ELECTRONIC TECHNOLOGY... STATE-OF-THE-ART IN
PROVIDING ACCESS TO COMMUNICATION, INDEPENDENCE, AND DIGNITY

BY

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A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Arts in Communication

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ACKNOWLEDGEMENTS

Carl Sandburg, poet and biographer, once said, "When a society or civilization perishes, one condition may always be found. They forgot where they came from. They lost sight of what brought them along." I have always tried to observe Sandburg's admonishment, and so today I want to acknowledge the benefactors of this thesis.

Dr. George Borden, advisor, mentor, and friend, provided the impetus for this thesis and assiduously guided me through its completion, despite some roadblocks we experienced along the way.

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- **1** -- Shannon and Weaver Model
- **2** -- SIPT Model
- **3** -- Emmert-Donaghy Model
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NOMENCLATURE

Authoring System: software that allows one, without programming knowledge, to create courseware.

Central Processing Unit: That part of a computer wherein the actual computing takes place.

Communicatively Handicapped: Individuals who, without the assistance of other persons or machines, cannot convey meaning to others because of an inability to transmit verbal or nonverbal symbols.

Electronic Communication Technology: The use of electrically-driven communication aids.

Information Processors: Commonly referred to as the central nervous system, which decodes incoming stimuli and encodes responses to them.

Input Devices: Instruments that transmit information to the microcomputer; they are external to the microcomputer.
**Intensive Interviewing**: Also known as "unstructured interviewing," is a guided conversation whose goal is to elicit from the interviewees rich, detailed materials that can be used in qualitative analysis.

**Interfacing**: The process of integrating or finding a "fit" between the microcomputer and the input device which activates it.

**Microcomputer**: Small scale computer, such as the IBM-PC.

**Microprocessor**: The unit which contains circuits to control and perform computer operations.

**Participant Observation**: Also known as field or qualitative observation, refers to the process in which the researcher establishes a relationship with research subjects to facilitate an understanding of some unit of analysis.

**Perceptrons**: Machines which interpret data from the environment.
RAM (Random Access Memory): The place where the computer keeps the instructions it is currently using.

Receptors: An instrument (our five senses) which can receive photic, thermal, or chemical energy, and transform that energy into a nerve impulse which travels to the brain for interpretation.

ROM (Read-Only Memory): A type of memory component in which the contents are permanently fixed, usually during manufacturing.

Sensory Enhancement: Clarification of audio or visual information at the sensory level so that it can be more easily understood.

Sensory Translation: Translation from one medium to another.

Single-Purpose Communication Aids: Aids that are specifically designed to fulfill the communication needs of a particular class of the communicatively handicapped population, such as the blind.
SIPT Model: A model which allows you to trace the path of a signal from the time it enters the sensory consciousness of a person until this person interprets the signal and reacts to the message by generating another signal.

Speech Recognizers: Machines which interpret vocal patterns from the environment.

Speech Synthesizers: Machines which transmit vocal stimuli to other communicators.

Software: A list of instructions that tell the computer what to do and in what order to do it.

Symbols: Arbitrary representations of other things.

Technocentric: Focusing on the signal, while basically ignoring the uniqueness of the communicators.

Transmitters: Vocal or nonvocal instruments which can transmit stimuli to other communicators.
CHAPTER 1

INTRODUCTION

More than twenty years ago, David Sarnoff prognosticated that continued research and development in computer technology would result in technological marvels and have fundamental socio-economic effects. In a speech to the 1964 Joint Fall Computer Conference, he stated:

Tomorrow's standard computers and their peripheral equipment will instantly recognize a handwritten note, a design or drawing which they will store and instantly retrieve in original form. The computer of the future will respond to commands from human voices in different languages and with different vocal inflections .... It will affect man's way of thinking, his means of education, his relationships to his physical and social environment, and it will alter his way of living.1

Today much of Sarnoff's prediction has materialized. The applications of this new technology range from increasing efficiency in the office to providing convenience in the home. This thesis focuses on the innovations that partially or totally fulfill the communication needs of individuals. These may well be the most significant innovations because they directly enrich the quality of life of the person -- you and me.

- 1 -
OUR MOST FUNDAMENTAL NEED -- COMMUNICATION

Our need to communicate with family, friends, and colleagues is not only a basic striving, but a matter of human survival. It is as prepotent as our fundamental needs for food and shelter, and it certainly must be satisfied before higher needs, such as self-esteem and self-actualization can be fulfilled.

For most people, effective communication skills are developed relatively early in life. But for those who are communicatively handicapped the scenario is quite different. The communicatively handicapped are individuals who, without the assistance of other persons or machines, cannot convey meaning to others because of an inability to transmit verbal or nonverbal symbols. Nearly 500,000 Americans who are not classified as retarded are unable to communicate either vocally or with standard hand signs. An even more sobering thought is that perhaps 100,000 or more individuals of normal intelligence are in institutions and have been diagnosed as retarded simply because they do not have the physical means to communicate.²
To communicate effectively we rely on three interrelated systems: receptors, information processors, and transmitters. These three systems are the sine qua non of human communication. The receptors (our eyes, ears, nose, skin, mouth) receive photic, thermal, or chemical energy, and transform that energy into a nerve impulse, which travels to the brain for interpretation. The information processors, commonly referred to as the central nervous system, decode incoming stimuli and encode responses to them. Finally, the transmitters, which may be vocal or nonvocal, transmit stimuli to other communicators.

A communicatively handicapped individual usually is characterized by having a loss of or deficiency in one or more of these vital systems. The manifestations of this may be complete blindness or, less severely, lack of muscle coordination. Many other problems are certainly possible. The significant point is that this individual's communicative potential will invariably be restricted.

Individuals who must endure silence, darkness, or speechlessness continually hope that the total experience of life may be restored. The deprivation of a sense is debilitative in itself, yet what is worse is that such a
loss may have an atrophic effect on the communicative abilities of the person. The degenerative condition of such a person is analogous to the physiological decay of the tunicate sea squirt:

The tunicate in its larval form swims freely about, guided by its eyes and ears, finding food and avoiding predators. Reaching adulthood, it loses its tail and attaches itself to a rock. For about two years, it sits on the rock, vegetating. Its eyes, its ears, and then its brain all degenerate and become useless.³

The urgency of providing alternative means of communication for these individuals is clearly evident from the foregoing explication. Two basic facts complete the persuasive quality of this argument: (1) Communication defines humanity, and (2) Communication affects the quality of human life.

First, communication defines humanity. Humans are distinguished from other creatures by their ability to communicate. While other life forms behave meaningfully and understand limited signals, only humans seem able to create and interact with symbols. Symbols are arbitrary representations of other things. A symbol may be anything that represents an act, event, idea, feeling, relationship,
person, process, or object. We use symbols to represent concrete aspects of our world (house, food) and abstract dimensions of our existence (ideas, feelings). Because we think and act symbolically, we can impose order and meaning on our experiences. We can persuade ourselves to new courses of action. And we can make sense of our past, adapt to our present, and plan for our future.

Second, communication affects the quality of our lives. Humans use communication to develop interpersonally, professionally, and socially. Through communication with friends we build worlds where we can feel a sense of belonging. We also use communication to develop intimate, romantic bonds with others. Moreover, demonstrated competence in communication is essential to gaining a rewarding career position, to performing skillfully, and to advancing professionally. Finally, a free society depends on a citizenry skilled in communication. Each of us is responsible for making informed judgments of people and ideas, and to achieve this we must promote the communicative development of all people.
THE COMPLEXITY OF THE HUMAN COMMUNICATOR

The source of knowledge about our receptor, information processing, and transmitter systems resides in the one thousand square centimeters of intricate gray convolutions which constitute the human brain. The complexity of the brain has confounded the most perspicacious scientists for centuries. And today there are still many unanswered questions concerning this remarkable "machine," a fact expressed cogently by Richard Gregory:

By comparison with our knowledge of the physical world we understand remarkably little about how we experience or perceive the world of things. Perhaps we know more about the interior of stars than the process going on in our heads which gives us feeling and knowledge.

Even though the intrinsic nature of the three systems is almost labyrinthine, neurologists, electronic engineers, and communicologists have indefatigably collaborated to achieve a keener understanding of these essential components of our communication system. One theory that has emerged from research compares the structure of our visual receptors with semiconducting materials. Investigators of hearing postulate that a certain ear fluid may be a source of electrical energy,
a living liquid battery. Another theory purports that microscopic nerve cells perform a computer-like function: each cell is a world unto itself yet, at the same time, each maintains a subtle relation with its neighbors, the whole system coordinating and signaling a pattern that gives meaning to the structure Sir Charles Sherrington described as "the enchanted loom." 

In Microchip Technology: The Past and the Future Charles Kerridge listed various operations (basically, the handling of data) and compared how they are performed by computers and by humans. This comparison is presented in TABLE 1.

Although human beings are exceedingly more complex than computers, the comparison has generated productive insights and speculation about creating electronic devices which partially or totally fulfill the communicative functions of humans. The major devices in use today are perceptrons, machines which interpret data from the environment; voice recognizers, machines which interpret vocal data from the environment; and speech synthesizers, machines which transmit vocal stimuli to other communicators. Perceptrons and voice recognizers are similar to human receptors in that they "receive" input, while speech synthesizers are like human transmitters as they transmit or convey output.
### TABLE 1

**Comparison: Computers vs. People**

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<th>Operations</th>
<th>Computers</th>
<th>People</th>
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<tr>
<td>Input (collecting data)</td>
<td>Optical character reader</td>
<td>Eyes, Ears, Mouth, Nose, Skin (touch)</td>
</tr>
<tr>
<td></td>
<td>Keyboard</td>
<td></td>
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<tr>
<td>Calculating</td>
<td>Central Processing Unit (where all the actual computing takes place)</td>
<td>Neurons of the brain (nerve cells)</td>
</tr>
<tr>
<td>Processing Instructions</td>
<td>Software (a list of instructions that tell the computer what to do and in what order to do it)</td>
<td>DNA code, Experience, Learning</td>
</tr>
<tr>
<td>Short-Term Storage</td>
<td>RAM (where the computer keeps the instructions it is currently using)</td>
<td>Neurons (facilitate short-term memory)</td>
</tr>
<tr>
<td>Bulk Storage</td>
<td>ROM (a type of memory component in which the contents are permanently fixed, usually during the manufacturing stage)</td>
<td>Neurons (facilitate long-term memory)</td>
</tr>
<tr>
<td>Communication</td>
<td>Electrical cables, Optical fiber cables, Radio links</td>
<td>Nervous system, Sight, Voice, Smell, Touch, &quot;Body Language&quot;</td>
</tr>
<tr>
<td>Output</td>
<td>Line printers, Visual display units, Speech Synthesizers</td>
<td>Handwriting, Speech, Body Motion</td>
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</table>
This area of research is exciting because of its great potential for restoring communicative competence to those who lack part or all of a necessary physiological mechanism [receptor, information processor or transmitter]. It is an area in which science fact and science fiction coexist. John Cater, author of *Electronically Speaking: Computer Speech Generation*, expressed the dynamic quality of speech synthesizers:

[This is] a scientific voyage into man ..., for the first time, science has attempted to duplicate a physiological process. Synthetic speech scientists could not simply sit down with equations and slide rules or calculators and decide how to create speech from electronic machines. Instead, they had to understand the mechanics of speech as we humans utter it, and then formulate electronic equivalents for simulating the vocal tract. Can you imagine the difficulty that the first computer scientists might have had if they had attempted to model the digital computer from the gray matter in our heads? Had that occurred, then computers as we know them today might be chemical in origin rather than electronic.8

SEARCHING FOR ALTERNATIVE MEANS OF COMMUNICATION FOR THE COMMUNICATIVELY HANDICAPPED

The primary goal of this thesis is to document and analyze the "state-of-the art" electronic technologies as they apply to human communication [partially or totally
fulfilling the reception, information processing, and transmission functions of the communicatively handicapped. The basic question to be answered is: What is the current development of electronic technology as a communication aid for the communicatively handicapped? Some of the primary functions to be considered are:

Sensory enhancement: clarification of audio or visual information so that it can be more easily understood [enlarging the characters on the visual display]

Sensory translation: translation from one medium to another [using speech synthesizers to produce auditory output from visual information]

Cognitive assistance: the prospect of cognitive prostheses is beyond the current state of technology, but not beyond the imagination of many people working in this area of research

This research will be of special interest to a host of parties: the communicatively handicapped, whose communication skills could improve by using superior
technology; worldwide rehabilitation institutions, similar to A. I. duPont Institute, who would prosper from adopting more effective "state-of-the-art" electronic technology; and certainly friends and family of the communicatively handicapped. They may soon begin to discern the improved communication skills of their loved ones.

CONCEPTUAL FRAMEWORK

This research is decidedly communication-based. Even so, it is helpful to establish an appropriate communication framework.

At first glance, Shannon and Weaver's Model (Figure 1) seems to provide an accurate description of this research, because it acknowledges the importance of the transmission, information processing, and reception functions of human communication.
Figure 1  Shannon and Weaver Model
According to this model, communication consists of five basic components: an information source, a transmitter, a receiver, a destination, and noise. This model was intended to describe telephone communication, and it works quite well for that purpose. The person who makes a phone call is the source of information, the telephone is the transmitter which converts the message into an electronic signal, another telephone is the receiver, and this reconverts the signal into a message which is heard by another person (destination). Static and other interference in the phone wires are noises that distort the signal so that the message received is not exactly the same as the one sent.

Shannon and Weaver's model was eventually extended to nontelephone communication. The source became the brain of a speaker, the transmitter became the vocal mechanism, the receiver became the hearing mechanism, and the brain of the listener became the destination. Noise was extended to mean anything that interfered with the message.

There are some weaknesses in this model when it is extended to nontelephone communication. First, communication appears as a linear sequence, rather than as
a dynamic interaction between people. Second, according to the model, noise exists only within the message, yet we know that noise occurs throughout the communication process. Finally, the model is technocentric, meaning that it focuses on the signal, while basically ignoring the uniqueness of the communicators. Being technocentric, the model would be relatively effective in studying the effects that different technologies might have on communication, but it undervalues the continuously interactive and human nature of communication.

It is a basic fact that to study communication you must study the person. The SIPT Model (Figure 2)\textsuperscript{11} acknowledges this fact. This model allows one to trace the path of a signal from the time it enters the sensory consciousness of a person [Source (or Reception) Phase] until this person interprets the signal [Information Processing Phase] and reacts to the message by generating another signal [Transmission Phase]. The person receives and reacts to his/her own as well as to other's signals.
Figure 2 SIPT Model
The SIPT Model recognizes that the whole person is involved in communication. The source (or reception), information processing, and transmission phases are taking place simultaneously, and probably are neurologically inseparable. The description of the three phases [Source (or Reception), Information Processing, and Transmission] is in reality an artificial division, but is useful for exposition. The reader must bear in mind that these three phases are profoundly interrelated.

The Emmert-Donaghy Model (Figure 3) builds upon and makes clearer the fundamentals of the SIPT Model. It is the most accurate framework for the present research.
Communication Involves Communicators

 Speakers speak and listeners listen, but communicators simultaneously and continuously do both. The roles of "speaker" and "listener" switch so rapidly and so frequently that such labels are not very useful, although, for some communicatively handicapped persons, their message transmission and reception may proceed at a rate less than normal or desired. These communicators have unique experiences, backgrounds, beliefs, and thoughts. Each communicator is, of course, composed of further subsystems. These include input, output, and processing subsystems, which were an integral part of the SIPT Model explained earlier.

Input [similar to Receptors]

 The input subsystem permits the communicator to receive stimuli from the environment. It involves the reception of light, temperature, touch, sound, odor, and taste via our eyes, skin, ears, nose and tastebuds.

Processing [similar to Information Processing]

 The processing subsystem of a communicator includes all thought processes. In processing we generate, organize, and reflect on ideas in response to the stimuli just received, and all the stimuli ever received.
Output [similar to Transmitters]

The output subsystem of a communicator includes the production of verbal or nonverbal signals, which are transmitted vocally or nonvocally.

Interfacing

One will notice that in the Emmert-Donaghy Model the input, processing, and output subsystems are overlapping. This suggests that they are inseparable, interdependent, and interaffecting.

Communication Is a Dynamic Process

Communication fluctuates constantly -- there are no clear beginnings and endings. Previous events affect current interactions, and communication in the present influences later events and situations.

Communication Is Systemic

To describe communication accurately the reader must recognize the context or system in which it occurs. A system consists of a group of elements or forces which interact to influence each other and the system as a whole. Communication takes place within a matrix of systems: the relationship between communicators is a
system; the society in which they live is another system; the physical situation is a third system. Each of these systems influences communication, and each system influences the other systems. Some relevant questions are: How does a nonhandicapped person view a handicapped person? Does this perception affect the communication process? Also, how does society treat the handicapped?

**Interference or Constraints**

System constraints are features which influence our efforts to communicate. They can modify, even distort, the meanings we intend to convey. Systems may contain physical constraints such as uncomfortable chairs, smoke-filled air, stereo noise, or in the case of a communicatively handicapped person, the transmission of unintelligible speech or unintended gestures. Systems may also be constrained by sociological factors such as status differences between communicators. Cultural constraints within systems include differences in language and custom.

**Communication Is Symbolic Interaction**

Human communication is symbolic in nature, which means it is created and employed by humans. As we interact with and through our language, we describe and classify our
experiences. We use language to represent beliefs about ourselves, our surroundings, and the people and events we encounter. In this way we imbue our experiences with meaning and value.

**Meaning Is Personally Constructed**

Each communicator generates an individual meaning from communication, on the basis of his/her past experiences and his/her way of interpreting others. No two people construct the same meaning, even if they see and hear the "same" thing it will be different because of their interpretations of it [Information Processing is significant]. From this perspective we are concerned with mental processes through which humans store experiences, interpret events, and attribute meanings. In addition, we are vitally concerned with symbols themselves, for it is symbols which allow interaction between humans and which guide the individual, mediational processes of interpretation.
LIMITATIONS

The focus of this research is on electronic communication technology (the use of electrically-driven communication aids); therefore, non-electronic or manual aids are not analyzed, although these simple, cheaper systems might be more appropriate for certain individuals.

The source of information about our reception, information processing, and transmission functions lies at the core of the human brain, the most complex and least understood organ. Illustrating this complexity, Douglas R. Hofstadter, computer scientist and Pulitzer Prize-winning author, posed the question:

What is an "A," anyway? The basic form buried in most people's minds seems to be a pair of slanting uprights and a crossbar. Yet people identify "A's" in limitless incarnations, with curved lines or broken lines or double lines, with flourishes and curlicues, upside-down or sideways, black-on-white or white-on-black, with or without uprights and crossbar. The process is instantaneous, and it is easy to suppose there is nothing to it -- until you try to teach a machine to do it.15

The perceptron, a machine that interprets data, is plagued by the foregoing problem. The speech synthesizers and speech recognizers also have shortcomings. Most speech
synthesizers fail to emulate the subtle nuances of the human vocal tract -- inflection, variation of rate, and vigor. In addition, vocabulary output is usually limited. For the speech recognizer to understand verbal input, the speaker must pause between each word so that the machine can tell where one word ends and another begins. Moreover, the recognizer is confused by homonyms -- words that sound the same but have different meanings, such as "their" and "there."

Despite these limitations, electronic engineers, neurologists, and communicologists continue to search for the optimal communication equipment -- those that imitate most accurately the human reception, information processing, and transmission functions. Their spirit and determination are captured by George Russell's poem, "The Twilight of Earth":

Oh, while the glory sinks within
Let us not wait on earth behind,
But follow where it flies, and win
The glow again, and we may find
Beyond the Gateways of the Day
Dominion and ancestral sway.16
PREVIEW OF SUBSEQUENT CHAPTERS

In Chapter Two a review of the relevant literature provides a preliminary examination of the role of electronic technology in the lives of the communicatively handicapped.

In Chapter Three the basic design for the research along with the procedures that were used are presented.

In Chapter Four an analysis of the data conveys a lucid picture of the "current" trend (defined herein as the period ending February 1986) that exists in the development and provision of state-of-the-art electronic technology for the communicatively handicapped.

In Chapter Five an analysis of the data (primarily from the major research centers to be interviewed) seeks to determine the communicatively handicapped's accessibility to the state-of-the-art electronic technology.

In Chapter Six the findings of the research are interpreted and the implications presented.
CHAPTER 2

REVIEW OF THE LITERATURE

The following review of the literature provides a synthesis of the available electronic technology used to assist the communicatively handicapped. It includes an integration of ideas from noted authors and experts in this field of research.

SINGLE-PURPOSE COMMUNICATION AIDS VS. THE MICROCOMPUTER

With the advent of the microprocessor (the unit which contains circuits to control and perform operations) it is now possible to design communication aids that embody a considerable degree of sophistication, and which can be dedicated to the task of enabling the communicatively handicapped to convey thoughts and feelings to others.17

Many single-purpose communication aids, those aids specifically designed to fulfill the communication needs of a particular class of the communicatively handicapped population such as the blind, are on the market today. These single-purpose aids are typically microprocessor-based with some form of printout and display. The sizes, weights, and battery lives of these aids vary.18
Although these aids proliferate, they have serious drawbacks. First, because they are built for one purpose, their use is restricted to a relatively small proportion of the communicatively handicapped population. Closely related to this drawback is a second limitation -- their initial purchase price is necessarily high because low-volume production cannot possibly compete with the economics of large-run production. Third, the distribution and service of these products present additional problems. Products with a limited market, such as single-purpose communication aids, cannot support extensive field or local sales organizations. Moreover, any repairs will likely be performed at a remote location that may be inconvenient for many users.  

In essence, while we now have the technology to build single-purpose communication aids to compensate for almost any communication handicap, not everyone who needs an aid can afford one. They can't be mass produced because (ideally) they all require some customization. Until this dilemma is adequately resolved, the single-purpose communication aid will continue to lose its popularity to a more flexible tool -- the microcomputer or small scale computer.
The following example from Britain illustrates that the tide of opinion is turning away from those who back single-purpose aids that have limited applications:

John Flack, the head of Electraid, an Aylesbury firm that sells equipment for the handicapped, says that Possum hardware, a single-purpose aid, is fine if the person using it only wants to write letters. But he says that giving the handicapped access to computers can help them in other ways -- with entertainment, education, and in employment. With this philosophy in mind, Flack is changing the nature of his products. Since he started his firm in 1969, Flack has sold some 300 (single-purpose) aids. But he is turning toward computers; Flack is now selling Apple machines ....21

Prentke Romich Company, one of the oldest companies working in the area of electronic aids for the communicatively handicapped, communicates its response to this market change:

Microcomputer technology offers cost effectiveness in manufacturing and great flexibility in responding to the varying needs of the handicapped user. In recognizing these facts, an increasing percentage of our products are computer related. Now, we believe computer applications for the handicapped warrant a special effort in awareness for both the rehabilitation professional and other interested consumers.22
The microcomputer is now widely available and relatively inexpensive. It is therefore becoming much more difficult to justify the design and construction of single-purpose aids when it is relatively simple to incorporate the same qualities in a mass produced, "off the shelf" aid at a considerably lower price. While it could be argued that a commercially available microcomputer may exhibit features that would never be of use to a particular communicatively handicapped person, these features are provided at no additional cost, and still generally at a lower price than could be achieved in a single-purpose aid. Also, we should not overlook the very real possibility that the communicatively handicapped individual may "grow into" the other applications offered by the microcomputer. Moreover, family members may find real utility in this microcomputer when it is not in use by the communicatively handicapped individual.
One of the most difficult tasks for the communicatively handicapped is to convince the general public that they are intelligent people. Many conspicuous single-purpose communication aids attract undue attention and sometimes suggest that the person using them is "different." Phil Odor, a researcher at Edinburgh University, claims that centers of research on the handicapped should invest money to purchase mass-produced, inexpensive microcomputers, because these standard computers help the communicatively handicapped to integrate with everyone else.24

Many people involved with the communicatively handicapped now espouse Odor's philosophy. One example illustrates this fact:

Peter Deakin, a computer programmer at Neath Hill Professional Workshop in Milton Keynes, says he deliberately chose relatively cheap, well-known microcomputers, such as Apple, to serve the communicatively handicapped at the workshop. He asserted, "It's central to our philosophy that we should use mass-produced computers. We want the (communicatively) handicapped to use the same machines as everyone else. Using Apples ensures the people here are not singled out as something different."25
It must be mentioned, though, that the microcomputer will never obviate the need for single-purpose communication aids. It is a fact that some individuals are better served by these communication aids.

AN INFORMATION SOCIETY: DEEMPHASIZING THE "HANDICAP"

John Naisbitt, author of nationwide best seller Megatrends, began his first chapter this way:

This book is about ten major transformations taking place right now in society. None is more subtle, yet more explosive, I think, than this first, the megashift from an industrial to an information society.26

In the information society, work becomes less the manipulation of things and more the manipulation of information and ideas, and, thus, the communicatively handicapped can participate on a more equal level with their colleagues.

The microcomputer is making this possible for many handicapped individuals, like Glynn Vernon. Glynn, a programmer for a British company, exclaimed, "When programming computers, we should not be looked upon as handicapped. In this we are no more handicapped than anyone else." The intellectual character of the work can
be far more personally and economically rewarding than
traditional homebound duties such as sewing and craftwork.
The handicapped individual today can engage in fields such
as data processing, accounting, and bookkeeping -- fields
of gainful professional employment in which there is
considerable outside contact through telephone,
telefacsimile, and, most notably, the computer. 27

ACCESSING THE MICROCOMPUTER

Many communicatively handicapped persons who cannot
handle a pen or pencil find such a program as word
processing very helpful in the preparation of written
documents. Some of these individuals can access the great
power of the microcomputer through the standard input
device used by the nonhandicapped population -- the
keyboard. 28

Unfortunately, there are many others who, with limited
functional ability, need alternate input devices to tap
the communication potential of the microcomputer. Input
devices are instruments that transmit information to the
microcomputer. They are external to the microcomputer.
Depending upon which part of the person's body is self-controllable, the input devices may take a variety of forms. TABLE 2 illustrates some of the possible ways to access the microcomputer:

<table>
<thead>
<tr>
<th>Controllable Function</th>
<th>Input Through ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye</td>
<td>Optic</td>
</tr>
<tr>
<td>Breath</td>
<td>Pneumatic</td>
</tr>
<tr>
<td>Voice</td>
<td>Audio, Speech Recognition</td>
</tr>
<tr>
<td>Tongue, Lip</td>
<td>Touch, Air Pressure</td>
</tr>
<tr>
<td>Shoulder</td>
<td>Pressure, Touch</td>
</tr>
</tbody>
</table>

Currently there are many types of input devices available, but no standardization has been established; therefore, equipment is frequently personalized, resulting in severe difficulties in maintenance and extreme cost.

THE INTERFACE PROBLEM

Cheap microcomputing is beginning to affect the area of communication for the communicatively handicapped, removing some of the frustrations and inflexibility of the single-purpose aids. However, according to W. J. Perkins,
Head of Computer Science Lab at the National Institute for Medical Research in London, the application of "high technology" to the interface component of microcomputing is advancing much more slowly. Interfacing is the process of integrating or finding a "fit" between the microcomputer and the input device which activates it.  

Perkins' feelings are corroborated by Director of the Trace R&D Center for the Handicapped at the University of Wisconsin-Madison, Gregg Vanderheiden, who claims that the major barrier to using microcomputers as communication aids is the custom interfacing needed. This involves the development of special input devices which are not commercially available -- a process which can negate many of the advantages of microcomputers.  

Experts in this field agree that research needs to address the interface problem. There is a need to evaluate the most common and practical input devices necessary for the communicatively handicapped population, and design a universally adaptable interface system which will effectively integrate the input device and the microcomputer. A universal system would offer the advantage of more available maintenance, theoretically lower prices, and less need for personalized equipment.
OTHER SHORTCOMINGS

The interface problem is a major obstacle in preventing the microcomputer from fulfilling its potential as a communication aid for the communicatively handicapped. There are additional shortcomings which should be noted.

Too Specialized

Often special software is designed for the communicatively handicapped. But special programs limit computers to special tasks. Current research and development is aimed at overcoming this limitation.34

Nonportability

Many microcomputers are nonportable, which tends to limit their use to work-station types of applications. These applications include computer-aided writing, filing, phone control and phone communication using the new speech synthesizers. However, even the stationary systems have not been able to meaningfully address the conversational needs of individuals with severe speech impairments.
The recent introduction, though, of portable and hand-held computers is opening up the potential for microcomputers to move out of the stationary writing-aid category and begin to address the categories of portable writing/note-taking aids and conversational communication aids. Unfortunately, the portable microcomputer is not widely used today.35

CONCLUDING REMARK

Peter A. McWilliams, author of Personal Computers and the Disabled, sees a bright future for the use of microcomputers (or personal computers) as a communication aid for the communicatively handicapped:

And as to what personal computers can do for disabled people -- well, personal computers can make the difference between communication and isolation, between productivity and non-productivity, between independence and dependence.36

This thesis pursues the development of electronic technology (especially the micro-computer) as a communication aid for the communicatively handicapped.
CHAPTER 3

RESEARCH METHODS

The major objective of this research is to determine the current state of development in electronic technology as a communication aid for the communicatively handicapped.

RELEVANT SOURCES OF INFORMATION

In every industry there are a few organizations whose work essentially shapes and defines the very nature of the industry. In the field of communication technology for the handicapped, the organizations which represent the creme de la creme are: Hugh MacMillan Medical Center in Toronto, Tufts-New England Medical Center in Boston, Trace Medical Center in Madison, The Artificial Language Laboratory at Michigan State University, Johns Hopkins Applied Physics Lab in Baltimore, and the many research groups of the IBM Corporation. These research centers are the major sources of information for this thesis. Their works, which represent the most innovative in this field,
are documented and analyzed to provide a unified picture of the current state of development in electronic technology for the communicatively handicapped.

In addition, key developments which can be discerned from the author's first-hand experience as an R&D Assistant for the IBM Corporation are detailed.

Only by understanding the current research and development being conducted by these industry leaders can we begin to make sense of the "cutting edge" of that industry, and possibly acquire the prescience to project its future.

Multiple Sources of Information

The most important advantage presented by using multiple sources of information (e.g., internal, external factors) is the development of converging lines of inquiry. Robert Yin elaborates:

Thus, any finding or conclusion in a study is likely to be much more convincing and accurate if it is based on several different sources of information, following a corroboratory mode. In this manner, the
potential problems of construct validity also can be addressed, because the multiple sources of evidence essentially provide multiple measures of the same phenomenon.37

ACQUIRING THE INFORMATION: MODES OF DATA COLLECTION

The procurement of meaningful data in the context of this research requires the incorporation of four modes of data collection: 1) participant observation, 2) intensive interviewing, 3) structured interviewing, and 4) literature update.

1) Participant Observation

Participant observation, also known as field or qualitative observation, refers to the process in which the researcher establishes a relationship with a human association (the research centers) to facilitate an understanding of some unit of analysis in this case "hands-on" investigation of the development of electronic technology as a communication aid. Yin emphasizes the importance of this mode, specifically referring to its use in the exploration of new technology:

Observation ... is often useful in providing additional information about the topic being studied. If a study is about new technology, for instance, observation of the technology at work is invaluable to any further understanding of the limits or problems with the technology.38
2) **Intensive Interviewing**

Intensive interviewing, also known as "unstructured interviewing," is a guided conversation whose goal is to elicit from the interviewees in this case, personnel at IBM and other research centers rich, detailed materials that can be used in qualitative analysis.  

The interviewees, some of whom might be better described as "informants" (e.g., computer scientists at IBM), are critical to the success of this research. Such persons not only provide personal insights and expertise, but also can suggest other sources of corroboratory evidence, and even initiate the access to such sources.

3) **Structured Interviewing**

A structured interview is conducted via telephone with the major organizations that were delineated earlier under the topic, "Relevant Sources of Information." This instrument seeks to document the available state-of-the-art electronic technology for the communicatively handicapped and to appraise this population's accessibility to the technology. A reproduction of the instrument is displayed in Appendix A.
4) Literature Update

The advance of technology, and hence of innovation, depends on the advance of scientific knowledge. The conversion of the results of scientific investigation into knowledge depends on the communication of those results to others. The primary research journal is the major means of communicating such knowledge — extending the universe of what is known and, hence, what can in the future be known.

A literature update is an ongoing and integral part of the success of this research. The significance of this mode of data collection is elucidated by A. K. Kent:

The "microchip" is an innovation that increasingly impinges on every area of life. Its dramatic development, and availability for the multifarious purposes to which it is applied, is largely the consequence of its value in the miniaturization of computing and control equipment for space exploration. There was a need for it, and the money and resources were available for its rapid and effective development. But the development of the microchip would not, ultimately, have been possible if there had not been available the results, reported in the primary research literature, of fundamental investigations of the properties of semi-conductor materials, investigations which (at least initially) were made for their own sake and without any application in mind. The curious properties of
such materials, reported long ago in the primary research journals, were the "trigger" which, when the need arose, provided the raw materials upon which the innovation was based and established an entirely new, and now all-pervading, industry. If, then it is accepted that the primary journal is the most reliable repository of accurate scientific information and hence scientific knowledge, then the essential source of information for innovation lies in the primary scientific literature as it appears in the primary research journal.

VALIDITY AND RELIABILITY

Is the method used in this research reliable (an accurate, consistent measurement) and valid (measuring what it claims to measure)? These questions are addressed below.

Construct Validity

In addition to the fact that this research will integrate multiple sources of information, there is another way that its construct validity will be enhanced. Min describes this validity procedure review of the research draft by others:
Have the draft reviewed, not just by peers, but also by the participants and informants in the study. This procedure is a way of corroborating the essential facts and evidence presented in the study. From a methodological viewpoint, the corrections made through this process will enhance the accuracy of the research, hence increasing its construct validity.42

Internal Validity

According to Yin, internal validity is a concern only for causal or explanatory studies, where an investigator is trying to determine whether event X led to event Y.43 This current research is of the descriptive or critical nature, yet does not seek to determine cause and effect nor to explain a certain phenomenon.

Representativeness

Because this research acquires its information from the foremost research centers in this field, the assertions regarding the state-of-the-art electronic technology are made with a fair degree of confidence.

Reliability

The reliability of this research will be promoted by creating a research data base, which is explained by Yin:
Too often, the (research) data are synonymous with the evidence presented in the (final) report, and a critical reader has no recourse if s/he wants to inspect the data base that led to the conclusions. A major exception to this has been the Human Relations Area Files at Yale University, which store the "data" for numerous ethnographic studies of different cultural groups, making these data available to new research investigators. However, independent of the need for a central repository, the main point here is to develop a formal, retrievable data base, so that in principle, other investigators can review the evidence directly and not be limited to written reports. In this manner, the data base will increase markedly the reliability of the entire (research).44

Another simple way that the reliability of this research will be increased is by maintaining a chain of evidence. The principle is to allow the reader of the thesis to follow the derivation of any evidence from the initial research question to ultimate conclusions. This is facilitated by citing specific interviews, documents, or observations.45

A FINAL NOTE

This research requires great flexibility of the investigator, who must remember the original purpose of the investigation, yet also be willing to change procedures if unanticipated events occur. In essence, newly encountered situations must be seen as opportunities, not threats.
CHAPTER 4

ANALYSIS OF STATE-OF-THE-ART ELECTRONIC TECHNOLOGY
FOR THE COMMUNICATIVELY HANDICAPPED

The following chapter conveys a lucid picture of the "current" trend (defined herein as the period ending February 1986) in the development and provision of state-of-the-art electronic technology for the communicatively handicapped. This broad appreciation of the state-of-the art is strengthened by an extensive analysis of a new product on which the author has worked.

SPEECH SYNTHESIS: A UNIFYING TECHNOLOGY

When you hear the term "speech synthesis," you might think of something hi-tech that was created three to five years ago. Actually, speech synthesis has been around since at least the 18th century. Theophilus Kratzenstein, a professor at the Imperial Academy of Sciences of...
St. Petersburg, won the Academy's annual science contest with a paper on speech synthesis entitled "On the Formation and On the Artificial Imitation of the Human Voice," and an accompanying speech synthesis device. According to James L. Flanagan, author of *Speech Analysis, Synthesis, and Perception*, nothing earlier is cited.46

Speech synthesis received its greatest attention at the World's Fair in New York in 1939. Here Bell Labs exhibited its speech synthesizer, named Voder, for Voice Operation Demonstrator. Voder had a keyboard, various pedals, switches, vacuum tubes, amplifiers, and three loudspeakers. A trained operator sat down and played its keys, much the same way someone would play an organ. This primitive speech synthesizer could imitate human voices, animal voices, airplane engines, in fact almost any sound imaginable.

Despite the excitement surrounding the Voder at the World's Fair, the synthesizer was not built for any practical application. It was not until its marriage with personal computers that the speech synthesizer really became a tool for man.47
Most significantly for the communicatively handicapped, speech synthesis gives microcomputers the power to verbalize the contents of software used in school- and work-related tasks. For instance, a blind operator working with a word-processing program might hear the phrase "edit an old document" when the cursor is placed on that menu item. Once in the document, the computer will "speak" whatever words are on the screen, as well as any changes typed in by the operator.

The Specialized Software vs. Off-The-Shelf Software Approach

There are numerous application programs for personal computers designed specifically for operation with speech synthesizers. For example, the Braille-Edit-Express program from Raised Dot Computing is a talking word processor that runs on Apple IIe and IIc computers. In addition to generating voice output, the program can produce large-print and braille output, and can link the Apple with other micro or mainframe computers.

Another approach, one which would seem to more directly integrate the visually-handicapped with other sighted users, involves "speech drivers" programs used to
voice the popular software sold to sighted users. These drivers are often referred to as "screen readers," but a more accurate name is "talking operating systems." A user simply loads such a system into the computer and then runs standard packages such as WordStar or Lotus 1-2-3 on top of it.

An example of a talking operating system is the Enhanced PC Talking Program sold by Computer Conversations for use on IBM's microcomputers and more than fifty compatibles. The program can verbalize up to 95% of the IBM software library without modification. Other talking operating systems such as Screen-Talk from Computer Aids and Freedom-1, sold by Interface Systems International work with most word processors, databases, spreadsheets, and telecommunications packages. These products are state-of-the-art because they take screen-based software and turn it into speech-based software without rewriting a single line of code. The talking operating systems sit in the background, just like a disk operating system, until they are called upon to accomplish their verbal tasks.
Quite simply, talking operating systems enable blind operators to function very much like their sighted counterparts, using the same application software. "I use an IBM PC/XT with the Enhanced PC Talking Program to do financial forecasting on our mainframe computer," says Albert Gayzagian, Director of Corporate Analysis at John Hancock Financial Services (Boston). "The talking software lets me accomplish my job as if I weren't blind."

While such talking operating systems give blind operators access to most commercial software (the programs are unable to voice graphics packages), they may not work as smoothly as the packages designed specifically for voice output. For example, some speech drivers might voice the entire screen every time a new character is typed on a standard word-processing package. (By contrast, a product like Braille-Edit-Express would speak just the new character.) To prevent the constant voicing of the entire screen, an operator might choose to turn off the voice feature while editing, and turn it back on to hear the completed changes. The fact that the talking operating systems give blind users access to most commercial software more than makes up for such shortcomings.
Even so, "talking operating systems" would be more valuable if these shortcomings were addressed and eventually overcome. In the next section an exposition of guidelines originally designed by the author for the visually-handicapped market is presented. What is interesting to note is that the majority of these guidelines are not inconsistent with the needs of sighted users. In fact, some of the proposed features could clearly benefit that user group. It is hoped that major software manufacturers will build some of these specifications into their "talking operating systems," and thus, make off-the-shelf software programs more accessible for the visually-handicapped, and concomitantly, more attractive to the sighted user.

Guidelines: Presentation of Document and Voice to the Visually-Handicapped

While reading a recent issue of International Newsweek, the author came across an excerpt which poignantly expresses the unfulfilled potential of personal computers for the visually-handicapped user:
A personal computer is often likened to a window that looks out onto mountains of valuable information. But if the user does not have healthy eyes, that window is shuttered.49

The relative lack of attention to the visually-handicapped user by the computer industry may be due to a host of reasons, but the fundamental reason seems to be that there doesn't exist a comprehensive set of guidelines upon which design decisions for this population can be made. In the next few pages an attempt is made to set forth these basic guidelines, which address both presentation of the document and presentation of the voice.

The significance of the following guidelines for the user will vary depending upon to what extent s/he is visually-handicapped. The creation of these guidelines takes into account the fact that there are differences among members of the visually-handicapped population. For example, a person who became visually-handicapped later in life would have a sense of the conventional textual and graphical presentation used by writers, whereas a person blind from birth would probably not have any preconceptions about this.
The following guidelines focus on two specific aspects: presentation of the document and presentation of the voice.

Presentation of the Document

**"ease of use" keys (convenient position and fewest keystrokes possible)

**succinct precis or abstract

**broad table of contents

**detailed table of contents

**alphabetized index

**summary construction (with option to save it for future reference)

**text should never be truncated prematurely at the bottom of the screen, as this requires the user to wait before completing the thought intended in the text

**complete and efficient movement among table of contents, body of text, index, and summary

**bookmarking capability (user can return to the page s/he last read)

**capability for pausing, bypassing certain text, and editing

**compatible with many types of displays
presentation of Voice

**choice of female, male or child voice

**flexibility in setting rate of speed, volume, pitch, and intensity

**description of the layout of each page

**punctuate mode (pronouncing even punctuation)

**pronounce mode (for instance, reading a question in an interrogative manner, not reading the character "?")

**within the punctuate and pronounce modes, the user should be able to hear the text spoken in a variety of units:

- continuous
- one panel or screen at a time
- one paragraph at a time
- one sentence at a time
- one line at a time
- one word at a time
- one character at a time (spell/digit)

**horizontal and vertical reading flexibility

**turn on/off the announcement of upper 128 ASCII characters

**suspend announcement of certain blocks of text (for example, the always-present listing of the function keys)

**interrupt speech
**abort speech and proceed to:**
- next chapter or major section
- next topic
- next subtopic
- next panel or screen
- next paragraph

**prevent the synthesizer from repeating the entire screen every time it is scrolled**

**review mode (efficient maneuverability to all parts of the screen, and resource to determine the user's current cursor position)**

It is desired that the above guidelines be gradually incorporated by software manufacturers into their "talking operating systems." If both visually handicapped and sighted viewers can be satisfied with such software -- and it seems that such a proposal is not incongruous with either user -- it is plausible that software manufacturers could enlarge their market and profitability. Most importantly, if implemented, this proposal would serve to hasten the integration of the visually handicapped with others, especially in the educational and vocational contexts.
more on Speech Synthesis: Portability and Personality

The Artificial Language Laboratory at Michigan State University is currently attempting to build a portable version of DECTalk, a speech synthesis terminal produced by Digital Equipment Corporation. DECTalk has provided great utility for both handicapped and nonhandicapped users. What makes DECTalk so attractive to both user groups is the fact that its inflection, intonation, stress, pitch, and rhythm closely approximate human speech. In addition, its 500-plus linguistic rules and exception dictionary empower the system to deduce speech usage almost flawlessly.50

Sources at Tufts, who have programmed the Panasonic Hand-Held Computer as a personal and portable communication device, emphasize that this type of research and development basing aids on a portable microcomputer design is long overdue.51 The Trace Center, seemingly concurring with Tufts, is developing a communication and writing aid based on the Epson HX-20 microcomputer, a "notebook-sized" computer.52 Portability is significant because many communicatively handicapped persons are not
ambiulatory. A portable communication aid can be carried by the person or mounted on his/her wheelchair, an important feature for anyone who wants to participate in our mobile society.

The Artificial Language Laboratory is also beginning to incorporate the SSI-263 speech synthesizer chip into its applications for communicatively handicapped persons. Reportedly, this SSI-263 chip, a form of the Votrax proprietary SC-01 speech synthesizer chip, allows one to create more phonetic sounds, which is significant to creating foreign language synthesizers; it can be gender-specific; and it even reflects a wider variety of differences in voice quality. This chip should allow research centers and clinicians to better tailor speech synthesis to the particular user, reflecting the importance of "individuality."53

SPEECH RECOGNITION: FACILITATING ACCESS

In the last few weeks of summer employment of 1985 as Research and Development Assistant at IBM, the author learned a little about speech recognition, the speech technology that deals with voice input.
Speech recognition is basically a two-step process that converts the sound of the spoken command or word into a digital package or template, and later matches it to the same spoken command given during an application program.

The above description belies the complexity of the speech recognition process:

The process of human speech, though taken for granted by most of us, is enormously complicated to the speech recognizer. Spoken sound shifts rapidly between two different components: vowel sounds produced by a single frequency generator (your vocal cords) and consonant sounds made up of the multi-frequency white noise of whooshing air passing teeth, tongue, and lips. Sorting through this jumble of audio babble takes more processing than most of us give our brains credit for.

Currently, most recognizers are of the speaker-dependent variety; this means that a specially "trained" template file must be created on the PC for each user's voice. This file is a list of voice prints for each command you want to use to run a particular program.

Until recently, speech recognition had been limited to commercial applications, such as quality control and inventory processing. Today this technology spans many applications, from the most futuristic (artificial intelligence) to the most fundamental (assisting a person in maintaining his/her quality of life).
Because of falling prices, it is increasingly cost-effective to add speech recognition equipment to an existing microcomputer, thereby enabling virtually any standard application program to be operated by voice command and control. In fact, current speech recognition software is flexible enough to be trained to almost any voice, even one that is garbled by limited muscle control. Most speech recognition software comprises sets of routines that break down spoken sounds into computer code commands understandable to the host microcomputer. The host "thinks" the information is being typed, but commands are really coming from a microphone, not a keyboard.

The immediate future of adaptive computer systems appears bright as the technologies become more reliable and less expensive. With prices now often running in hundreds of dollars rather than thousands, consumers are increasingly able to afford these devices.

What is so encouraging about the prospects of this technology is that it provides real utility for many different types of people, both handicapped and nonhandicapped. For the latter user group, speech recognition represents a quicker, more efficient way to input and access information. "Rapid" typing is a
relatively uncommon skill, and even "fast" typing rates are significantly slower than speaking rates. In addition, the full capabilities of telephone interaction with machines can be harnessed with speech recognition technology. For the communicatively handicapped, these systems of voice entry can endow the user with total control of the microcomputer by the use of voice commands. The systems can be trained to recognize any voice and made to perform any computer functions, just as keyboard access would. Moreover, it can function as a means for the user to control his/her environment. 55

At a camp for the handicapped in Connecticut in 1985, the author witnessed some of these "fundamental" applications of speech recognition:

Matt, a 12-year old who could control only his voice, was training his synthesizer to understand some commands that he would use in some application programs. With some straining he began to speak, "delta, Edward, Frank, gamma, ...."

Eric, a 15-year old who was paralyzed from the neck down, automatically loaded his command vocabulary, which he had previously trained. The menu appeared on the screen, presenting several options: a.) control appliances, b.) stereo on/off, c.) light on/off, ....
Research in speech synthesis and recognition is one of the more fascinating areas of research today, both as an investigation into human abilities and as an emerging engineering discipline. As computers become more universally available to nonprogrammers, the desire to communicate with them in more natural ways becomes increasingly urgent. Speech processing by computer provides one vehicle for natural communication between people and machines. Although fluent communication in spoken natural English for unrestricted application is not possible today, a great deal is known about how to build computer systems that recognize a restricted range of spoken commands and synthesize intelligible speech output. Moreover, the foundations are being laid, and research is in progress to develop technology that will permit natural English communication in continuous speech to be used for an increasingly complex range of applications (current research at IBM Yorktown). With the increasing role of computers in modern life, there is little doubt that we will eventually want them to talk to us and allow us to speak to them. For nonhandicapped persons this represents a more natural, preferred way of receiving and transmitting information; for many communicatively handicapped persons this mode of exchange is wholly indispensable.
STATE-OF-THE-ART IN PROMOTING INDEPENDENCE

One of the most dramatic leaps in technology for the physically handicapped has occurred in the relatively static world of wheelchair manufacturing. A Swedish company named Permobil challenged the conventional thinking that the purpose of the wheelchair is simply to transport, and subsequently created a line of wheelchairs that might be more accurately termed "livingchairs" wheelchairs that not only transport the physically handicapped, but also support their communication and environmental control needs. All these important functions are powered by sophisticated microcomputer technology.

Visual Design

The positive first impression formed regarding the Permobil wheelchairs originates in a cosmetic, rather than a functional basis. The wheelchair seems to be free of the "handicapped aura" that many other traditional wheelchairs convey. This notion is primarily attributable to the attractive, bright-colored fabric cushions which are not only comfortable but also of pleasing visual
design. The significance of this "nonfunctional" aspect of the Permobil wheelchair cannot be underestimated, since the wheelchair design as a perceived extension of the physically handicapped person contributes to the owner's self-image.

Operation

The Permobil wheelchairs may be operated by virtually any physically handicapped person. Steering and speed controls, which may be standardly operated by a small control lever, joystick, foot control, chin control, and sip-and-puff control, can also be adapted for other special requirements, making it suitable even for people with very severe functioning impairments.

Maneuvering

Many of the Permobil wheelchairs are functional in both outdoor and indoor environments. They can cope well with a variety of outdoor surfaces from urban landscape to hilly terrain, even on ice and snow. The wide drive wheels and the flexible back of the MAX-IOR model, for instance, maintain all wheels in contact with the surface, even on uneven ground. An electronic brake and a magnetic
brake provide gentle braking even if the control lever or joystick is quickly released. The chair has absolute speed control which enables it to overcome obstacles and drive down steep slopes very slowly. Should other driving qualities be required the microcomputer can be reprogrammed to provide, for example, a lower maximum speed, altered acceleration and steering speed.

The MAX-IOR performs quite well indoors also. The electronic drive control facilitates small movements and inching forward. Moreover, its narrow width and short length means that it copes with most doorways and requires little turning space. The HEX-IOR model which has a special six wheel design with drive wheels in the middle, requires 20% less turning space than conventional electrical wheelchairs. These features are essential in promoting adaptation to an organizational or school environment. Finally, most Permobil wheelchairs have a seat lift which makes reaching high places (shopping shelves or cupboards at home) a relatively simple task.
**Environmental Control**

The inability of a physically handicapped person to control his/her environment often reinforces a feeling of dependence, and sometimes even helplessness. Permobil chairs help the physically handicapped person reclaim his/her autonomy in all important contexts home, school, and work. In a Permobil chair, the user can turn lights on and off, operate a TV, open and close doors, and make telephone calls directly from the chair's control box. Infra-red signals are sent from the chair's control panel to a receiver which operates a relay that accomplishes these tasks.

**Communication**

Two Permobil models, MAX-IOR and MIN-IOR, allow the addition of a communication system called "Alfa writer." This system uses the same control panel that runs the chair for writing purposes, so adaptation to the user is promoted. The fact that no changeover between different control panels is needed also makes good economic sense for the user. The system comprises a chair-mounted screen (9 x 15 cm) which displays text, a built-in wireless transmitter which relays edited text to a printer (and
microcomputer), and a receiver, which operates the printer (and microcomputer), the main power switch, room lights, and the telephone. Finally, the edited text may be optionally transmitted to a speech synthesizer mounted on the chair.

Adaptability

For ease of adaptability the chair is built around several independent units: chassis, seat, electronics, and control panel. The chassis is prepared for all standard accessories; the standard seat can be replaced by several seats in Permobil's range; the control panel can be mounted on either left or right arm rest; and the driving characteristics can be altered by reprogramming the drive program. Moreover, the modular construction of a Permobil wheelchair keeps the servicing costs at the lowest possible level.57

Permobil's implicit philosophy seems to be that the wheelchair must become a liberating technology, one which fosters the self-sufficiency and independence of the communicatively handicapped. Clearly, Permobil's "advanced electronic wheelchairs" embody this philosophy.
Incidentally, the Hugh MacMillan Medical Center is currently working on a modular wheelchair mounting system that will readily accommodate a communication aid (like Prentke Romich's Light-Talker). In addition, Tufts is conducting research on the use of robotics to help the communicatively handicapped control their environment. Like Permobil, both these research centers affirm the significance of the person's need for mastery over one's environment, a point poignantly expressed in a presentation at the 1983 Council for Exceptional Children Conference on Microcomputers in Special Education.

Severely physically handicapped infants and toddlers are limited in the amount of interaction they can have with their environment. This may limit the amount they can learn from it, causing secondary handicaps and thus creating an even more handicapped individual. This cycle can possibly be broken by using a microcomputer to give some of the environmental interaction back to the infant.58

FOCUS ON "AUG": ANALYSIS OF A STATE-OF-THE-ART PRODUCT

In the following section an extensive analysis of a state-of-the-art telecommunication product called Augmented Phone Services is presented. Created by IBM,
Augmented Phone Services (or AUG) allows individuals with hearing and/or speech impairments to communicate over the telephone with hearing individuals. For purposes of organization and clarity, much of the analysis will alternate between the concerns of the "sender" population (defined as hearing- and speech-impaired persons) and those of the "receiver" population (defined as hearing persons). Before the analysis is offered, though, a brief description of the operation of AUG is warranted.

**Brief Overview of AUG Operation**

Augmented Phone Services (AUG) is a computer program that helps people with hearing and/or speech impairments who are using an IBM-compatible Personal Computer to communicate via telephone with hearing people who are using a touch-tone telephone. The process differs slightly depending upon whether the conversation is between a hearing-impaired person and a hearing person, or between a speech-impaired, non-hearing-impaired person (hereafter referred to as speech-impaired) and a hearing person.
If the conversation is of the first form, the process is as follows: first, the hearing-impaired person types his/her message on his computer keyboard; next, AUG converts this message to synthesized voice and transmits the voice over telephone lines to the hearing individual. Finally, the hearing person replies by spelling his/her message on the keypad of his/her touch-tone telephone; that message is retransmitted over telephone lines and subsequently displayed on the hearing-impaired person's computer screen.

If the conversation is of the latter form, the process is as follows: first, the speech-impaired person types his/her message on his/her computer keyboard; next, AUG converts this message to synthesized voice and transmits the voice over the telephone lines to the hearing person. The next step constitutes the essential difference between the two forms of conversation. Here, instead of having to spell his/her message on the keypad of his/her telephone, the hearing individual may talk as s/he usually does on the telephone. Again, this step assumes that the speech-impaired person is not also hearing-impaired.
Sender Population: Benefits Derived

In using AUG, hearing- and speech-impaired persons derive significant benefits, both physiological and social. Physiologically, a hearing-impaired person lacks the abilities to auditorily receive and usually to vocally transmit information over the telephone, while a speech-impaired person cannot vocally convey information. AUG allows a receiver's (hearing person's) messages to be visually displayed on a microcomputer monitor, thus fulfilling the reception need of the hearing-impaired person. In addition, AUG transmits intelligible vocal output to the receiver, thus satisfying the transmission needs of both hearing- and speech-impaired persons. Moreover, AUG helps realize these persons' needs for social contact. Because AUG permits you to reach anyone who has a touch-tone telephone a very common, widely distributed piece of technology the number and types of persons the hearing- and speech-impaired can communicate with is almost boundless.
In using AUG the hearing person, too, obtains very real benefits, though they are more likely social and professional, rather than physiological. Certainly many hearing individuals have a need to communicate via telephone with hearing- and/or speech-impaired persons, and regardless of the motivation -- whether to have a conversation with a friend or to make a business contact -- AUG makes this connection possible.

AUG is characterized by availability (IBM-compatibility), quality, and first-rate customer support. These characteristics guarantee that the AUG system will be available to a far-reaching population of hearing- and speech-impaired persons; will function dependably, especially important in emergency situations; and will be serviced quickly and efficiently, ensuring the continuity of operation.

Since IBM is the most respected computer manufacturer in the world, its products (AUG as an example) invariably become standards that are emulated by others, thus its benefits may be diffused. One computer expert claims:
The IBM microcomputer is the standard for all microcomputers, and is likely to remain so for years to come. The signs of an IBM reign are everywhere. Not only is almost every significant new piece of software being introduced first on the IBM, but almost every piece of software that's ever been written is being rewritten for the IBM. And, most telling of all, other computer manufacturers are turning out computers that are advertised proudly as "IBM compatible."59

The foregoing auspicious appraisal is further strengthened by two additional features of AUG: its multiple-user capability and its optional coordination with other office functions.

First, AUG can support up to nine users, a characteristic which makes this product cost-effective, as the cost of the equipment can be spread over the number of users, making it less expensive per user (Reliable cost figures could not be obtained at the time of this study). In an organizational context, this cost advantage represents a powerful, tangible reason for companies to adopt AUG, consequently promoting hearing- and speech-impaired persons' accessibility to the office environment. Similar cost-efficiency benefits can be accrued in the home and in an institution where there may be many hearing- and speech-impaired persons.
Second, AUG is part of the IBM Personal Computer Voice Communications Option (PCVCO), an adapter card which can support other add-on functions, such as speech recognition, voice storage, speech synthesis, telephone management, and modem emulation. Many of these functions on the PCVCO can be used by both handicapped and nonhandicapped persons, signifying a real integration of the handicapped into the computerized office environment of "today."

AUG's built-in speech technology contributes to this product's value. Its vocal output is created using synthesis-by-rule algorithms, a very contextual-sensitive method of speech synthesis. As such, it is quite responsive to the inherent nuances and ambiguities of the human language. For example, AUG will correctly pronounce the symbol "Dr." as "Doctor" or "Drive" and the symbol "St." as "Saint" or "Street" depending upon the context of the sentence in which those symbols are used. Such accuracy ensures that undue attention will not be given to the mechanics of a conversation, and, further, that the spontaneity of the conversation will be preserved. In addition, AUG permits the user to control the volume, pitch, and speed of the synthesized voice. These built-in features help simulate the variety and complexity of human vocal production, thus appealing to a user's need to
project his/her individuality in a conversation. Furthermore, such diversity in vocal output reflects an appreciation for the different needs in unique situations. For instance, if a hearing- or speech-impaired person is conveying very complex, technical information, s/he can decrease the rate of output, while, if s/he is making an emergency call, s/he may slightly increase the pitch and volume.

The speech output of AUG possesses some negative attributes, too. It lacks "gender" and "age" options (the voice simulates that of an adult male), and so, is clearly unresponsive to the female and child populations. In addition, although this synthesized voice is intelligible, it is less "human-sounding" than pre-stored speech output, a form of speech synthesis that uses an actual human's pre-recorded voice as the basis of its output.

Receiver's Equipment

As mentioned above, using AUG, hearing- and speech-impaired persons may communicate over the telephone with anyone who has a touch-tone telephone, a very widely available, inexpensive piece of equipment. This concept is liberating since it represents a further extension of
the potential audience with whom the hearing- and speech-impaired may communicate. Moreover, such a system does not require the receiver to modify his/her existing telephone equipment and incur expense in the process. s/he needs to only pick up the apparatus s/he normally uses to conduct such telephone communication.

Though admittedly a relatively small market, people who own rotary/pulse generating telephones are effectively excluded from participating in this AUG-initiated communication. This limitation, no matter how small, represents a constraint on the number of persons with whom the hearing- and speech-impaired may communicate.

Sender Transmission Process

Hearing- and speech-impaired persons input messages through a computer keyboard, a conventional piece of equipment that most people can manipulate facilely. Many of the functions desired by the user require minimal keystrokes -- an ease of use factor. For example, dialing someone who is in your AUG telephone directory can be accomplished with one simple keystroke. One negative aspect of typewritten input is the fact that it is ordinarily slower than our normal speech rate.
Consequently, the rhythm and consistency of the conversation may be distorted. It must be mentioned, though, that it is not impossible for a person to acquire, through practice and routine use, a typewritten input rate that rivals the normal human speech rate. A testimony to this are the visually-impaired persons who can "read" synthesized text output with exceptional rapidity. It seems very probable that hearing- and speech-impaired persons would be sufficiently motivated to acquire the necessary skill described to use AUG optimally.

Our desire to make contact with others in personal and professional contexts is paramount. AUG is equipped with an "introductory/find" message which ensures that the intended receiver is reached, at least with a message.

As can be discerned from much of the foregoing analysis, the AUG system attempts to as much as possible simulate "normal" telephone conversation. Consistent with this philosophy, AUG allows a hearing-or speech-impaired person to transmit vocalized verbal stimuli, the customary mode of telephone conversation (i.e., they are carried out vocally). As noted earlier, however, the AUG-produced vocal output is not quite commensurate with human-produced speech.
Gender Reception Process

Although the transmission process is essentially similar for both hearing- and speech-impaired persons, the reception process differs among these two groups. Hearing-impaired persons recognize an incoming call visually, in the form of a "flashing" computer screen, while speech-impaired persons can identify the customary "ringing" and receive ensuing messages auditorily. Because hearing-impaired persons require that the person communicating with them do so by creating messages from a touch-tone telephone keypad -- a process that is slower than vocally-created messages -- they may receive messages slower and more sporadically than the usual pace of telephone conversations. Speech-impaired persons, on the other hand, do not demand such a new process from the other person, and thus should receive messages with little or no irregularity.

Because the user cannot always be near his/her telephone (in this case, AUG), many potential messages could be lost. AUG is furnished with an auto answer function, though, which receives messages when the hearing- or speech-impaired person is unable to do so. The benefits inherent in such a function are vitiated to a degree by the general aversion to answering machine services.
Because the telephone over which the hearing- or speech-impaired receives calls can also be used by other hearing persons (this is especially the case in an office environment), it is quite possible that the impaired individual may need to join a conversation that was initially received in a "non-AUG" manner. AUG provides a "JOIN" function which grants the hearing- or speech-impaired person the ability to evoke AUG status at any point in a conversation, thus s/he is not excluded from general correspondence. This represents another example of how AUG integrates the impaired person with the "status quo," especially in an organizational context.

Receiver Reception Process

The hearing person's initial reception process is essentially no different than what s/he is accustomed to -- s/he picks up the telephone receiver (no special equipment required) and vocal, verbal stimuli is received (as mentioned earlier, the synthesized voice is not perfect, but intelligible). This point is important because the existence of fewer special adjustments tends to lessen the probability that an AUG-initiated conversation will be resisted.
While "static" during a telephone call can be a relatively normal occurrence, AUG-conducted conversations possess another form of interference: minor "clicking" noises, which emanate from the hearing- or speech-impaired person's typewritten input. The significance of this is that as more interference impinges on a communication process, there is a greater likelihood that messages will be misinterpreted or "missed" altogether.

The rate at which a hearing person receives messages may be slower than usual, because the rate of typewritten input is ordinarily slower than the rate of human speech. The existence of many delays and pauses can clearly be a substantial form of interference for the hearing individual. Depending upon the sender's level of typewritten proficiency, the degree of interference will differ. As discussed, some hearing- and speech-impaired individuals may acquire a level of input rate that approximates the normal speaking rate, thus attenuating the noise state.

Receiver Transmission Process

The hearing person's transmission process will differ depending upon the person with whom s/he is communicating: a hearing- or speech- impaired person. If s/he is
communicating over the telephone with a speech-impaired person, the hearing person transmits messages vocally as usual, in his/her normal tone, pitch, and volume. So no real transmission adjustment is required of the hearing person when conversing with a speech-impaired person. If s/he is communicating with a hearing-impaired person, though, the hearing individual must transmit his/her messages through his/her telephone keypad, a completely new process of sending messages and one that has attendant negative aspects, which are examined below.

First, such a method of transmission is error-inherent. The process of pressing the buttons on a telephone keypad can be tactilely tedious, consequently, pressing an "incorrect" button is highly possible. Mistakes are further engendered by the rule-laden nature of this method. Some of these rules follow:

To end a word, press *; to end a sentence, press **, to end a message, press ***; to input a number like 32.75, press #, then the numbers to the left of the decimal, then *, followed by #*, then press #, followed by the numbers to the right of the decimal, and finally *.*

Over time these rules will probably become assimilated by the user, but mistakes are still likely to occur as they do in most rule-burdened systems.
Errors are also likely because of the fact that each button of the telephone contains three letters or symbols, as depicted in Table 3:

TABLE 3
AUG'S ELEMENT OF AMBIGUITY

<table>
<thead>
<tr>
<th>If hearing person presses this button</th>
<th>These letters may be indicated</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>A, B, or C</td>
</tr>
<tr>
<td>3</td>
<td>D, E, or F</td>
</tr>
<tr>
<td>4</td>
<td>G, H, or I</td>
</tr>
<tr>
<td>5</td>
<td>J, K, or L</td>
</tr>
<tr>
<td>6</td>
<td>M, N, or O</td>
</tr>
<tr>
<td>7</td>
<td>P, R, or S</td>
</tr>
<tr>
<td>8</td>
<td>T, U, or V</td>
</tr>
<tr>
<td>9</td>
<td>W, X, or Y</td>
</tr>
</tbody>
</table>

With such a system, it is quite conceivable that the buttons pressed by the hearing person could produce several possible words. For instance, if the user presses: 7, 5, 3, 2, 7, 3, *, 2, 2, 5, 5, *, two possible messages include "Please call" and "Please ball." AUG would display: "Please (ball, call)," and the speech- or hearing-impaired person would have to determine the correctly intended message. Although the correct message can often be determined from the context of the sentence and overall conversation, the ambiguity involved can slow or distort the flow of a conversation.
Second, this method of transmission fragments the conversation process, i.e., the hearing person must either send or receive messages -- never both. Yet, in ordinary telephone conversation participants are actually sending and receiving messages simultaneously, though they may not be cognizant of this. Closely related to the above point is the mechanical, almost formal nature of this method -- somehow a hearing person might become too conscious of the mechanics of conducting a conversation, compromising the spontaneity that makes telephone calls so unique.

Finally, the button-pressing method is unquestionably slower than the vocal output that a hearing person is conditioned to using in telephone conversations. Such a sluggish method of conveying messages must sap some of the enthusiasm the hearing person brings to the conversation.

The Basis of the Conversation -- AUG Word List

AUG is equipped with a "word list" which contains all the words that will be recognized and, hence, spoken during a conversation. In addition to this initial base, words special to the sender and receiver (e.g., names of family members, obscure locations, job jargon,
abbreviations) may be added by the AUG-owner. However, there will be a limit to the number of words that can be stored (specific figures on the storage limit were not available). Given that there is a storage limit for the word list, there must necessarily be a corresponding limit on the expression of shared experiences and on explanatory and descriptive power -- variety and nuance are essentially compromised to a degree. An even more fundamental shortcoming of this limited word bank is the possibility that a word used may not be recognized by AUG. Such an occurrence would stall the conversation, causing discomfiture in the participants. Moreover, it would impinge on future conversations, affecting their spontaneity and possibly even their frequency.

AUG vs. TDD

In the early 1960's Western Union donated a batch of outdated teletype machines to the deaf community for the purpose of communications over existing telephone lines. A creative young engineer, Bob Weitbrecht, developed a modem (modulator-demodulator) to convert keystrokes to Baudot codes (audible tone signals) that could be transmitted over telephone lines. This allowed the Rube
Goldberg-type teletypes to become the first useable communications systems for the deaf. The Telecommunication Technological systems for the deaf are called Telecommunication Devices for the Deaf (TTY's). The old teletypes were replaced by modern style electronic Telecommunication Devices for the Deaf (called TDD's).

However, the disbursement of these machines was slow, spotty geographically, and use never did become widespread. In 1982, the entire TDD network was estimated to consist of between 25,000 and 60,000 machines, depending on the source of the count. Either figure is woefully inadequate to serve a total hearing-impaired population of 14.7 million in the U.S. alone.62

The limited use of TDD's is traceable to several factors. First, the machines and the Baudot language of transmission are used only by the deaf community and a few service organizations with a need or desire to communicate with the deaf. TDD's are not compatible with the American Standard for Communications Information Interchange (ASCII) code used by microcomputers. This limits their effective communication to other deaf persons, and blocks communication with the hearing world. AUG, on the other
hand, links the microcomputer with the conventional touch-tone telephone (of course, microcomputers can be linked with other microcomputers, too), two pieces of technology that are used by many population groups, including the deaf and the hearing.

Second, TDD's are dedicated communication devices with no other use. AUG is used on a microcomputer, a multi-purpose technology that can be used for education, business, environmental control, and communication.

Third, the TDD's communication potential with public settings is limited. Deaf consumer groups have advocated placing TDD's in public places -- shopping centers, libraries, transportation terminals -- for use like conventional pay telephones. Although a few public TDD's have been put in places where there is a large deaf population (e.g., on the campuses of schools and colleges for the deaf), the access of deaf people to public telecommunications service remains extremely limited. AUG helps the user communicate with anyone who has a touch-tone telephone, equipment that is very common in public settings.63
Limitations to the Analysis of AUG

As mentioned earlier, because reliable cost figures for AUG could not be obtained, no cost comparisons with other equipment could be made. Such data would have helped to more completely appraise the relative value of AUG to the hearing- and speech-impaired. In addition, due to a lack of equipment, an evaluation of how AUG operates with IBM compatibles was not possible. Such an endeavor could be pursued as part of a follow-up study.

SUMMARY

The foregoing analysis indicates that a state-of-the-art electronic technology is evolving that provides potential benefits to both handicapped and nonhandicapped users. Historically, handicapped users have been furnished "special" equipment that performs "special" functions, often divorcing them from nonhandicapped users. AUG and "talking operating systems," two new products analyzed above represent new technologies that integrate these users. Using AUG, a handicapped user can communicate with an almost limitless number of people;
using a "talking operating system," this same user may access the "popular" software used by his/her nonhandicapped colleague. Furthermore, these two technologies offer real value to the nonhandicapped user. Advances in speech technology are primarily responsible for forging these product concepts that integrate users.

Of course, there are products such as wheelchairs that essentially provide utility for handicapped users only. However, such products should possess some fundamental qualities, those that promote the independence and dignity of the user. Permobil's wheelchairs, analyzed earlier, clearly personify these qualities.

Although many of the new electronic technology products discussed possess characteristics that make them mutually beneficial for both the handicapped and nonhandicapped, the production of single-purpose electronic technology for the communicatively handicapped continues to fulfill important needs, attested to by the role that the Artificial Language Laboratory at Michigan State University (a provider of specially-designed equipment for the communicatively handicapped) upholds in this industry. A few notable current single-purpose technology projects include: The Trace Center's "White
House Project," a research project devoted to adapting operating systems for the communicatively handicapped; and the Veterans Administration Medical Center's (Palo Alto, California) development of a "mechanical hand" that will communicate output to people who are both blind and deaf. A researcher at the VA Medical Center emphasizes that just as Helen Keller had communicated by feeling the finger positions of her interpreter, this state-of-the-art mechanical hand uses these same finger positions to allow deaf-blind persons to understand what is on the computer screen.

What is most consequential is that the communicatively handicapped can access the electronic technology (whether it is single-purpose or multi-purpose) that assists them in improving their quality of life. This question of access is examined closely in the next chapter.
CHAPTER 5

ANALYSIS OF THE COMMUNICATIVELY HANDICAPPED'S ACCESSIBILITY TO STATE-OF-THE-ART ELECTRONIC TECHNOLOGY

In the following chapter an analysis of the structured and intensive interviews will be presented. The major findings that emerge from the analysis converge on the issue of access, both in terms of "physical" and "informational" access to state-of-the-art electronic technology.

ACCESS I: PHYSICAL ACCESS

The majority of the research centers interviewed acknowledge that the communicatively handicapped's physical access to the electronic technology is always a challenge, but that it can be accomplished for any communicatively handicapped person, albeit with imperfections, which are addressed below.

The Trace Center believes that the major imperfection to physical accessibility today is the lack of standardization across the industry for electronic technology. The negative consequence of this state of affairs is that
there is never a guarantee that a person's input device will run with another particular communication aid on the market, at least not without expensive modification.

For the past few years, the staff of the Trace Center have coordinated an effort to develop a standard connector format to make it possible for aids and input devices from different sources to be plug-in compatible. Ideally, for example, "tab a" and "slot b" should be the same on all industry-wide equipment. If implemented, such a voluntary standard would make it more efficient for clinicians, researchers, and developers to mix and match input devices as needed.

One manufacturer of communication aids, Prentke Romich Company, has participated in this effort since its inception. In fact, last year Prentke Romich introduced two new products using the proposed compatibility standard: The Computer Entry Terminal CET-1 and the Light Talker LT-1. In addition, clinicians and evaluation centers that have a variety of input devices and communication aids are beginning to acquire adapters and/or have input devices upgraded to the proposed standard. The Trace Center is encouraged by the early progress of the standardization proposal, but emphasizes that all standardization is voluntary.
The Hugh MacMillan Medical Center (HMMC) shares Trace's view that the major limitation in the physical accessibility to electronic technology is the lack of coordination necessary to reliably connect many input devices and communication aids. Their philosophy or approach to overcoming this problem, though, is slightly different from that of the Trace Center.

The Hugh MacMillan Medical Center espouses an ideal philosophy that modification to existing equipment should be avoided whenever possible (of course, HMMC does not disapprove of modification if this is the only alternative that achieves access for a communicatively handicapped person). The HMMC philosophy is one that is essentially pitched in the future. Specifically, they are currently developing a "universal accessing system," which is proprietary at this time. The system seeks to ensure that a communicatively handicapped person, with any input device, will be able to access any microcomputer-based technology, not only the microcomputer, but any microcomputer-based technology in his/her community, such as telephones and banking machines. So HMMC's approach is much broader than that of the Trace Center, although both seek to achieve a harmonious inter-compatibility among all electronic technology.
A general outline of the system was offered by a source at the Hugh MacMillan Medical Center:

First, we are coming up with specifications that manufacturers could use in their design of future technology. I cannot be more specific here. Second, we are trying to produce a clinical research manual, which would incorporate our framework for assessing skills and matching these skills with appropriate technology.67

The "universal accessing system" is in its embryonic stage and, as mentioned earlier, researchers could not elaborate because of the private nature of this concept.

Concurrently, while trying to refine its conceptualization of a "universal accessing system," HMMC is developing an interface for I-CON, Toronto's approved educational microcomputer that has been inaccessible for the communicatively handicapped since its creation. So, HMMC is simultaneously engaging in present and future orientations -- using current knowledge to solve today's problems and pursuing new knowledge to obviate tomorrow's problems.68

The analysis of the above approaches by the Trace Center and HMMC reveals the complex and redoubtable task of achieving standardization among the many electronic technologies on the market.
Tufts-New England Medical Center purports that there may be a way to transcend the complicated connections that are used to interface the communicatively handicapped with the electronic technology. They assert that in this century the most effective interface will be the "eye gaze" method, and in the next century a "mind reading" method. The concept of eye-controlled communication interfacing is not new. For years, many researchers believed that the "eye-gaze" method, once developed, would eliminate the need for other methods. (Incidentally, the Trace Center is currently developing a long-range optical pointing system for those who cannot use conventional keyboards.) Indeed, the "eye-gaze" method does provide a powerful and direct mechanism for communication for many persons, but its application still has limitations.

For instance, many severely handicapped individuals have ocular-motor problems that prove a problem for all of the eye-controlled techniques available today. The use of glasses or other corrective lenses is very common with severely handicapped individuals, presenting a further problem for many optical techniques. In addition, many of these individuals have difficulty in holding their head still or even keeping it within a reasonable movement box,
as required by some eye-controlled communication techniques. Thus, while the "eye-gaze" method can be used effectively in some contexts, it cannot be projected as a panacea for current interface shortcomings.\textsuperscript{69}

It is intriguing to consider the possibility of using "mind-reading" as a way for the communicatively handicapped to access technology. But again, it seems probable that this method of interfacing will have some limitations, like all other methods discussed. Effective control requires a high level of predictability, and at present human brain activity, the proposed control or input "device," is very complex, capricious, and difficult to predict -- making it a relatively unreliable, inconsistent means of control. We must never discount the possibility, though, that future research would determine a way to make brain activity a dependable method of control.

The significance of this is that today there is not one "best" way of interfacing communicatively handicapped persons with electronic technology. A complex set of factors, including the specific physical abilities of the individual, such as his/her motoric, cognitive, and visual aspects, precludes the realization of one "best" method.
This state of affairs ensures the continued need for an organization like the Artificial Language Laboratory at Michigan State University in East Lansing, Michigan. The Artificial Language Laboratory, whose mission is to develop customized electronic technology that is not commercially available, seems to fulfill a very important role, given the lack of real coordination among manufacturers of commercial equipment.

Sources at the Artificial Language Laboratory claim that they first write descriptions of customized communications aids for a communicatively handicapped individual; then, if the person can afford the proposed aid, the developers at the Laboratory will produce it. The final product is usually an amalgamation of diverse electronic technologies, such as the "Brooks Communications System" that was built for a student at Michigan State University. This particular system is a wheelchair-portable, foot-operated communication system, which is made up of a Rockwell AIM-65 minicomputer, a Votrax voice synthesizer board, and three modules: an 80-position pedal, a printer and display unit, and a control and power distribution unit.
The Artificial Language Laboratory believes that adapting equipment is a reality that cannot be escaped, and, furthermore, a method that, as one source unequivocally asserts, "ensures accessibility for a particular individual." Of course, such accessibility may come at a greater financial expense to the individual.

As indicated by the foregoing exposition, the communicatively handicapped's physical access to electronic technology is manageable -- virtually any person can be interfaced with this technology. The following quote reiterates this line of thinking and, further, propounds that another form of "accessibility" must be viewed as an equally significant issue:

The most perplexing part of the problem -- that gaining the knowledge, the "know how" -- is not in any way difficult. The "difficult" parts already have been done. Apple Computer Company, Inc. and all the other computer companies have invented, marketed, and brought the microcomputer to the public. Scott Instruments, Street Electronics Corporation and organizations like them have developed the peripherals. Literally thousands of software publishers have brought their products to market. It's all sitting there, waiting to be used. The only hurdle left is getting the information about how this technology can benefit the handicapped into the hands of the public and to somehow make them understand how easy it really is to implement.
ACCESS II: INFORMATION ACCESS

The following quote, expressed by a source at Johns Hopkins Applied Physics Lab, suggests that the communicatively handicapped are relatively unaware of the potential benefits that state-of-the-art electronic technology offers for them:

You keep thinking that access is good, but you learn that many aren't aware of the technology out there, its uses, its advantages ... I don't think enough people are aware of Trace, either.\textsuperscript{72}

Making people aware of the usefulness of state-of-the-art electronic technology is indeed consequential. So how have the major research centers attempted to tackle this challenge? While it might be taken for granted that the research centers would be involved in research and development activities, the interview responses reveal that some of these centers are beginning to devote a good deal of their efforts to "information brokerage."

The Trace Center asserts that they are the "ad hoc authority" on electronic technology for the communicatively handicapped, and as such are solicited by both individuals and companies. They dutifully accept the responsibilities that accompany this elevated position -- handle a high
volume of letters and telephone calls, answer questions, and make referrals. In addition, Trace has contracts with IBM and Apple to furnish these corporations information they can use in research and development. In carrying out this particular function, Trace acts as a liaison between the communicatively handicapped seeking optimum electronic technology and the manufacturers of this technology. The degree to which Trace can accurately assess the needs of the communicatively handicapped and communicate these needs to manufacturers of electronic technology directly affects the utility and effectiveness of future developments in electronic technology.

The Artificial Language Laboratory at Michigan State University contributes to the efficient and broad information that fuels this industry. The Lab publishes Communication Outlook, a quarterly publication that boasts a world-wide circulation. Communication Outlook reviews new journal articles, provides a reader-to-reader question and answer forum, and occasionally discusses legal issues that affect the communicatively handicapped population. Furthermore, the Laboratory is a major participant on Confer, a computerized information network that functions as a powerful forum for discussion and inquiry.
among professionals and the communicatively handicapped. Most significantly, it is a means for the communicatively handicapped to share their similar frustrations, hopes, and successes. Today, "Confer" links approximately eighty members. 74

The Hugh MacMillan Medical Center recognizes "information sharing" as an integral part of their mission. HMMC administers "Confer," the computerized information network described above. The Center also maintains a central mailing location for ISAAC (The International Society for Augmentative and Alternative Communication), an organization whose sole focus is the advancement of the field of Augmentative and Alternative Communication Techniques and Aids. Finally, the Hugh MacMillan Medical Center takes its greatest pride in the fact that it was instrumental in setting up the "Assistive Devices Program" in Ontario, which is funded by the Canadian government. Some of the notable features of this program are: the government provides 75% of the cost for a communication aid; and the government supports 100% of cost for "prescriptive experts," professionals who evaluate and recommend appropriate technology for the communicatively handicapped. 75
The "Assistive Devices Program" is but one example of Canada's genuine commitment to equip the communicatively handicapped with appropriate technology. Canada also boasts a unique organization, the Canadian Rehabilitation Council for the Disabled (CRCD), which is an association of non-profit organizations at national, provincial, and regional levels whose objectives and activities are directed toward ensuring the provision of comprehensive rehabilitation services for physically disabled adults and children. Jean Caine, president of CRCD, describes the influence of this organization:

CRCD is an inimitable, world-envied federation, which draws its strength from eighty member organizations and agencies across the country. This gives us a unique ability to speak and act nationally with enormous strength, passion and power.76

CRCD's information sharing activities, discussed below, are diverse and far-reaching: the sponsoring of committees and conferences, the development of publications, and the operation of TASH, Technical Aids and Systems for the Handicapped, Inc.

The most notable committees sponsored by CRCD include the National Professional Associations Committee (NPAC) and the Canadian Committee on Communication Aids for the
Speech-Impaired (CCCASI). NPAC supports an interdisciplinary forum for professionals in the field of rehabilitation to share innovative programs, services, scientific data and advances in technology. CCCASI seeks to collect information on equipment, projects and programs in Canada, and in so doing establishes a link among professionals working in this specialized area.

An important aspect of CRCD's information service is its publications. CRCD's quarterly magazine Rehabilitation Digest is the only periodical in Canada dealing solely with matters relating to rehabilitation of handicapped people. CRCD also publishes a quarterly newsletter, ACCESS, that focuses on the activities of CRCD and its member organizations. Recently, CRCD published "Centres de readaptation pour les personnes handicapées physiques au Canada," the first French edition of their popular information directory containing data on rehabilitation treatment centers across Canada.

For the past seven years, CRCD, in cooperation with the National Research Council of Canada, has been responsible for the operation of "Technical Aids and Systems for the Handicapped, Inc." (TASH), a non-profit company which markets technical aids and systems that are not readily available to disabled consumers.
CRCD believes that their greatest accomplishment to date, however, is its development of a "National Information Resource Centre on Rehabilitation and Disability," a broad-based bank of data relating to the needs of the handicapped. The data in the "Resource Centre" is accessed through written requests, telephone inquiries, and at exhibits where resource material is distributed. Information requests in 1985 were approximately four times greater than those recorded in 1982, attesting to the handicapped's thirst for relevant information.

Finally, CRCD is currently working with IBM Canada on the development of a computerized information program. A pilot project is planned for the immediate future with the ultimate goal being an electronic network across Canada, linking CRCD members in a comprehensive information service "that will be a model for the rest of the world."77

Training: A Manifestation of Information Sharing

The one context in which the research centers invest the smallest portion of their efforts is training (the assistance of the communicatively handicapped in
educational and/or vocational endeavors). While admittedly training in general is not the major focus of the centers' missions, it is interesting to note the diversity of roles it assumes in each "camp." For instance, Tufts\textsuperscript{78} and the Artificial Language Laboratory\textsuperscript{79} devote practically no discernable resources to training; the Trace Center\textsuperscript{80} consigns this function to its sister organization at the University of Wisconsin - Madison; and The Applied Physics Lab\textsuperscript{81} at Johns Hopkins appropriates ten-percent of its budget to training special education teachers and students in the use of new technology; but only the Hugh MacMillan Medical Center\textsuperscript{82} of Toronto, Canada, seems to possess the most formal and elaborate training endeavor, which commands a strong thirty-percent of their overall effort. However, IBM's "Project to Train the Disabled"\textsuperscript{83} emerges as the most comprehensive training program overall. Training programs are really a manifestation of the information brokerage activity discussed above, as they attempt to make the communicatively handicapped aware of the roles that electronic technology can play in their personal and, especially, professional lives.
The Hugh MacMillan Medical Center uses a "mediator model" as the basis of its training programs. This model clearly states that a patient (communicatively handicapped person) will be accepted only if the community in which the patient resides agrees to become part of the training process during and especially after the patient leaves the program. This provision exists so that HMMC's efforts will be carried on when the patient eventually returns to the community.

The most notable of HMMC's training programs include its Computer Facilitator Training Program, which is essentially a "hands-on" computer education workshop for the communicatively handicapped individual, his/her family and his/her teachers, and its Outreach Program, which involves "going out" to the Toronto handicapped community six times a year to meet the needs of this community.  

IBM's Project to Train the Disabled: Objective and History

In the context of training, one program clearly emerges as innovative and far-reaching: IBM Corporation's Project to Train the Disabled: The major objective of this
bellwether project is to establish, under the sponsorship of state rehabilitation agencies, self-sustaining programs to train and place severely, physically disabled individuals as computer programmers.

Project to Train the Disabled began in 1972 when IBM joined with the Rehabilitation Services Administration (RSA) and Vocational Rehabilitation of Virginia to design, develop and demonstrate for possible replication in other states a new joint training and placement project to benefit the most severely disabled people, who were envisaged as primarily wheelchair-bound -- quadriplegic, paraplegic, cerebral palsied, and advanced arthritic. With time and subsequent replication, however, the project has served a broader spectrum of disabilities, including deafness and blindness.

To date IBM and RSA have helped to establish twenty-nine computer programmer training programs which span from Maine to California. All of the programs have a common goal: to train the severely disabled persons as computer programmers and to place them in competitive and challenging programming positions. Since its inception, Project to Train the Disabled has achieved a placement rate which consistently exceeds 85%.
IBM developed a model for program development and maintenance which is based on active and continuing cooperation among the business sector, the vocational rehabilitation agency, and the education and training entities in each locality. Each of these community groups (business, rehabilitation, and training) performs a particular function in these programs.

The model is not rigid and the specific roles assumed by each group in any particular program may vary, although historically the participants have assumed the following responsibilities:

First, the business involvement in each of these programs is frequent, active and directive. Each training program is designed specifically to meet the needs of the local business community, and the needs are defined by that business community operating as a Business Advisory Council (BAC) to the program. The BAC specifies prerequisites, identifies training objectives, helps design the curriculum, evaluates student and program progress on a scheduled basis, and assists directly in the placement of successful graduates. In this way, the BAC assures itself of the competence of the graduating programmers.
Second, the local rehabilitation agency is responsible for the provision of support services to the programs and to the students. Such services include housing, driver training, special devices and aids, physical and emotional therapy, and consultative services to business with regard to facilities modification and sensitivity training.

Finally, the training agency, working closely with the BAC, is able to provide occupationally-directed training which results in graduates who are almost immediately productive on the job. Many of the programs use an internship which puts the student at a business site for four to eight weeks in a working environment, thus preparing him/her for his/her coming employment. The training agents for these programs range from universities to independent rehabilitation centers, and the evaluative process employed by the BAC ensures training competence. So highly thought of is the training that several of the universities and colleges have begun to award college credit to the successful graduates.

**IBM's Role**

IBM acts as the initiator and catalyst, molding and developing the program from community resources. Its objective is to establish local programs, under local
leadership, directed toward local needs. In this consulting role the IBM team provides the experience and knowledge to bring the fledgling programs to maturity, but does not exercise direct control over its eventual administration.

The IBM "Project to Train the Disabled" is a regenerative program, each year establishing new locally controlled programs dedicated to a single objective and based on techniques developed in previous programs. The programs themselves have formed a national Association of Rehabilitation Programs in Data Processing (ARPDP) to foster communication among existing programs and between existing and new programs. 85

SUMMARY

The communicatively handicapped's accessibility to electronic technology has traditionally been a major concern in this field of research. The foregoing analysis has determined, though, that this question of access can no longer be conceptualized solely in terms of the physical dimension (i.e., the "fit" between the
communicatively handicapped person and the technology s/he operates). Rather, it must also include an informational dimension -- the creation of awareness among the communicatively handicapped and professionals in this field about the available state-of-the-art electronic technology. It is clear that the major research centers are employing resources to address both these dimensions in very constructive ways.
CHAPTER 6

SUMMARY AND CONCLUSIONS

This final chapter seeks to furnish an appreciation of the current trends and issues that characterize the development and provision of state-of-the-art electronic technology for the communicatively handicapped. In addition, limitations of this research are acknowledged and implications for future research are addressed.

THE STUDY

This work sought to discern the "current" trend (defined as the period ending February 1986) that exists in the development and provision of state-of-the-art electronic technology for the communicatively handicapped, and, furthermore, to determine this population's accessibility to the technology. It was desired that the thesis be current and proximate, thus increasing its utility for the communicatively handicapped and interested parties today.
In the early part of 1985 a literature review was conducted to learn the major issues and trends that characterized this field of research. The review did provide a preliminary profile of these issues and trends, however, it could only serve as a "jumping-off" point, since information from journal articles was not relatively "current." The "current" nature of the information in this thesis was primarily achieved through other unique modes of data collection, which are discussed below.

In the summer of 1985 the author was given an opportunity to become a Research and Development Assistant at IBM Corporation, where a great deal of the "cutting edge" was investigated. The author participated on a number of diverse R&D projects and, in the process, was able to informally interview key research decision-makers. Both these methods of data collection, used intensively over the three-month summer period and periodically throughout the remainder of the year, yielded a breadth of information regarding state-of-the-art electronic technology.

In February of 1986 the author conducted structured telephone interviews with five major research centers working in this field. While the informal interviews
conducted at IBM produced a relatively broad appreciation of electronic technology, these "formal" telephone interviews furnished much more focused, specific information. Both modes of collection, though, contributed favorably to the immediate, "current" character of this work.

THE STATE OF THE "STATE-OF-THE-ART"

The interviews conducted with the research centers reveal a richness and diversity in the research, development, and marketing of state-of-the-art electronic technology for the communicatively handicapped. In all this heterogeneity one palpable pattern, even philosophy, can be discerned: these product concepts are encouraging the integration of the communicatively handicapped with the rest of society.

The emergence of multi-sensory technology, like speech synthesis and speech recognition, specifically its appeal to both handicapped and nonhandicapped populations, is greatly contributing to this integration process. The nonhandicapped population covets the productivity and
efficiency that this technology furnishes. While the handicapped population surely profits from these qualities, they benefit to an even greater degree from the fundamental need this technology serves -- granting them access to the world. Because it embodies attributes that are desirable to both populations, this multi-sensory technology is a unifying technology.

One of the major research projects at the Johns Hopkins Applied Physics Lab involves the incorporation of speech synthesis, along with other forms of stimuli, into a multi-sensory authoring system. Authoring systems are types of software that allow a teacher, without any programming knowledge, to create courseware. Using an Apple computer along with an Echo speech synthesizer, Johns Hopkins Applied Physics Lab has created truly "interactive" courseware that includes positive reinforcements issued both graphically and vocally. What is significant about this authoring system is not only its simplicity and ease of use, but also its incorporation of multi-sensorial stimuli to benefit users, both handicapped and nonhandicapped. 86
The people who were the subjects of the author's research as a Research and Development Assistant at IBM usually lacked the functioning of at least one sense. Despite their disabilities, these individuals compensated quite well by developing to a greater degree the senses they did have. However, most of today's computer programs seem to be easily accessible only to the nonhandicapped.

From the author's interaction with the communicatively handicapped, special education teachers, and co-researchers, a distinct paradigm began to emerge: that computer programs, especially as they pertain to education, should have multi-sensorial accessibility. This means that each individual may experience the program through as many senses as s/he has or chooses to use. For the motorically-, speech-, and visually-handicapped, the one or more functioning senses they possess would be all that's necessary to access the promising world of computers.

Speech synthesis, speech recognition, and other sensory technologies are the keys that can hasten the acceptance of this paradigm. These technologies can no longer be perceived simply as optional accessories; rather, they must become standard, integral components of
the computer so the benefits of computing can be reaped by all. With the cost of speech synthesis and speech recognition rapidly declining, this proposal becomes even more justifiable. If manufacturers of general electronic technology (technology not specifically produced for the communicatively handicapped) adopt this proposal, the assimilation of the handicapped with the nonhandicapped would be promoted; moreover, the cost of equipment to the handicapped would probably be reduced.

Just imagine that one has at his/her disposal: voice input, voice output, tactile output, visual output, and other modes of computer communication. Computing becomes a multi-sensorial process -- stimulating to those who have all their senses; essential to those who don't.

Manufacturers of general electronic technology are beginning to incorporate product concepts that, although not specifically intended to benefit the handicapped population, are "coincidentally" achieving this result. The production of portable computers, for instance, serves the general nonhandicapped purchaser in many ways, its transportability (size and weight) being the major way. Many communicatively handicapped persons are nonambulatory, and, thus, require a communication aid that
can be carried wherever they go. The portable computer, as discussed in Chapter 4, satisfies this need nicely. Its transportability, then, is quite congruent with the needs of both populations. In addition, the IBM Voice Communications Option, which comprises AUG and other packages, is not solely designed for either the communicatively handicapped or the nonhandicapped populations, yet it provides tangible benefits to both. This is a supreme example of how a new product can unify, not splinter, these user groups. It also sends a clear message that the handicapped user is a truly valuable resource, especially in the organizational context, where a product like AUG is most likely to be used.

It must be acknowledged that, generally, products which serve a wide variety of persons will not always be tailored precisely to the needs of some people. This is the case for the AUG and "talking operating systems" products. AUG, for instance, may require one or more persons in a telephone conversation to carry out this process in an unconventional manner (e.g., requiring the hearing individual to transmit his/her messages through the telephone keypad rather than vocally). Also, the "talking operating systems" may "voice" an entire page
when only one line was desired to be spoken. Despite these shortcomings, these two products help the communicatively handicapped user to integrate much further with the status quo (with "talking operating systems," they can use "popular" software unmodified; with AUG, they can reach a larger potential audience than was possible with a TDD), especially in organizational environments.

A product that does not serve a particular utility for the nonhandicapped, like the wheelchair, should nevertheless be endowed with characteristics that promote the autonomy of the communicatively handicapped. Permobil's wheelchairs, which equip the user with mobility, communication access, and environmental control, embody this viewpoint. The Permobil user, by virtue of the technology at his/her command, achieves greater independence, which, in turn, effectuates the integration process.

The landscape of state-of-the-art electronic technology for the communicatively handicapped seems to be assuming a distinct hue: new product concepts are beginning to incorporate technology that accommodates the needs of both handicapped and nonhandicapped users harmoniously. An example of this concept is voice
recognition, a mode of input that can be used effectively by both user groups. These new product concepts foster the integration of the communicatively handicapped with the rest of society. However, there are other "hues" that represent another important philosophy: some communicatively handicapped persons are better satisfied by special-purpose technology. So it is vital that the development of this technology continues, too.

ACCESS: A BROADER DEFINITION EVOLVING

The initial literature search suggested that a communicatively handicapped person's physical access to electronic technology was the major concern of this industry, however, subsequent interviews with research centers indicate that, although physical access is an important challenge, it is a relatively tractable challenge. Moreover, the responses of these research centers propound that "information access" -- the process of making interested parties aware of the available electronic technology with the goal of fitting the communicatively handicapped with the most appropriate technology -- should assume an equally significant role in their research and development frameworks. In essence,
Furthermore, it is purported that more efficient information-sharing among these concerned parties may obviate other physical accessibility problems similar to those the communicatively handicapped experience today.

Gregg Vanderheiden, Director of the Trace Center, underscores the significance of two points: (1) technology must be based upon the needs of the communicatively handicapped, and (2) developers, manufacturers, and clinicians in this industry must work together to ensure the satisfaction of these needs:

An understanding of the techniques that are not commercially available is important if clinicians are to begin to direct the efforts of developers and manufacturers based upon clinical needs rather than having to rely on the aids that become available from the developers/manufacturers. This is especially important at this time, when manufacturers are seeking cooperative efforts with clinicians in the development and refinement of new aids and techniques, and when the advent of microcomputers is allowing clinicians and small research and development groups to develop and implement new and innovative augmentative communication systems.87

Assuredly, the communicatively handicapped must be conceived as the sine qua non of this industry. Their needs justify the very existence of the research centers, manufacturers, and clinicians who work in this industry.
Thus, a formal means of communicating these needs should exist. If, for instance, a user is dissatisfied with his/her control device because it is causing chafing, fatiguing, or other problems s/he should be able to communicate this to research centers and manufacturers, who can, in turn, use this information to improve their products. The "Confer" information network discussed earlier achieves this goal, but for a paucity of individuals -- its membership numbers only eighty.

The collaboration which Vanderheiden exhorts is beginning to occur today. The Trace Center shares vital information about the communicatively handicapped with Apple and IBM so that future research and development will originate from and reflect the needs of this population. The Hugh MacMillan Medical Center's research and development is almost entirely supported by IBM. This particular alliance represents an attempt to shorten the gap between conceptualization of a product idea and its eventual creation, the entire process being referenced against the needs of the communicatively handicapped. These partnerships should accelerate the progress of new developments and, further, enhance the potential fecundity of future developments.
These cooperative efforts must also involve other relevant entities, those that may not be specifically part of this industry. The Hugh MacMillan Medical Center emphasizes that their approach (especially in regard to the "universal accessing system") is multi-disciplinary -- absorbing input from engineers, communicologists, speech pathologists, and other specialties. Such a collaboration seeks to produce a comprehensive corpus of knowledge (in regard to the communicatively handicapped) upon which researchers can base evaluations of the individual's needs, and subsequently, satisfy those needs.

Research on speech technology, for instance, the major state-of-the-art electronic technology discussed earlier, is clearly a multi-disciplinary endeavor, involving aspects of phonetics, linguistics, artificial intelligence, electrical engineering, communication, and computer science. Consequently, regular input from these disciplines is necessary to provide a coherent appreciation of speech technology.

Limitation to the Cooperative Efforts

The professional community of a technology (the research centers, manufacturers, clinicians) is a system proper, not an aggregate of loners. This systemicity is
ensured by professional societies such as ISAAC and publications like COMMUNICATION OUTLOOK. However, this technological community is not completely "open" because patents (note the secrecy of the "universal accessing system") limit the circulation of technological knowledge. Technology is a merchandise -- patents and secrets can be had at a price.89

AN INNOVATIVE PARTNERSHIP

The advances in electronic technology for the communicatively handicapped are varied and potentially life-altering. Keeping pace with new developments, which seem to be growing geometrically, represents a continued major challenge for the research centers and other concerned organizations. Today some unique, innovative information-sharing programs exist, as detailed earlier, however their relative numbers and distribution are spotty. CRCD's pilot project with IBM Canada on the development of a computerized information network symbolizes the type of partnership needed among researchers, manufacturers, clinicians, and the
communicatively handicapped. If such an effort can eventually become worldwide in scope, we could be virtually assured that "there will never be another intellect, trapped in a body, unable to communicate."^{90}

LIMITATIONS OF THIS RESEARCH

This thesis obtained information primarily from the major research centers (described in Chapter 3) to appraise the current trends in state-of-the-art electronic technology for the communicatively handicapped. In using this finite number of sources the thesis necessarily could not incorporate information from other sources whose research and development might be significant. Despite this limitation, it was assumed that the R&D activities of the major research centers used as primary sources in this thesis provide a broad, accurate representation of this dynamic field.

FUTURE RESEARCH

An area of study such as state-of-the-art electronic technology for the communicatively handicapped is truly prolific, generating a wide array of issues and concerns,
often at a frenetic pace. The foregoing thesis necessarily could comprehend but a portion of this fertile realm of study, thus much remains to be explored.

Primarily, the exploration of the "state-of-the-art" electronic technology for the communicatively handicapped begun in this thesis should be continued so that a sense of continuity is achieved, and, furthermore, change can be appraised. One possible question to be answered is: To what degree has the product concept discussed in Chapter 4 evolved over time? Such an endeavor would contribute favorably to the information accessibility needed in this industry.

One state-of-the-art concept that should receive careful scrutiny is Hugh MacMillan Medical Center's "universal accessing system." In its rudimentary stages at this time, this universal accessing system should undergo dramatic evolution and could eventually alter the very nature of the industry. A concept of such magnitude should certainly be examined throughout its life cycle.

Because AUG, the state-of-the-art telecommunication product analyzed earlier, has only recently been distributed, this thesis could not include an assessment of its actual usage among hearing- and speech-impaired
users, a much more revealing barometer of AUG's value. It is strongly recommended, then, that such a proposed assessment be conducted among this population to determine the product's efficacy.

Finally, the partnership concept discussed in Chapter 5 was affirmed as tantamount to the provision of effective electronic technology for the communicatively handicapped. As such, this concept should be evaluated, especially the communication and sharing/networking patterns among research centers, manufacturers, clinicians, and the communicatively handicapped.


12Ibid, p. 31.


16George Russell, "The Twilight of Earth."


20Dahmke, p. 6.


24Marsh, p. 595.


32Vanderheiden, p. 142.
33 A. I. duPont Institute, p. 4.

34 Childress, "Rehabilitation Engineering," p. 64.


38 Yin, p. 85.


40 Yin, p. 83.


42 Yin, p. 137.

43 Yin, p. 38.

44 Yin, p. 92.

45 Yin, p. 97.


50 Steve Blosser, Artificial Language Laboratory at Michigan State University, private telephone interview held March 4, 1986.

51 Patrick Demasco, Tufts-New England Medical Center, private telephone interview held March 3, 1986.

52 Dale Bengston, The Trace Center, private telephone interview held February 27, 1986.

53 Blosser, 1986.


55 Lazzaro, p. 55.


59 McWilliams, p. 136.


61 Ibid.


64 Bengston, 1986.


68 Ibid.
69 Demasco, 1986.

70 Blosser, 1986.

71 Hagen, p. 64.

72 William Buchanan, Johns Hopkins Applied Physics Lab, private telephone interview held March 5, 1986.

73 Bengston, 1986.

74 Everyl Yankee, Artificial Language Laboratory at Michigan State University, private telephone interview held March 4, 1986.

75 Parnes, 1986.

76 Canadian Rehabilitation Council for the Disabled, Annual Report, CRCD: A Broadly Based Community of Organizations Having a Deep Concern with and Involvement in the Rehabilitation and Environment of All Physically Disabled People, 1984 - 85, p. 3.

77 Ibid, pp. 3 - 7.

78 Demasco, 1986.

79 Blosser, 1986.

80 Bengston, 1986.

81 Buchanan, 1986.
82 Parnes, 1986.


84 Parnes, 1986.

85 IBM, Federal Systems Division, Computer Programmer Training.

86 Buchanan, 1986.


88 Parnes, 1986.


90 Hagen, p. 64.


APPENDIX A

ORGANIZATION:

Interviewee:

Position:

INTERVIEWER: May I speak with the director of state-of-the-art electronic technology for the communicatively handicapped?

Representative of Organization:

INTERVIEWER: Hello, my name is Bob Kelly. I am currently writing my graduate thesis, which focuses on state-of-the-art electronic technology for the communicatively handicapped (a person who, without the assistance of other persons or machines, cannot share meaning with others because of an inability to transmit verbal or nonverbal symbols). Do you clearly understand the focus of my thesis?

Interviewee:
Interviewer: The success of this work depends on procuring information from experts in this field like (Organization). I am conducting a short survey to gather this important information. The entire survey takes ten to fifteen minutes. Would you take some time to discuss your work with me?

Interviewee:

Interviewer: First, are you currently devoting any efforts to state-of-the-art electronic technology for the communicatively handicapped?

Interviewee:

Interviewer: I am interested in learning about this state-of-the-art electronic technology within four contexts: research (the conceptualization of problems and creation of ideas to address those problems), development (the design and testing of a physical product), applications (the search for new uses of state-of-the-art electronic technology), and training (the assistance of the communicatively handicapped in educational and/or vocational
endeavors). Approximately what percentage of your total effort is devoted to each context?

Interviewee:

Interviewer: Please elaborate on your efforts within each context.

Interviewee:

Interviewer: Other than the contexts mentioned, are there any other areas in which you find yourself working? If so, please elaborate.

Interviewee:

Interviewer: What is your appraisal of the communicatively handicapped population's accessibility to the state-of-the-art electronic technology that we have been discussing?

Interviewee:
Interviewer: Finally, to what degree have you specifically addressed this issue?

Interviewee: