d. Did using this computer help you or not help you? In what way did it help you or not help you?
 - e. Was this computer difficult to use or to understand? If so, why?

6. Have you ever used tape recorded lessons?
 - a. When did you use tape recorded lessons?
 - b. For what purposes did you use tape recorded lessons?
 - c. Did using tape recorded lessons help you or not help you? In what way did it help you or not help you?
 - d. Was using tape recorded lessons difficult? If so, why?
 - e. How did using the tape recorded lessons compare with using the computer with speech generation?

7. What is your current field of study?

8. What are your career goals? .

9. On a job, what types of adaptations do you feel an employer could make to help you do your job best?
10. Do you think training on a computer would be helpful? with voice?

APPENDIX C. ATTITUDINAL QUESTIONNAIRE

1. On a scale of 1 to 7, how easy was it to read the information on the screen?

1-----2-----3-----4-----5-----6-----7
very very
easy difficult

2. On a scale of 1 to 7, how easy was it to understand the computer voice?

1-----2-----3-----4-----5-----6-----7
very very
easy difficult

3. On a scale of 1 to 7, how natural did the computer voice sound?

1-----2-----3-----4-----5-----6-----7
very not at all
natural natural

4. On a scale of 1 to 7, how fast did the computer speak?

1-----2-----3-----4-----5-----6-----7
very very
slow fast

5. On a scale of 1 to 7, how easy do you think it would be to learn new tasks using a computer that speaks?

1-----2-----3-----4-----5-----6-----7
very very
easy difficult

APPENDIX D. PARTICIPANT'S INFORMED CONSENT FORM

The purpose of this research experiment is to examine how persons with learning disabilities can understand what they read when listening to computerized speech. Computerized speech simply means that the computer does the talking instead of a person.

Before you participate in the study you will be asked to participate in a screening procedure. The purpose of the screening procedure is to identify persons with the characteristics needed to participate in the study. Should you have these characteristics, you will be asked to participate in the actual experiment. Below are more detailed descriptions of the screening procedure, the actual experiment and what would be expected of you.

Screening Procedure

The study you are being asked to participate in requires that subjects have certain characteristics. In order to see if you have these characteristics, you are being asked to provide information relating to your experience with computers, and your learning disability. In addition, you will be asked to listen to a number of passages. These passages will be presented through a tape recorder. After listening to the passages you will be asked to answer some questions about what you have heard.

Not everyone is expected to have the characteristics needed to participate. You should not feel bad if you are not able to be in the study.

Should you have the characteristics needed to participate you will be paid \$5.00 per hour at the end of your participation. If you are not selected to participate, you will be paid \$5.00 for your time to complete the screening process.

Experiment

The experiment consists of two parts. One part of the study involves participating in a standardized reading test. Like the screening process, you will be asked to answer a number of questions. These questions will be administered by the experimenter.

Another part of the study consists of answering questions which will be presented to you on a computer screen. You may or may not listen to the computer speak as you read the questions. The answers that you provide will be recorded. After answering the questions, you will be asked to fill out a questionnaire about your opinion of various aspects of the study.

Please be aware that all the information you provide will be kept strictly confidential. There is no physical danger involved in this study. If, for any reason, you wish

to end your participation at any time, you may do so.

The research team consists of:

1. Barbara Glickstein, Graduate Student, IEOR Dept.
2. Dr. Robert Williges, Faculty Member, IEOR Dept.

Additional instructions will be given to you after you read and sign this consent form. A member of the research team will answer any questions that you may have. However, if a question may affect the outcome of the experiment, the team member may wait until the experiment is over to provide a detailed answer.

Please do not discuss the experiment with any other person who may become a subject. We expect to collect all data by May 5, 1990. Following May 5, 1990 you may feel free to discuss the experiment with anyone you wish.

Again, we would like to point out that all data will be kept confidential.

Finally, if you have any problems with, or questions about the research itself, you may contact Dr. Robert Williges at the phone number and address given below. If you have questions about your rights as a participant, you may contact Dr. E. R. Stout, Chairman of the Institutional Review Board at Virginia Tech at (703) 961-5281.

If you wish to receive a summary of the results of the research, please include your address with your signature below. If you would like more detailed information after receiving this summary, please contact the Human Computer Laboratory, and a full report will be provided to you.

The faculty and graduate student involved in this study greatly appreciate your help as a participant.

Your signature below indicates that:

1. you have read this entire document,
2. your questions have been answered, and
3. you agree to participate in the study described.

You, nevertheless, retain the right to withdraw at any time.

If you include your printed name and address below, a summary of the experimental results will be sent to you.

Signature

Printed Name

Date

Street

City, State, Zip Code

Human Computer Laboratory
IEOR Department
Virginia Tech
Blacksburg, Virginia 24061
(703) 231-4603

APPENDIX E. INSTRUCTIONS FOR SCREENING

Welcome to the Human Computer Lab. The study you are being asked to participate in requires that subjects have certain characteristics. In order to determine if you have these characteristics you will be asked to complete a background questionnaire and to participate in a listening skills exercise. Not everyone will have the characteristics needed to participate. You should simply answer the questions as honestly and as best you can.

APPENDIX F. INTRODUCTION TO STUDY

Welcome to the Human Computer Lab. The study you are being asked to participate in consists of two parts. During each part you will be asked to read and answer some questions. In one part of the study you will be asked questions by the experimenter. In the other part of the study you will be seated in front of a computer and the questions will be presented to you on the computer screen. You may also hear the computer speak the questions.

The questions are not meant to be especially hard or easy. You should simply do your best. Additional instructions will be given before the beginning of each part of the study.

If you have any questions please ask them of the experimenter at this time. Thank you for your participation.

APPENDIX G. SUBJECT'S INSTRUCTIONS (COMPUTER)

Welcome to the Human Computer Lab. During this part of the study you will be asked to read and answer a number of questions. The questions will be shown to you on the computer screen. You might also hear the computer speak the information that is shown on the screen. Each question will consist of one or more sentences. A word will be missing from one of the sentences. Your job during this phase is to simply read each question to yourself, and then answer it by saying the missing word out loud. The questions are not made to be especially easy or difficult. You should just do the best that you can.

A message will appear on the screen telling you when all the questions have been answered. After you have answered the questions, you will be asked to fill out a short questionnaire regarding your experience.

Before you begin answering questions, these instructions will be shown to you on the computer screen. They will also be spoken by the computer so that you will be familiar with how the computer sounds when it speaks. After you have read the instructions, the questions will be presented.

If you have any questions please ask the experimenter at this time.

Thank you for your participation.

APPENDIX H. SUBJECT'S INSTRUCTIONS (MANUAL)

Welcome to the Human Computer Lab. During this part of the study you will be asked to answer a number of questions. These questions will be presented to you by the experimenter. Each question will consist of one or more sentences. A word will be missing from one of the sentences. Your job during this phase is to simply read each question to yourself, and then answer it by saying the missing word out loud. The questions are not made to be especially easy or difficult. You should just do the best that you can.

If you have any questions, please ask the experimenter at this time.

Thank you for your participation.

BARBARA H. GLICKSTEIN
800L Foxridge Apartments
Blacksburg, VA 22302
(703) 951-0950

EDUCATION:

- M.S. Industrial Engineering and Operations Research
Major: Human Factors May 1990
Virginia Polytechnic Institute & State University
- M.A. Education
Major: Learning Disabilities Dec. 1990
Virginia Polytechnic Institute & State University
- B. S. The Pennsylvania State University
Major: Psychology May 1984

EXPERIENCE:

6/89 - 5/90 Virginia Polytechnic Institute & State
University, Blacksburg, VA
Research/Teacher Assistant. Conducted a literature review
of the relationship between cognitive abilities, age and
computer abilities.

11/88 - 9/89 Management Systems Labs, Blacksburg, VA
Program Support Technician. Developed a reference library
study of consensus and its role in government for the
oversight agencies.

10/87 - 6/88 Science Applications International Corp.
McLean, VA
Staff Scientist/Human Factors Specialist. Provided
technical assistance to the NRC during reviews of nuclear
power plant's Control Room Design Reviews, and Safety
Parameter Display Systems and Operating Procedures.

4/85 - 10/87 Essex Corporation, Alexandria, VA
Research Associate. Human factors engineer for commercial
projects including those for the Federal Aviation
Administration, Exxon, and numerous nuclear power plants.

9/84 - 4/85 National Institutes of Health, Bethesda, MD
Research Associate. Monitored details of research project
and assisted in analyses

3/83 - 5/83 The Pennsylvania State University
University Park, PA
Research Assistant. Studied effects of varying luminance and
size on optokinetic nystagmus.

AFFILIATIONS:

Human Factors Society
Psi Chi Honor Society

SPECIAL PROJECTS:

Computer Workstation for the Learning Disabled. VPI&SU 1989.
Designed a computer workstation for the learning disabled.
The Effects of Music on Mathematical Performance. PSU 1983.
Designed experiment to study effects of music on
mathematical performance.

HONORS:

Virginia Teacher Scholarship/Loan Program, VPI&SU, 1988
Employee Bonus Award. Outstanding new employee of the year,
Essex Corp. 1986

REFERENCES FURNISHED UPON REQUEST

Barbara Hockett