DOCUMENT RESUME

ED 043 171 | 40 | EC 030 060

AUTHOR	Kafafian, Haig
TITLE	Study of Man-Machine Communications Systems for the Handicapped. C/R/I Second Report, Volume I.
INSTITUTION	Cybernetics Research Inst., Inc., Washington, D.C.
SPONS AGENCY	Bureau of Education for the Handicapped (DHEW/OE), Washington, D.C.
BUREAU NO	BR-18-2003
PUB DATE	Feb 70
GRANT	OEG-2-7-070533-4237
NOTE	151p.
AVAILABLE FROM	Librarian, Cybernetics Research Institute, 2233 Wisconsin Avenue, N. W., Washington, D.C. 20007 ($5.00)
EDRS PRICE	EDRS Price MF-$0.75 HC-$7.65
DESCRIPTORS	*Communication Skills, *Cybernetics, Demonstration Programs, *Exceptional Child Research, Handicapped Children, Instructional Materials, *Man Machine Systems, Raised Line Drawings, Sensory Aids, Technological Advancement, Telephone Communication Systems, Typewriting
IDENTIFIERS	CYBERCOM, HAIBRL

ABSTRACT

Reported are studies of man-machine communications systems and instructional procedures for facilitating the education of the handicapped. (The studies are a continuation of the program covered in C/R/I's preceding Interim Report.) To enhance the capability of the severely handicapped to communicate and thereby to develop intellectually, aspects of the study of this CYBERCOM family of man-machine systems include developing tests to observe and measure their effectiveness, studying man-machine interfaces, developing and testing instructional materials for teaching the use of the systems to the handicapped, demonstrating the systems to educators, and disseminating information for use in school systems. Specific topics covered include research and training programs with handicapped children, using bilateral-input interfaces for producing written communications; varied interfaces and transfer codes; telephone communications for the deaf or speech impaired; HAIBRL, a two-dot tactile system for reading and writing; sensory aids for the blind, and other collateral studies. Conclusions, recommendations, and future plans are detailed. Appendixes include descriptions of trainig, instructional materials and techniques, handwriting and typing samples, case studies, and other related items. (KW)

C/R/I

C/R/I Second Report

Project No. 18-2003
Grant No. OEG2-7-070533-4237

STUDY OF MAN-MACHINE COMMUNICATIONS SYSTEMS FOR THE HANDICAPPED

VOLUMES I and II

HAIG KAFAFIAN

CYBERNETICS RESEARCH INSTITUTE
2233 WISCONSIN AVENUE, N.W.
WASHINGTON, D. C. 20007

February 19, 1970

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF EDUCATION
BUREAU OF EDUCATION FOR THE HANDICAPPED

"What has to be done, has to be done by government and people together or it will not be done at all. . . . To match the magnitude of our tasks, we need the energies of our people—enlisted not only in grand enterprises, but more importantly in those small, splendid efforts that make headlines in the neighborhood newspaper. . . . With these, we can build a great cathedral of the spirit—each of us raising it one stone at a time, as he reaches out to his neighbor, helping, caring, doing."

—President Richard M. Nixon

Library of Congress Catalog Card Number 70-123385
Printed in the United States of America

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C/R/I

C/R/I Second Report

Project No. 18-2003
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STUDY OF MAN-MACHINE COMMUNICATIONS SYSTEMS FOR THE HANDICAPPED

VOLUME I

HAIG KAFAFIAN

CYBERNETICS RESEARCH INSTITUTE
Washington, D. C.

The research reported herein was performed pursuant to a grant with the OFFICE OF EDUCATION, U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE. Grantees undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official OFFICE OF EDUCATION position or policy.

February 19, 1970

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF EDUCATION
BUREAU OF EDUCATION FOR THE HANDICAPPED

C/R/I

CYBERNETICS RESEARCH INSTITUTE, INC.

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February 19, 1970

United States Office of Education,
Bureau of Education for the Handicapped,
Board of Trustees and Cybernetics Advisory
Council, C/R/I

Dear Ladies and Gentlemen:

It is a privilege to present the C/R/I Second Report, Volumes I and II of "Study of Man-Machine Communications Systems for the Handicapped," prepared at the request of the Bureau of Education for the Handicapped, United States Office of Education, Department of Health, Education, and Welfare, Project No. 18-2003.

In accordance with the mandate of the Bureau of Education for the Handicapped, C/R/I has directed its efforts across a broad spectrum of educational systems, particularly from the cyberneticist's and special educator's coign of vantage. Our major concern is to study the feasibility of employing appropriate innovations that are matched to the child-controller, in environments extending from classrooms and multimedia centers to homes and work areas.

Achievements with the learning-disabled are being demonstrated at field stations throughout the Nation with man-machine systems under study. More recently, severely handicapped children at the D. T. Watson Home for Crippled Children in Leetsdale, Pennsylvania, who heretofore could not effectively write, type or verbally communicate, dramatically demonstrated their ability to communicate with Cybertype$_{TM}$ within one month of training.

Benefits of C/R/I's efforts are also being demonstrated in the development of related diagnostic-prescriptive techniques, implementation of innovative man-machine systems, and associated instructional materials with a programmatic approach to the education and training of handicapped children.

As principal investigator of this study, I am grateful for your support, as I am to C/R/I's sponsors at the Bureau of Education for the Handicapped, and I express appreciation for assistance and guidance, without which this program would not be successful.

Respectfully yours,

CYBERNETICS RESEARCH INSTITUTE

Haig Kafafian

HK/rg

Haig Kafafian
President and Director of Research

A Nonprofit Organization

PREFACE

This report on studies of man-machine communications systems for the handicapped covers the period August 20, 1968 to February 19, 1970. The program was conducted by members of Cybernetics Research Institute (C/R/I), with major sponsorship by the U.S. Office of Education, Bureau of Education for the Handicapped, and partial support by Cybernetics Research Institute, Inc., and other benefactors.

The studies described in this, the C/R/I Second Report, are a continuation of the program covered in C/R/I's preceding Interim Report, entitled *Study of Man-Machine Communications Systems for the Handicapped* (Kafafian, August 19, 1968), under Project No. 7-0533, Grant No. OEG2-7-070533-4237, for the Bureau of Education for the Handicapped, Office of Education, Department of Health, Education, and Welfare.

> "Educators today have the responsibility of embracing those applications of technology which are viable, and not ephemeral—conceptually or operationally. It is their duty to upgrade the quality of our Nation's educational system.
>
> "Your goals, as engineers, must be structured to support this philosophy as related intimately to that objective. Yours is the mandate, the obligation—even more so, the demand—to work together with general and special educators. Let us advance our children's knowledge with the finest instructional technology and educational management, along with appropriate equipment that will not end up in corners of the classroom as mere impressive or depressive decorations.
>
> "It is desiderate, now, that truly useful curricula, instructional materials, and automata be more firmly embodied into educational systems, in support of the most important element of this cybernetic environment: the teacher, to whom all have entrusted the Nation's most precious resource, our children."
>
> —Kafafian. Excerpt from a paper "Man-Machine Systems for Aiding the Learning-Disabled," for The Institute of Electrical and Electronics Engineers (IEEE) 1970 International Convention, New York, N.Y. (Other boxed quotations which follow, unless otherwise noted, are from the same paper.)

Responsible and clear thinking national leaders have long recognized that a society has the moral duty to care for its handicapped individuals, be they physically or intellectually disabled. The recognition of this duty can be traced from antiquity as evidenced by the following account:[1] "During the pontificate of St. Nerses the Great, descendant of St. Gregory the Illuminator and Katholikos of Armenia from 353 to 373 A.D., a vast network of hospices, hospitals, and schools dotted the landscape of Armenia. Immediately on accession, Katholikos St. Nerses

> '. . . directed that in every province, every canton, and every corner of the territory of Armenia the most suitable places be selected to construct hospices for the indigent and the orphans, and hospitals for the sick, the lepers, the paralytics, that is all those who suffered from any kind of malady. Hospitals for the lepers and for ordinary patients were established simultaneously and provisions made for their daily needs and for giving the poor what was necessary . . . . In every district of Armenia he founded schools . . . . In his home the widows, the orphans, the indigent always found shelter and food, and the poor found solace. His palace and his table were always prepared to receive the poor, the strangers, and the wayfarers. Although he had already built many hospices in every canton and had supplied them with the indispensable provisions so that they may not be obliged to leave their beds and go begging, he, inspired by his great love for the poor, permitted them free access to his palace and the lame, the blind, the paralytics, the deaf, the crippled, the wretched, the indigent, all set at his table and shared his meals.'
>
> Faustus of Buzanda[2]
> Circa Mid-5th Century, A.D."

The fulfillment, in our day, of similar responsibilities can be realized. As man approaches the 21st century, let historians record an era exemplified not only by technological achievements that allowed a handful of courageous men to travel to and from the moon. Let future scribes also extol the story of their 20th century forebears, who balanced the scales in the remaining three decades, by directing man's attention to even more fertile fields to be conquered. New vistas here on Earth, with humanitarian goals to be probed and explored, are in view. Let us emulate the work begun by the exemplary Katholicos Nerses with programs that will benefit man, enhance his environment, and allow his progeny to survive.

It is hoped that this study designed to help handicapped children, in a small way, stimulates others to rise to this challenge.

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[1] S. A. Essefian, PhD. Candidate, "Socio-Political Aspects of Armenian History," Georgetown University lecture series, Washington, D.C., February 1970.

[2] Faustus of Buzanda, *History of Armenia*, ed. P'awstosi Buzandac'woy Patmut'iwn Hayoc' (Venice, 1933), Iv. 4.85. Cf. V. Langlois, *Collection des historiens anciens et modernes de l'Arménie* (2 vols.; Paris, 1866, I, 239–240).

CONTENTS

VOLUME I

Tables

Figures

VOLUME II

Appendixes

ACKNOWLEDGMENTS

Members of CYBERNETICS RESEARCH INSTITUTE (C/R/I) gratefully acknowledge support and advice received from the Chief of the Projects and Program Research Branch, the Director of the Division of Research, and other members of the Bureau of Education for the Handicapped.

Words are inadequate to express appreciation to the late Professor Warren S. McCulloch, friend, colleague, and one of the founding fathers of Cybernetics Research Institute, and past Chairman of the Cybernetics Advisory Council, for his untiring devotion to this project in seeking knowledge beneficial to the world's handicapped children, their parents, and teachers.

It is with a deep sense of gratitude that the principal investigator expresses appreciation to Professor Heinz von Foerster, former Chairman of the Board of Trustees for Cybernetics Research Institute, and present Head, Biological Computer Laboratory, University of Illinois, for his valuable counsel and encouragement.

To Professor Julian H. Bigelow, Chairman of the Cybernetics Research Institute Board of Trustees, and Permanent Member of the Institute for Advanced Study at Princeton, New Jersey, the principal investigator is most grateful for his stimulating ideas and advice.

During the period of this report, the guidance of the following scientists was of great importance: Professor Samuel C. Ashcroft, Chairman, Department of Special Education, George Peabody College for Teachers; Professor W. Ross Ashby, Department of Electrical Engineering, University of Illinois; the late Professor William Tisdall, Chairman, Department of Special Education, University of Kentucky; Professor Emerson Foulke, Head, Perceptual Alternatives Laboratory, Department of Psychology, University of Louisville; Professor N. Henry Moss, Associate Clinical Professor of Surgery, Albert Einstein Medical Center and Temple University Health Service Center; and Dr. Joseph H. Engel, Director of Planning Research and Services, Communications Satellite Corporation, Inc.

The principal investigator is especially grateful for the continued advice rendered by Professor John C. Townsend, Department of Psychology and Psychiatry, The Catholic University of America, and Professor A. Rosenfeld, Computer Science Laboratory, University of Maryland.

Cybernetics Research Institute personnel express deep gratitude for the kindly reception given by the superintendents, administrators, and teachers at the Belle Willard Elementary School in Fairfax, Virginia; the Fairfax County School System; and the summer school staff of the Francis Scott Key School in Arlington, Virginia. Special appreciation is extended to Mr. Maxwell D. Millard, Chairman of the Board of Trustees of the D.T. Watson Home for Crippled Children, in Leetsdale, Pennsylvania, and to Miss Catherine Fletcher, for their resourceful cooperation in this program. To all of the children who served as subjects, and their parents, C/R/I's staff takes this opportunity to commend them for their wholehearted cooperation in this program.

The principal investigator also is grateful to members of Perkins School for the Blind, to Howe Press, and especially to Dr. Edward J. Waterhouse and to Mr. Harry Friedman for their assistance.

For the study on man-machine group instructional techniques, the principal investigator appreciates the creative work of its project coordinator and educator, Mrs. Isabelle J. LaMont, and her research associate Mrs. Arlene K. Shegerian, psychologist.

Contributions made in the area of correlations of visual defects and speech deficits by students Mary Pat Scaliatine, Barbara Halpern, and Sandra Rest at the University of Illinois, are gratefully acknowledged.

The principal investigator appreciates the efforts of Gourgen H. Assaturian, linguist and scholar, who is to be commended for his contribution of material in the "Phoneme Study for Punctographic Codes;" and to Dr. Arra S. Avakian, Mr. James Gouge, and Dr. Horace N. Reynolds, new members of the staff at C/R/I who, in a short period of time, have made significant contributions to the advancement of the program.

Again, the principal investigator's research colleague, Anna Mae Gallagher, is to be commended for the dedicated and remarkable contributions she continues to make with handicapped children. Also, Mrs. Marilyn Foulke is to be commended for her research in determining the discriminability of HAIBRL characters.

To Mrs. Nona Flynn, Mrs. Phyllis Noble, Mrs. Ann Levine Parker, Mrs. Suzi Silverman, Mrs. Mary Ridel, Mrs. Peggy Warkentin, and Mrs. Mary Chorewycz, teachers and research assistants, the principal investigator is especially grateful.

The principal investigator also expresses appreciation to Mr. Paul Kellam, one of the first members of the research team, and to Mr. Robert Mees of the C/R/I laboratory, for their splendid work and untiring effort and dedication; to Mr. James Sturman, for his graphic arts contributions and to Miss Evelyn Williams, Mr. Nathaniel Blackmone, and Mrs. Carol Pinson for their assistance.

The author expresses his appreciation to Mrs. Rose G. Kafafian for her management of administrative functions at the Institute.

SUMMARY

This report describes educational, instructional, and evaluative activities, conducted at Cybernetics Research Institute (C/R/I). The purpose of this program is to evaluate man-machine communications systems and appropriate instructional procedures for facilitating the education of handicapped persons.

The term $CYBERCOM_{TM}$, as defined in the Interim Report (Kafafian, 1968) includes the family of communications devices which employ such cybernetic principles as control of motor responses through information feedback. CYBERCOM* devices include among others $Cybertype_{TM}$, $Cyberphone_{TM}$, $CyberTone_{TM}$, $Cyberlex_{TM}$, and $Cyberlamp_{TM}$.

"Cybertype" employs a remote-controlled electric typewriter and dual-input keyboard. This keyboard or interface is available in various configurations to match the performance capabilities of handicapped operators. In one configuration, the interface consists of two sets of seven keys, one set for each hand, or prosthesis. Most of the interfaces require a concurrent, bilateral response by the operator, consisting of two key actuations, one in each of the two sets of keys. Each key is capable of operating a single switch with a single contact. When two keys, one from each key group, are operated concurrently in accordance with a predetermined code, the desired output is produced automatically. Thus, each of the letters, symbols, or functions of the typewriter, brailler, alphanumeric display lamp, or other output device corresponds to an assigned bilateral-input combination of keys on the interface.

A principal advantage of this communications system is that it provides great flexibility in matching the interface to the performance capabilities of many handicapped persons. For example, children with muscular dystrophy or cerebral palsy, and children with upper limb prostheses, can operate the bilateral-input system with appropriate, portable keyboards. "Cybertype" equipment is intended for children who cannot effectively operate the standard 49-key typewriter keyboard.

Interface configurations include among others the following:

1. A split-keyboard interface with two separate groups of seven keys which may be mounted on the arms of a wheelchair, or strapped to a child's body.
2. A keyless typewriter with a control-stick interface consisting of two levers (no keys are used in this configuration), each of which can be moved into seven radial positions, corresponding to the seven keys in each group on the basic 14-key interface, for children with muscular dystrophy or other debilitating conditions who cannot operate keys but whose body movements permit operation of a lever mechanism.
3. A single-bank interface for single-handed operation.
4. A foot- or fist-controlled interface consisting of a large area keyboard with 14 keys.
5. A contact plate interface used with appropriate contacts mounted on the user's fingers, and a glove interface.

Cybernetics Research Institute has conducted a number of exploratory instructional studies with subjects for the following purposes:

1. To investigate the relative efficacies of the bilateral-input control system and the standard electric typewriter for production of written communications by handicapped and nonhandicapped children.
2. To study feasibility of integrating man-machine communications systems into classroom environments for children whose handicaps

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preclude other modes of writing.
3. To observe the performance of children with learning disorders who are taught to communicate through writing with bilateral-input interfaces.
4. To provide intensive instruction with man-machine communications systems and exploit the flexibility of bilateral-input interfaces for children having specific sensory, motor, or cognitive disorders.
5. To develop and evaluate instructional procedures for individual and group experience with these bilateral-input systems.

Two CYBERCOM systems, "Cyberphone" and "Cyber-Tone," promise to extend the utility of the telephone to those who are deaf, lack functional speech, or are deaf-blind. "Cyberphone" is a portable, battery-powered system contained in a briefcase-size unit. It provides controls and displays for transmitting and receiving across telephone lines, but requires no permanent installation into telephone circuitry. The sender transmits a message by operating a 14-key, bilateral-input keyboard. The message or the output may be received and displayed by illuminated alphanumeric lamps, an electric typewriter, a braille typewriter, or other means.

The second system, "Cyber-Tone," requires only a Touch-Tone® telephone for transmitting and a decoder unit at the receiving site. The message is transmitted by using a simple, sequential, two-digit code. At the receiving end, the decoder unit allows the message to appear on a visual display, electric typewriter, braille typewriter, or any combination of these or other output systems.

Systems developed and designed in the present program include HAIBRL$_{TM}$, a new, unambiguous one and two-dot punctiform tactile writing system, based on a center reference bar and a multi-dot cell. Another experimental tactile system employs a standard six-dot braille cell with two of the dots modified to reduce pattern ambiguities. These two punctographic systems were undertaken to develop unequivocal punctiform tactile writing codes for blind individuals who cannot readily learn the standard, six-dot, equivocal braille code.

The program also includes evaluations of other man-machine communications equipment, including Patient-Operated Selector Mechanisms,* or P.O.S.M. This mouth-controlled pressure system employs an efficient sequential code of various combinations of "puffs," "no actions," and "sucks," through a tube having a mouthpiece, to produce typing and other output responses for a patient with nearly total muscular paralysis.

"The deaf, deaf-blind, and those who cannot speak or have severe speech impediments, who have heretofore been denied use of effective telephone communications, will, we hope, have access to a new generation of communicative and educational aids. These new telecommunication systems should enable this population to communicate via standard telephone and radio circuits."

®Registered Trademark of AT&T.
*Proprietary to P.O.S.M. Research Project, Aylesbury, Bucks, England.

INTRODUCTION

"Strengthen ye the weak hands, and make strong the feeble knees.
Say to them that are of a fearful heart, Be strong, fear not. . . .
Then the eyes of the blind shall be opened, and the ears of the deaf unstopped.
Then shall the lame man leap as a gazelle and the tongue of the mute sing. . . ."

—Isaiah 35: 3–6
circa 725 B.C.

This C/R/I Second Report, following the Interim Report (Kafafian, 1968), covers work accomplished from August 20, 1968 to February 19, 1970, under Office of Education Grant No. OEG2-7-070533-4237.

The purpose of the total program, as set forth briefly in its title, is to study a variety of man-machine systems that will enhance the capability of severely handicapped children to communicate and thereby enable them to receive the benefits of education and develop intellectually. The study of this special family of man-machine systems includes developing tests to observe and measure their effectiveness in enhancing the communicative capability of various classes of handicapped subjects; studying man-machine interfaces; developing and testing instructional materials, appropriate in teaching the use of these systems to the handicapped; demonstrating the systems to educators; and disseminating the information for application in school systems.

This and similar programs that seek to break through the present barriers to making special education effective for our Nation's handicapped children are critically needed.

> *"Less than 40 percent of the nation's handicapped children are receiving an appropriate response from our educational system. Of the almost six million children who are mentally retarded, hard of hearing, deaf, speech impaired, visually handicapped, seriously emotionally disturbed, crippled, or who have other health impairments which require special education and related services only slightly over two million are now receiving special education treatment, . . . "*
>
> *—Martin. "Education of Physically Handicapped Children." Report to President Nixon's Task Force on the Physically Handicapped. U.S. Office of Education internal document, Nov., 1969.*

Even the gifted child may suffer from disturbing factors that handicap him and require techniques in special education.

> *"Children who are chronic underachievers, who seem to perform below their intellectual aptitude year after year, provide a most frustrating problem for the teacher."*
>
> *—Gallagher.* Teaching the Gifted Child. *1964.**

The need for help in the area of special education is great. The help must come from several quarters, and the capabilities of modern technology are ready to be applied to create significantly important man-machine systems for relief in the education of the handicapped.

During the period of the present report, distinct progress was made in prosecuting the current phase of the program. The accomplishments, the principal activities, and the plans for the continuing program are described in this report in detail.

Continuing work includes group and individual instructional pro-

*Reprinted from *Teaching the Gifted Child*, by James J. Gallagher, copyrighted 1964, by Allyn and Bacon, Inc. Permission has been granted by the copyright owners to Cybernetics Research Institute, Inc., for use provided that appropriate copyright notice is applied thereto.

grams conducted in numerous schools and field stations. For example, at the D.T. Watson Home for Crippled Children in Leetsdale, Pennsylvania, eight severely handicapped children have learned in group instruction to operate bilateral-input interfaces matched to their performance capabilities and have learned the keying positions for the letters, symbols, and typewriter functions in only four weeks of instruction, four hours per week. The interfaces include a pedal keyboard for foot operation and a keyboard operated with the fists or heels of the hands. Effects of instruction on subjects' written communicative performance and on verbal and intellectual ability are assessed. Instructional materials are being prepared to accompany the bilateral-input systems in field operations.

The topics covered in the present report are listed below.

I. RESEARCH AND TRAINING PROGRAMS WITH MAN-MACHINE SYSTEMS

Special educational programs were undertaken with handicapped children to determine the overall value of using bilateral-input interfaces as means for producing written communications for various classes of handicaps. Results of these studies are set forth in this report, together with examples of instructional materials used. These studies were intended primarily to be instructional or demonstrational programs; consequently, many of the projects do not adhere strictly to principles of experimental design.

II. INTERFACES FOR MAN-MACHINE SYSTEMS

Interfaces for control of systems operation (input) and display of information (output), together with transfer codes, are illustrated and described.

III. TELEPHONE COMMUNICATIONS FOR THE HANDICAPPED

Utility of two telephonic systems for deaf or speech-impaired children is reported. A preliminary evaluation was made with "Cyberphone," a portable, two-way telephone communications system employing a 14-key, bilateral-input keyboard. "Cyber-Tone," a second system, was again successfully demonstrated, using Touch-Tone® keys at the transmitting site and a portable "Cyber-Tone" decoder which operates type and braille writers, and word displays at the receiving sites.

IV. HAIBRL

A detailed report is presented covering the considerable progress on HAIBRL, previously described in C/R/I's Interim Report (Kafafian, 1968) as a two-dot, punctiform tactile system with a reference bar, for reading and writing, but expanded now to include studies of important variants.

V. SENSORY AIDS FOR THE VISUALLY HANDICAPPED

Specific studies, tests, and recommendations for improvement of sensory aids for blind children were made. Canes, tactile maps, and measuring tools, among others, were considered and studied.

VI. COLLATERAL STUDIES

The main program of measuring effectiveness of man-machine communications sytems for handicapped children incorporated other supporting studies, one of which concerned the use of phonemes of English and other important languages, to explore more efficient written linguistic forms. Another supporting study concerns an abbreviated language structure and a minimal alphabet. Still another study deals with the correlation of visual defects and speech deficits.

VII. STUDY OF OTHER COMMUNICATIONS AIDS

During the course of the present program, attention was given to equipment outside the CYBERCOM family of man-machine communications systems. Particular attention was given to two systems developed and produced in England, one of which was obtained for expanded study and evaluation.

Concepts, descriptions, and data from C/R/I's Interim Report (Kafafian, 1968)—when necessary for continuity—are repeated in the C/R/I Second Report, sometimes verbatim, in order to preclude the need for frequent reference to the Interim Report; however, for complete, detailed descriptions of the overall program, it is essential for the reader to have access to the Interim Report. Repetitions within the present report are intentional so that each section will be complete in itself.

CONCLUSIONS AND RECOMMENDATIONS

The work and accomplishments of the investigators at C/R/I during this phase of study have led to the following conclusions and recommendations:

A. RESEARCH AND TRAINING PROGRAMS WITH MAN-MACHINE COMMUNICATIONS SYSTEMS.

1. Many handicapped children whose impairments are so severe that they cannot write effectively either with a writing instrument such as a pen or pencil, or with an electromechanical device such as a standard typewriter, can use the remote, bilateral-input interface for written communication. There remain the needs to measure more objectively the effectiveness, and to demonstrate more broadly the educational uses, of the bilateral-input interface as a communication tool in a classroom environment for these handicapped children.

2. Studies in this program strongly indicate that bilateral-input interfaces for communicating are easily adapted for group instruction and for instruction without the actual apparatus. Fingering on separate, detached keyboards, or even on phantom keyboards, permits the children to practice the lettering code. Hence, writing can be practiced effectively by movement of appropriate fingers even though a keyboard is not available.

3. Bilateral-input keyboards provide important flexibility in matching the configuration of man-machine interfaces to the sensory and motor requirements of handicapped children.

4. Dual-input lettering codes can be learned easily and used for communicating. The potentials of other, more efficient codes for providing additional gains for learning and retention are being studied. For example, other codes reflect the prominence of popular letter pairs and sequences, as disclosed in the C/R/I Interim Report (Kafáfian, 1968). The physical ease, speed, and accuracy of using more efficient codes may reduce emotional and mental stress created by the task of communicating for certain categories of severely handicapped children.

5. For persons whose handicap leaves an unequal lateral capability, special interfaces and codes may be used. Unsymmetrical arrangements of the key groups of the dual-input system, with a corresponding use of other keying codes to match individuals' full capabilities, should be studied.

6. As already noted, communicating in writing for multihandicapped individuals imposes a mental, emotional, and physical hardship. This burden can be alleviated not only by use of more efficient letter-keying codes, but also by exploiting the inherent redundancy in English, to produce an abbreviated language through a modified or minimal alphabet. Such language economy may be beneficial to the multihandicapped sighted child just as the contractions in grade two braille help the sightless. Another way is to use a word storage system to facilitate the production of written communications.

7. School records available on the multihandicapped children used as subjects in the present studies have been incomplete, inaccurate, or not directly relevant for prescribing the kind of interface or the instructional procedure to be used. Better diagnosis is needed for more effective research in enhancing a subject's ability to communicate. Research teams engaged in this kind of work should include a person with special qualifications in the diagnosis of neurological, sensory, and motor disorders. The gifted child who is physically handicapped, for example, may suffer from inappropriate diagnosis which overlooks his intellectual potential.

8. Children with specific learning disabilities who have been exposed to typing with the bilateral-

input interface have shown new interest in reading and in expressing themselves. This fact suggests that the exposure has had a beneficial effect on overcoming their disabilities. It is necessary to establish a measure of the degree to which increased interest occurs, and to identify factors underlying it. Such factors may include:

- the bilateral keying responses and the consequent interaction of both cerebral hemispheres or areas of a single hemisphere involved in associations required to direct command signals to the bilateral-input interface;
- the process of writing with a machine that produces whole letters digitally with simple, single strokes rather than with a continuous motion (as in cursive writing);
- or even the presence of spurious effects on the subject such as awakened interest or intellectual stimulation resulting from the special attention received during the instructional program.

9. It is desirable to classify characteristics of the handicapped in terms of the levels of afferent and efferent capabilities remaining. In such a classification it would be possible and convenient to identify individuals with those handicaps for which certain configurations of equipment provide a necessary or improved medium for communication. This classification also will permit a better measure of the nature and degree of handicap, making it possible to achieve better experimental control of this variable.

10. Valid and reliable results can be obtained from the research programs involving handicapped (as well as gifted) children only if special standardization and control procedures are adopted. These special procedures involve the following, as stated in part in the above conclusions:

- Classifying handicapping characteristics in terms of kinds and levels of sensory, motor, and cognitive capabilities remaining.
- Defining those classes of handicapped individuals whose disabilities preclude or greatly impede performance with normally available writing tools.
- Structuring test programs with proper controls to isolate the parameter being tested while maintaining comparable conditions on other variables.
- Selecting test subjects appropriate for the objectives of each test program.
- Employing instructional techniques and materials that are equated as closely as possible so that comparable results can be obtained in comparison programs involving several different writing systems.
- Measuring, quantitatively and objectively, significant performance characteristics of subjects (e.g., communicative ability; psychomotor response; motivation; academic achievement before, during, and following the experimental program).

B. MAN-MACHINE SYSTEM INTERFACES

1. The several basic physical configurations of the two-bank, bilateral-input interface used in the program have enabled a variety of handicapped individuals to adapt to the interface and communicate. Other configurations are needed in order to match interfaces with the performance characteristics of individuals with a variety of handicaps.

2. A single-bank, dual-input interface, although it does not lend itself to being split into two physically separated groups of keys, nevertheless offers some other advantages as described in C/R/I's Interim Report (Kafafian, 1968). New advantages and constraints are yet to be determined. Experiments with a closer grouping of the keys for one-handed operation must be considered.

3. Research programs are presently evaluating foot- and fist-operated keyboards for individuals with very poor muscular coordination in hands and arms. These keyboards consist of large keys, spaced far apart, arranged in two groups of seven keys as with the finger-operated interface. These large keys are operated with the feet or the fists, and initial testing

has provided encouraging results with diplegic children having little or no arm-hand coordination.

C. TELEPHONIC COMMUNICATIONS FOR THE HANDICAPPED

1. "Cyberphone," which permits typewritten and/or alphanumeric display outputs at a remote point operates successfully with regular telephone circuits, both by direct keying on its own interface and by use of prerecorded cassettes. Tests have been successful also over long distance telephone lines and transoceanic and land radio circuits.

2. The use of prerecorded cassettes with these systems permits deaf persons to obtain stored information via the telephone from central educational sources, in either visual, audio, or typed form. Tactile output is available for the deaf-blind.

3. Continued experimentation is required to establish procedures for use of these systems by handicapped children in classroom situations.

4. Other configurations providing telephonic communications for the handicapped have been explored and found promising, in particular, "Cyber-Tone," which uses the standard Touch-Tone® telephone unit as the transmitter and a simple portable decoder for print and/or braille output.

D. HAIBRL

1. HAIBRL punctiform writing promises a new dimension in communication for the blind who cannot effectively use braille, by offering:

- a readable punctiform system using no more than two dots;
- characters that are easy to recognize because of the fewer dots used;
- unequivocal characters;
- a large number of different characters.

Research is necessary to measure the effectiveness and the value of HAIBRL in each of these areas.

2. The HAIBRL cell is larger in size than the standard braille cell. However, assigning more efficient symbols and thereby reducing the number of characters required in written copy partly compensates for the size difference. Also, the larger cell yields a large number of one and two-dot configurations not exceeding the three-dot height of a standard braille cell.

3. Research is presently being conducted to determine the most equitable assignment of letters, contractions, symbols, words, etc., to the large number of easily read, unambiguous configurations.

4. The large number of different dot configurations available in HAIBRL allows for the inclusion of phonetics in the character code. Combining HAIBRL characters in which phonemes have been substituted for letters, with a system of contractions as in grade two braille, offers a writing system that transforms more directly from graphemes to spoken words. In addition, phoneme characters will enable the writing of foreign languages without changing the basic code.

E. SENSORY AIDS FOR THE VISUALLY HANDICAPPED

The cybernetic multidisciplinary and interdisciplinary approach to developing educational aids for multihandicapped individuals provides researchers with new means for enabling the blind to communicate and become independently ambulatory.

F. GENERAL.

The "Possum" equipment offers a reliable and effective communications system for the multihandicapped. Paralytic individuals, especially where they have minimal control over their muscular system, have demonstrated its usefulness and values.

> "Cybernetics, the science of control of man and automata, has taught us the concepts of feedback and purposeful behavior control systems. Using these principles, handicapped persons can be taught to communicate via human-engineered interfaces."

FUTURE PLANS AND PROGRAMS

Based on conclusions and recommendations drawn from work accomplished under the present study and reported herein, the following outlines future plans and programs at C/R/I:

I. RESEARCH AND TRAINING PROGRAMS WITH MAN-MACHINE SYSTEMS

The program in research and training with man-machine systems will proceed in these three areas:

A. INTEGRATE CYBERCOM SYSTEMS INTO THE CLASSROOM ENVIRONMENT AND COMPARE WITH OTHER WRITING SYSTEMS.

PURPOSE:

To determine the feasibility of integrating CYBERCOM systems with specific instructional materials into classroom environments for children whose physical disorders preclude or greatly impede their ability to write or to use a standard typewriter keyboard. In addition, assessment will be made of the effects of instructional experience with these systems on verbal, intellectual, and motor abilities, as measured by a battery of tests. Another experimental program will compare the CYBERCOM system, a standard electrical typewriter, and a form of hand-lettering in terms of training time, writing speed and errors, and memory for use of the systems. Subjects will include children handicapped by a variety of motor and sensory disorders or by specific learning disabilities.

Results of these experiments will contribute to the development of a package of instructions and materials that will accompany these kinds of systems for teachers and other researchers in the field. This material will be used for training new populations of handicapped children to communicate.

METHOD:

Prior work has been to obtain data that largely are descriptive, principally to ascertain and demonstrate the feasibility of a particular kind of man-machine system in enhancing the educational capability of multihandicapped children.

Future work in educational research will validate and demonstrate various types of man-machine systems and obtain a measure of their effectiveness when used with seriously handicapped children. It is critical, therefore, in these research programs designed to aid the handicapped, to gather extensive and precise data. The data are to be gathered from the field, using subjects appropriate in number and kind, and working with personnel on the staffs of several cooperating institutions and organizations. Essentially, three distinct Field Test Studies are planned:

1. Field Test I will be a carefully controlled experimental comparison of the bilateral-input interface and standard typewriter interfaces in terms of training time, typing speed and errors, and retention of typing codes, using as subjects children handicapped by different motor and sensory-motor disabilities. For proper control, this experiment will include a group of children having prior instruction in cursive writing only and will employ procedures standardized across treatment groups. The pur-

pose of this phase of the study is to determine the relative rates of learning the three writing systems and the educational benefits to be derived from their respective programs of instruction. A further purpose is to measure the educational value of learning to produce writing with a dual-input interface in those cases involving children who are so severely handicapped that they have no other means for written communication.

2. Field Test Study II will determine the feasibility of integrating man-machine systems with specific instructional materials into classroom situations for children whose physical disorders preclude or greatly impair ability to write or to use standard typewriter keyboards. This study may reveal whether a handicapped child's classroom performance is enhanced by providing him the means with which to express ideas and thus help develop intellectual potential.
3. Field Test Study III will be designed to measure the degrees to which children with specific learning disabilities would be directly benefited by learning to write via dual-input interfaces, thus necessarily exercising bilateral responses.

The specific and various defects and deficits of the handicapped child call for exploiting the "best" and "most effective" techniques in teaching him to communicate. Included in the techniques that C/R/I will use are specifically prepared motion picture films and 35mm slide presentations geared to specific classes of the handicapped. Each presentation will be devoted to instruction in the total use of various, bilateral-input interfaces for each significant class of handicap.

Special film techniques have been developed by Withrow (1969) and their effectiveness tested and validated in programs at the Illinois School for the Deaf, Jacksonville, Illinois, and the Pilot Institute for the Deaf, Dallas, Texas. For example, a deaf child or one with severe auditory loss, would benefit from a visual presentation on film giving both pictorial instruction and verbal instruction through written captions. In addition to teaching the operation of the dual interface, such films can develop vocabulary and language concepts and augment the academic program in the classroom.

Frequently the handicapped child suffers from diminished sensory capabilities. Hence, he all the more needs an enhanced learning environment. C/R/I, as indicated in the detailed reports on the several studies, seeks to provide such an enhanced learning environment to augment the effectiveness of instruction with man-machines. Features of an environment favorable for learning are numerous and constantly emerging. Especially effective may be the techniques of a family of projection systems (Ray, 1968) in which all or a major part of the area of a room, of whatever shape, serves as the projection surface, creating a strongly influential environment.

B. STUDY THE IDENTIFICATION AND CLASSIFICATION OF SENSORY AND MOTOR DEGREES OF FREEDOM OR CAPABILITIES REMAINING

PURPOSE

To initiate the preparation of reference classifications of sensory-motor disorders in terms of remaining afferent and efferent capabilities. This classification will be used to identify effective configurations of man-machine communications systems for each category of disabilities. The various systems will be interrelated as much as possible to reduce the number of systems required and to allow consistency of instructional techniques and materials across groups of subjects.

METHOD

A master classification table is to be constructed. In a two-dimensional array it will list afferent degrees of freedom remaining versus efferent degrees of freedom remaining. Afferent degrees of freedom will list remaining capabilities; e.g., visual, auditory, tactile, kinesthetic, and other sensory modes. Efferent degrees of freedom will list remaining capabilities in controlling the digits, hands, arms, legs, mouth, and other parts of the body. Categories may be divided into two or more levels of capability.

This "stratification" table can be constructed so that it eventually may be viewed as a map of the remaining total capability of an individual. Hence, the properties or characteristics of handicapped individuals can be mapped against the array and both qualitative and quantitative stratification will be possible.

Distribution of the population and the interrelationship of handicaps suggested by this mapping may be valuable for better understanding of specific handicaps and especially how they may be educationally treated. The population of the classification will be comprised of subjects previously participating in the program and subjects who are to participate in future programs. Results from test programs with this population, using man-machine communications systems, will be correlated to the classification tables and/or charts. Learning and performance curves will be developed as a function of the characteristics of the handicapped.

Man-machine system block diagrams will be made to assist in the analysis. Through study of the several elements comprising these systems, it should be possible to analyze the contribution, both enabling and impeding, of afferent and efferent capabilities of the subjects to the learning and communication process.

C. ANALYZE CODING AND PROGRAMMING OF CYBERCOM SYSTEMS

PURPOSE:

The purpose is to determine means of enhancing the communicative capabilities of multihandicapped children by analyzing coding in terms both of interface keying configurations and abbreviations in the language.

METHOD:

Letter-keying codes will be explored to identify some of those codes which facilitate learning, retention, and keyboard operation. Coding then will be reexamined, taking into account other factors, such as frequency of occurrence of letter pairs or sequences, prevailing efferent degrees of freedom remaining for various categories of handicaps, special learning problems, and ease of memorization and retention.

Data will be obtained from a computer analysis of hand and finger movements necessary to produce representative written material, and from a photographic analysis of the operation of experimentally coded interfaces. Also, time and motion studies will be made with appropriate subjects to determine the relative ease of using various experimental interfaces.

Studies will be conducted to take advantage of possible language economies to reduce the burden which handicapped persons experience in communicating (conventional English has high redundancy in its informational content). Numerous researchers have made extensive measurements to establish quantitative values of the redundancy in conventional English found to be present in the language both morphologically and orthographically. It is the nature of conventional English that the informational content permits anticipating with high probability of accuracy what the next word, morpheme, or letter (grapheme) will be in a normal sequence. Thus, not all words, morphemes, or graphemes contain meaningful information, but are in the normal language as part of its natural adornment. This work will be supported with an appropriate literature search.

In the area of communication for handicapped children, where effecting written communication presents a severe physical burden, it may be possible to take advantage of this redundancy in normal English, thereby reducing the physical burden that unabridged writing imposes on severely handicapped children, and thus reducing mental and emotional stress and facilitating intellectual development.

II. MAN-MACHINE SYSTEM INTERFACES

PURPOSE:

To study physical configurations of interfaces for the most favorable matching to the several classes of handicapped individuals and to provide sensory feedback in one or more modes to help the handicapped in communicating.

METHOD:

This program is principally an effort to establish an extensive family of interfaces configured to fill the special needs of many classes of handicapped individuals. Using human factors engineering and physiological data on individuals involved, numerous styles of interfaces will be tested with subjects, observing and measuring the degree of match between the interface and the efferent capability remaining. Factors in producing a matching design involve the following: shape, stiffness of action, amount of travel, spacing, coding, size, etc., of keys and/or controls; use of ortheses, prostheses, other parts of the body, other than digits or hands; use of the breath; exploration of auxiliary, restraining devices, e.g., magnetic clamps, key fences, guards, etc., to improve control of the interfaces by handicapped operators.

III. TELEPHONIC COMMUNICATIONS FOR THE HANDICAPPED

PURPOSE

To continue the study of effective and portable means for telephonic communications for the deaf, deaf-blind, and for those individuals with severe speech impairment, which would enable them to augment their education.

METHOD

Operational procedures with "Cyberphone" and "Cyber-Tone" will be established through tests prepared and conducted at first by staff personnel, followed by tests by handicapped subjects. Data will be gathered on the ease and convenience of use; speed and accuracy; reliability; dependability; and, most importantly, the educational value of these communications systems.

"Cyberphone" tests will involve simulated conditions wherein subjects who are deaf or deaf-blind or who have severe speech impairments will employ the system for communication from remote telephones to a central CYBERCOM station equipped with type and/or braille printers. Prerecorded tape cassettes containing appropriate responses to inquiries will be used in these simulated exercises.

Other systems also will be evaluated under simulated conditions, using appropriate subjects in an educational environment.

IV. HAIBRL

PURPOSE

To develop and design a punctiform tactile system that will enhance the capability of multi-impaired blind individuals who have not been successful in learning braille; that will serve those with marginal vision or others who may want a tactual augmentation in communicating; and that will lend itself to more extended educational use in such fields as scientific and technical work, music, and foreign languages, through its richness in unequivocal patterns and adaptability to international phonemes.

METHOD

This phase of the program has two principal parts. One is to continue the design, development, study, test, and evaluation of the current HAIBRL cell and appropriate writing slates and styli having a pattern of 16-dot positions and a reference bar. Another phase is to conduct parallel studies with modified characters of braille and other punctographic systems.

A preliminary assignment of HAIBRL characters will be made to denote letters of the alphabet, phonemes, abbreviations and contractions comparable to grade two braille, signs, punctuation, new contractions, special terms, etc. The emergent punctiform language will be subjected to rigorous tests and evaluation, using blind and sighted subjects, with and without prior tactile reading experience.

V. OTHER PROGRAMS

PURPOSE

1. To study innovative sensory aids for deaf-blind individuals.
2. To evaluate the effectiveness of a variety of commercially available man-machine systems for the handicapped and to determine their position in the family of all such aids for the handicapped.
3. To carry on dissemination activity to acquaint other researchers in the present field with the work of C/R/I and to obtain related information on work being conducted elsewhere.

METHOD

Other parts of the total program provide a variety of aids for the visually handicapped. These aids arise in the HAIBRL program and in the various parts of the CYBERCOM system as a concomitant part of the development. This program element seeks to study innovative sensory aids specifically for the visually handicapped which would not arise elsewhere in this or other programs.

Categories of sensory aids to be studied are those pertaining to ambulating (obstacle avoidance); navigating (maintaining true direction or following a desired route); recognizing the character of objects (space sense); and signalling (calling attention to the deaf-blind).

Ambulating aids concern canes, sonic and radio sensors, gently acting physical devices to warn of obstacles. Navigating aids concern radio direction sensors and built-in cooperating guidance devices. Recognizing the character of objects concerns measuring tools, maps, and charts. Signalling devices concern acoustic generators, overhead fans, overhanging mobile ribbons and strings that can be activated, vibrators, and olfactory indicators.

The approach to be followed is to study the feasibility and various aspects of the several aforementioned categories in which the multihandicapped child is constrained and suffers a particular inconvenience in his overall attempt to communicate. Visually handicapped children may have reached a reasonably balanced situation between their various activities concerned in communicating with their environment; however, when one phase of their activity is suddenly enhanced, as it may be through other aspects of the present program, other phases may fall out of balance or degenerate, thereby requiring enrichment to permit full utility of the new potential benefits. Hence, this phase, of the program element seeks to provide collateral support of the main thrust of the program.

Innovative man-machine communications equipment developed elsewhere will be studied in the light of the educational needs of handicapped children.

Dissemination activity and interchange with others engaged in the education of handicapped children is critically important and will be undertaken by C/R/I's professional, management, and research staff in order to maintain a significant level of dissemination.

> "When researchers achieve a better understanding of the individual's stratification of sensory and motor capabilities, and how these capabilities change with, among others, training, growth, and environmental modifications, educators will be in a better position to aid the learning-disabled and/or physically handicapped student with interfaces that match the automata to the characteristics of the human operator."

METHODS

Part One OVERVIEW OF RESEARCH AND TRAINING PROGRAMS WITH MAN-MACHINE SYSTEMS

Six research and training programs were conducted to study the effectiveness of bilateral-input systems in providing multihandicapped children with a capability of communicating through writing. These programs were intended to be preliminary and exploratory for the purpose of developing teaching techniques and materials, and generating hypotheses for future experimental validation. Initial results have been most rewarding and have reinforced the investigators' conviction that bilateral-input systems provide a channel of graphic communication for handicapped children who have no other means of writing. Experiments developing from these exploratory studies are being initiated and are described in the "Future Plans and Programs" section of this report.

The six exploratory studies are summarized below, with more detailed descriptions of each program provided in Volume II of this report (Appendix A).

1. COMPARISON STUDY

This exploratory study was performed to compare typing speed and errors for the 14-key bilateral-input system and the 49-key interface of a standard electric typewriter. Subjects consisted of 24 physically handicapped children and 32 nonhandicapped children, ages 6 to 12. The 24 handicapped subjects were divided into two equal groups roughly matched according to physical disabilities, age, sex, reading level, visual and auditory impairments, and IQ's from school records. One group (Group A) was given instruction with the bilateral-input system, while the other group (Group B) received instructions with the 49-key standard electric typewriter. The 32 nonhandicapped children were divided similarly into two groups, Group C receiving instructions with the bilateral-input system and Group D with the standard electric typewriter.

Subjects in Groups A and C (those using the bilateral-input interface) were taught the letter-keying code using associative principles based on the Cyber-Circus Story$_{TM}$, developed by Anna Mae Gallagher (Kafafian, 1968). Subjects in Groups B and D (those using the standard electric typewriter) were instructed using the "Keyboard Town Story" (Gallagher, 1965). None of the keyboard interfaces provided letters or other coding on key tops.

During the training sessions, the instructors administered timed 3-minute tests consisting of words and phrases to be produced. At the end of training, one final test was given to Groups A and B, while C and D received a different final test. Tests were scored for number of characters and functions (e.g., space, carriage return) produced in three minutes, and errors as a percentage of the number of characters and functions produced. Median test scores for handicapped subjects, both for the training tests (averaged) and for the final test are shown in Table I.

Examination of Table I reveals that performance for the two groups did not differ greatly. On the training tests, Group A subjects, using the 14-key interface, produced on the average slightly fewer characters but with a smaller error percentage than did Group B subjects using the standard electric typewriter. On the final test, however, subjects using

TABLE I

MEDIAN NUMBER OF CHARACTERS/FUNCTIONS AND PERCENT ERRORS PRODUCED BY HANDICAPPED SUBJECTS USING BILATERAL-INPUT AND 49-KEY INTERFACES

	Training Tests (Averaged Scores)		Final Test	
	Median No. Characters	Median Errors (Percent)	Median No. Characters	Median Errors (Percent)
Group A (14-Key) (N=12)	44.0	6.3	47.0	6.0
Group B (49-Key) (N=12)	51.4	11.0	40.0	14.0

TABLE II

MEDIAN NUMBER OF CHARACTERS/FUNCTIONS AND PERCENT ERRORS PRODUCED BY NONHANDICAPPED SUBJECTS USING BILATERAL-INPUT AND 49-KEY INTERFACES

	Training Tests (Averaged Scores)		Final Test	
	Median No. Characters	Median Errors (Percent)	Median No. Characters	Median Errors (Percent)
Group C (14-Key) (N = 16)	64.3	6.0	62.0	7.0
Group D (49-Key) (N = 16)	65.3	6.7	67.0	10.0

the bilateral-input system produced more characters with a smaller error percentage than did standard typewriter subjects. These data suggest a post-training facilitative effect of the bilateral-input system for handicapped children.

Data for nonhandicapped subjects are presented in Table II. It can be seen that there are only negligible differences between Group C (bilateral-input system) and Group D (standard typewriter) in terms of number of characters produced and error percentages.

These preliminary results suggest that, for nonhandicapped persons, the bilateral-input system is no more difficult to use than the standard 49-key typewriter. This finding provides some assurance that a handicapped child using the bilateral-input system is operating an interface which is not intrinsically more difficult to control than a standard typewriter keyboard. This assurance, combined with the adaptability of the bilateral-input interface to match the handicapped operator's limited performance capabilities, reinforces the value of the system for severely disabled individuals.

Unique contributions of the bilateral-input system lie not only in its small number of keys and a major reduction in the area of the keyboard, but in its interface flexibility which permits modification to match the performance capabilities of the handicapped operator. This adaptability is demonstrated by some of the modifications of the basic bilateral-input system, described later in this report, such as, the control-stick interface, the foot-operated pedal interface, and the single-bank interface. Thus, a person whose physical disability might preclude or greatly impede his operation of a standard typewriter would be able to communicate more successfully with a bilateral-input system matched to his remaining sensory-motor capabilities.

2. DIAGNOSTIC EXPLORATORY STUDY

The purpose of this study was to explore teaching procedures which would prepare children to use the bilateral-input system for production of written exercises in a classroom environment.

The subjects were eight children, ranging in age from 6 to 13, with a variety of physical disabilities resulting from cerebral palsy, encephalitis, arthrogryposis, polio, or muscular dystrophy. Subjects were provided with interfaces to match their performance characteristics and each child was given between fourteen and twenty-one ½-hour instructional sessions with the bilateral-input system over a three-month period. Teaching procedures and materials included use of the "Cyber-Circus Story," developed by Anna Mae Gallagher (Kafafian, 1968), vocabulary exercises with the Dolch Basic Word List (Garrard Publishing Co., 1960), sandpaper letters for tactual feedback reinforcement of letter recognition, creative writing, and classroom exercises.

By the end of this instructional program, the subjects had received sufficient training with the bilateral-input system to type two to five words per minute in copying from printed text, and to produce creative writing and classroom exercises. Exploratory attempts to integrate the bilateral-input system into the classroom suggested that children can use the system successfully for production of written responses under these conditions. However, further research is necessary to establish more precisely rates of acquisition of the letter-keying code, effects of instructional experience with bilateral-input systems on verbal and intellectual ability, and academic achievement through use of the systems in the classroom.

3. FOLLOW-UP STUDIES.

These studies were undertaken to provide intensive instruction with the bilateral-input system for handicapped children who previously had received instruction in earlier programs. The objective was to extend training experience for these children to develop a level of independence and competence in the use of the system which would allow production of creative writing and classroom exercises.

Nine subjects were involved in this study. Children were given individual and (occasionally) small group instruction in 30-minute sessions, several days a week, over a period of 1 to 3 months. Teaching procedures and materials included those used in the "Diagnostic Exploratory Study," with emphasis on the production of creative writing. Additional teaching techniques included visual feedback of letters and symbols from an alphanumeric lamp display and cooperation between two or more children working together on individual interfaces.

At the start of this program, all subjects showed good retention of the letter-keying code learned during previous instruction, in spite of a lapse of at least 4 months. Performance with the bilateral-input system showed continuous improvement during the study, as revealed by timed 3-minute tests administered periodically, which consisted of phrases and sentences for subjects to copy. Toward the end of the instructional program, subjects were typing a median number of 35 letters, symbols, and functions, with a median of five errors, on tests requiring knowledge of 24 different letters, symbols and functions. This was more than twice the number of characters/functions produced by the same subjects on comparable tests during earlier studies.

Subject performance showed improvement not only in terms of typing speed and errors, but also in the production of creative stories and classroom-style exercises. Academic improvement resulting from operation of the bilateral-input system in a classroom environment remains to be assessed in future research.

4. LEARNING DISABILITIES STUDY

One of our nation's most serious problems in the field of education is the teaching and training of children with learning disabilities. According to the House Committee on Education and Labor, approximately 500,000 to 1,500,000 children, or 1 to 3 percent of our school population, suffer from specific learning disabilities severe enough to require remedial educational programs. Between 10 and 15 percent of 53,000,000 school-age children in the United States have language and reading disabilities (Education and Labor Committee, 1969).

The term "specific learning disabilities" in this study is used in accordance with the National Advisory Committee on Handicapped Children:

> *"Children with learning disabilities means those children who have a disorder in one or more of the basic psychological processes involved in understanding or using language, spoken or written, which may manifest itself in imperfect ability to listen, think, speak, read, write, spell or do mathematical calculations. Such disorders include such conditions as perceptual handicaps, brain*

injury, minimal brain dysfunction, dyslexia, and developmental aphasia. Such term does not include children who have learning problems which are primarily the result of visual, hearing, or motor handicaps, of mental retardation, of emotional disturbance, or of environmental disadvantages."

—National Advisory Committee on Handicapped Children, House Committee on Education and Labor: "Children with Learning Disabilities – Act of 1969."

Children with learning disorders often demonstrate poor motor coordination caused by underlying physiological or central nervous system deficiencies. According to Fernald (1943), when poor motor coordination or other factors interfere with the acquisition of cursive writing skills, the development of reading ability may be impeded. However, this reading impediment might be partly overcome by providing the handicapped child with a simpler method of writing than cursive handwriting. Campbell (1968), in a study of reading acquisition by children with severe learning disorders and motor disabilities, employed an electric typewriter to simplify the task of writing. She found that children using a typewriter to produce written exercises showed significantly greater improvement in vocabulary than did a comparable group of children using cursive handwriting.

Since the bilateral-input typing interface may be adapted to utilize the limited motor capabilities of a handicapped child, many such youngsters will find this system easier to operate than an electric typewriter. Accordingly, children with motor disorders should demonstrate improvement in reading skill as a result of writing experience with the bilateral-input system.

The purpose of this pilot study was to observe the performance of children with learning disabilities and motor disorders when learning to use the bilateral-input system for the production of written communications. It is expected that these observations will lead to experimentation on the use of bilateral-input communications systems by children with specific learning disabilities.

This observational study involved eight children, ages 6 to 14, who showed evidence of learning disabilities with accompanying motor disorders. Learning disabilities were reflected by the fact that almost all subjects showed test performance below their school grade level in basic academic skills.

Children were provided with 14-key interfaces connected to an electric typewriter, and were given instruction in learning the letter-keying code and in communicating through use of the system. Teaching procedures and materials were similar to those used in the studies described above.

Questionnaires were distributed to the children's parents toward the end of the instructional program. Answers to the questionnaire revealed observations of general improvement in children's finger dexterity, speech, posture, and confidence. The instructor's observations of subjects' verbal performance suggest that improvements in reading and writing ability might be expected to develop from an intensive program of instruction with the bilateral-input communication system. This system will be particularly advantageous for those children with learning disabilities whose motor handicaps impede operation of a standard electric typewriter but allow use of some version of the bilateral-input interface.

Further research is required to classify children with specific learning disabilities in terms of remaining sensory and motor capabilities, and to assess objectively any improvement in communicative ability resulting from the use of bilateral-input systems human-engineered to match the individual's requirements.

5. GROUP INSTRUCTIONAL PROCEDURES

The purpose of this portion of the program was to conduct an exploratory educational study concerned with teaching a group of children to communicate using bilateral-input keyboards. Emphasis was placed on developing group instructional materials and applying appropriate teaching techniques to accelerate the learning process, improve verbal comprehension and expression, and develop manual skills. It was hoped that the program would enable students who were underachievers, due to reading or learning handicaps, and students who were not handicapped, to communicate better verbally.

The complete report from the project coordinator describing this study is provided in Volume II of this report (Appendix F), but is reviewed briefly here in the context of other C/R/I education research projects.

Eleven children participated in the teaching sessions, including five children with physical handicaps or learning disorders, and six nonhandicapped children. Subjects were introduced to the bilateral-input system through the use of visual aids including a large chart showing finger positions for each letter, symbol, and function. With only one typewriter and two 14-key interfaces in the classroom, subjects took turns using the machine, while the rest of the group practiced with other instructional aids. Projects and games designed to enhance learning of the fingering code were created and used effectively. Tape recorded instructions also were prepared for use in the training sessions. Subjects were given a total of eight sessions of ½ to 1 hour duration each. The teachers created a high level of enthusiasm by relating the exercises to each subject's reading level and personal experience, by explaining the development of words and sentences and the importance of written communications in everyday life, and by developing mnemonic stories and games which the children found fascinating.

The teachers observed each child's performance during the teaching sessions and recorded notes on motivation, attitudes, and progress. The following observations were made:

1. The bilaterally operated 14-key code can be taught successfully to a group of subjects in relatively few training sessions, using only one machine with two keyboards when appropriate group instructional procedures are employed.
2. The bilateral-input interface can be used by individuals having motor disabilities which cause poor coordination or dexterity and which would impede performance on a 49-key typewriter.
3. Acquisition of the function, symbol, and letter code provides an intense experience with individual letters and the formation of words and sentences, and enhances the development of skill in written communications for persons with or without learning and/or motor disorders.

The group teaching techniques, games, and aids developed for this study will be refined and extended for application to future programs involving groups of children. Descriptions of these techniques and games are found in Volume II, Appendix F.

6. SPECIAL PROJECTS AND CASE STUDIES.

A number of handicapped persons were given individual attention at C/R/I to study bilateral-input interface configurations which would utilize their best remaining motor capabilities, and to provide preliminary testing of research equipment and materials. These subjects included two deaf-mute women, trained to use the 14-key bilateral-input interface for testing "Cyberphone," a paralyzed girl testing the operation of a tongue-activated mouth switch for operating a "Cybertype" system, and several multihandicapped children given instruction in communicating through writing with bilateral-input interfaces designed to utilize their remaining motor capabilities. Most of these subjects have shown gratifying progress in their ability to communicate using "Cybertype" systems and have contributed to the improvement of C/R/I research and instructional programs.

> "The task of equating the 'transfer function' of the human controller into operative systems which incorporate these characteristics in surrogate biological mechanisms presents new challenges to researchers. At the present time there are few algorithms to follow, although gaming theory has introduced exciting approaches for the engineer and designer to consider."

Part Two INTERFACES FOR CYBERCOM MAN-MACHINE SYSTEMS

I. MAN-MACHINE SYSTEM FAMILY

The major elements of the CYBERCOM family of man-machine communications systems for the handicapped are represented in the accompanying system block diagram (figures 1 and 2). "Cyberphone" and "Cyber-Tone," totally compatible with the system, are described separately in Part Three.

The inputs to the system are the man-machine interfaces, the "Cyberphone" and the "Cyber-Tone." A transfer code translates the dual input from the keys of the input interfaces through the system logic circuitry to drive or signal the characters and control functions of the output devices.

The total system is interconnected with appropriate junction boxes, connectors, cables, and, where required, code reversers and converters. The code reverser is used with left-hand dominant individuals, for the purpose of transferring principal activity to the left hand. The code converters are used where parts of the body other than the hands or arms are used to control the interface and where it is desired to experiment with other codes. Supporting the use of the total system are instructional materials and techniques, described in Volume II, Appendix C.

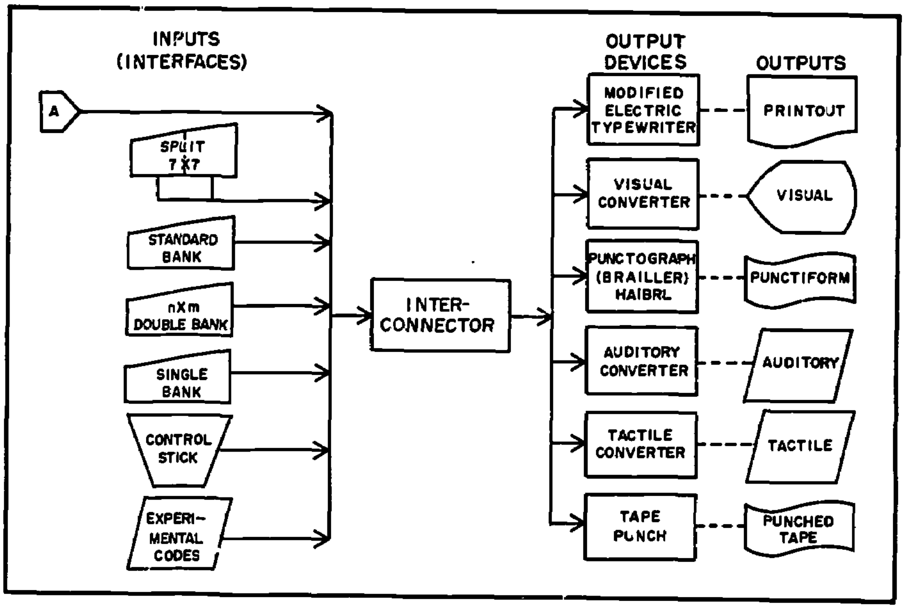


Figure 1. CYBERCOM Family of Man-Machine Communications Systems

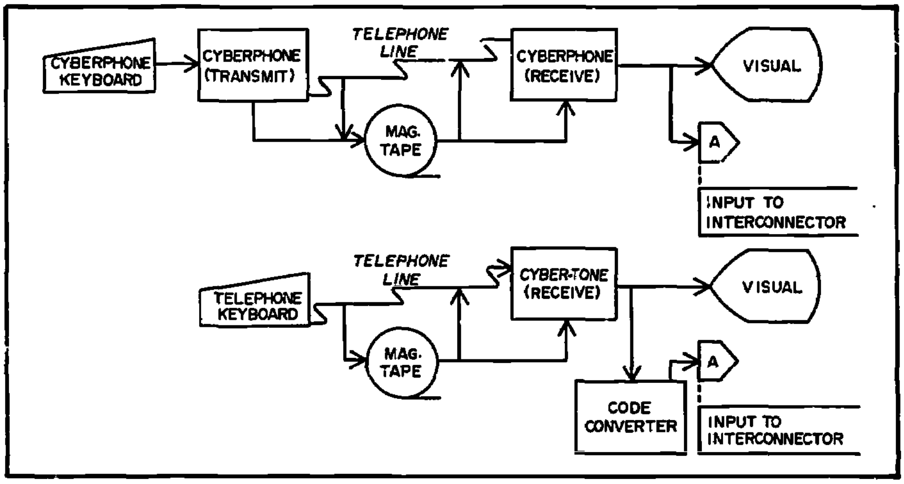


Figure 2. "Cyberphone" and "Cyber-Tone"

II. INPUT INTERFACES

The man-machine interfaces can be configured to assume virtually any physical form to meet the individual needs of multihandicapped persons, and can be operated by bodily motion, prostheses or ortheses. The accompanying photographs illustrate several interface configurations, including a large foot-operated interface, and an interface with keys designed for operation with the fists or heels of the hands (see plates 1 a-e, 1 a-d, and 3 a-b.).

Plate 1a. CP Subject Using 14-Key Interface with Rubber Pads on Keys to Prevent Slippage

Plate 1b. Armless Subject "Cybertyping" with His Prostheses

Plate 1c. CP Subject Learning the Cybercode through the "Cyber-Circus Story"

Plate 1d. Subject Using the Knuckle of Her Left Index Finger to "Cybertype"

Plate 1e. Subject Using the Heels of Her Hands on the Foot Interface

Plate 2a. CP Subject Using Large Foot Interface

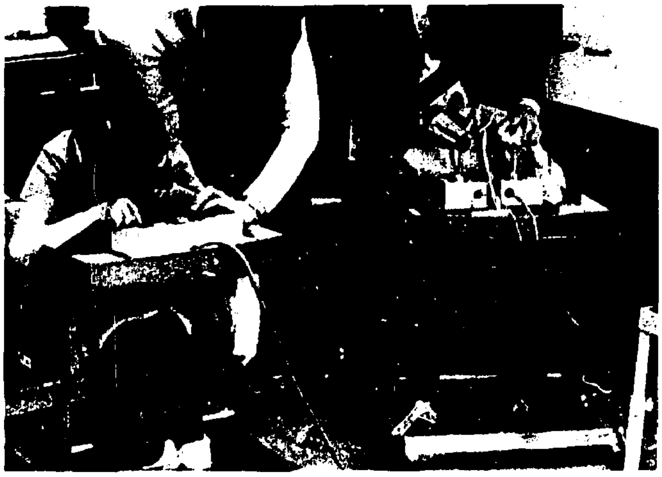


Plate 2b. Two CP Subjects Using 14-Key and Control-Stick Interfaces

Plate 2c. CP Subject Typing a Word List on the Control-Stick Interface

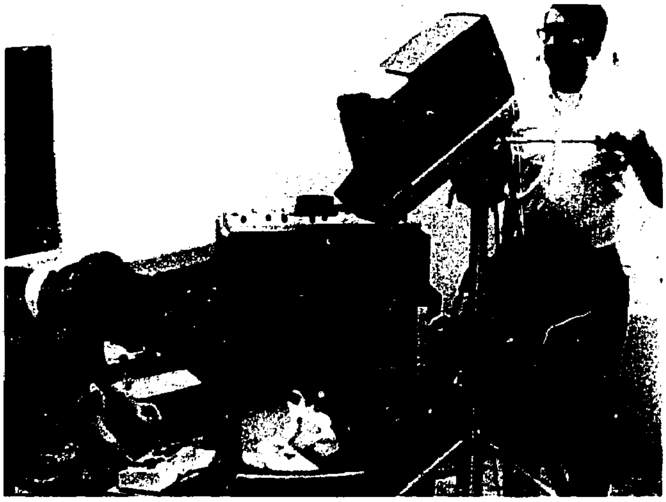


Plate 2d. Videotaping of the CP Subject Shown in Plate 2c. Trying a 14-Key Interface

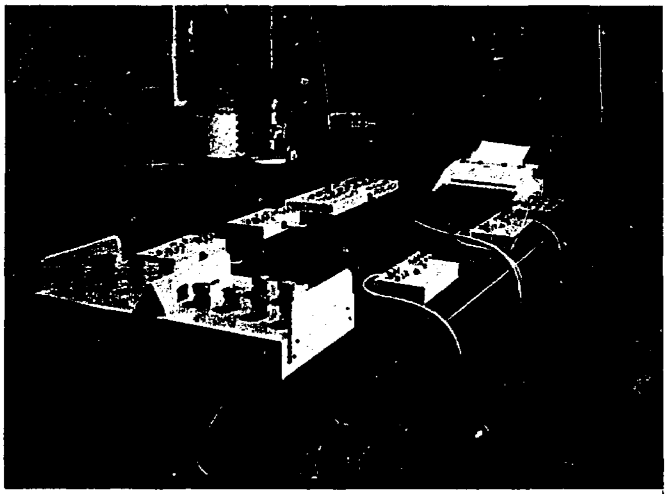


Plate 3a. Various Interfaces Connected to a Single Typewriter

Plate 3b. Group Instruction with Various Interfaces connected to a single typewriter.

The principal interfaces used in this phase of the program consisted of remote keyboards of 14 keys in two groups of seven, each key operating only one momentary contact switch. Two switches (one and only one switch from each group) operated concurrently produce a typewriter function or other output. Plate 4 shows a portable interface connected to a modified standard electric typewriter.

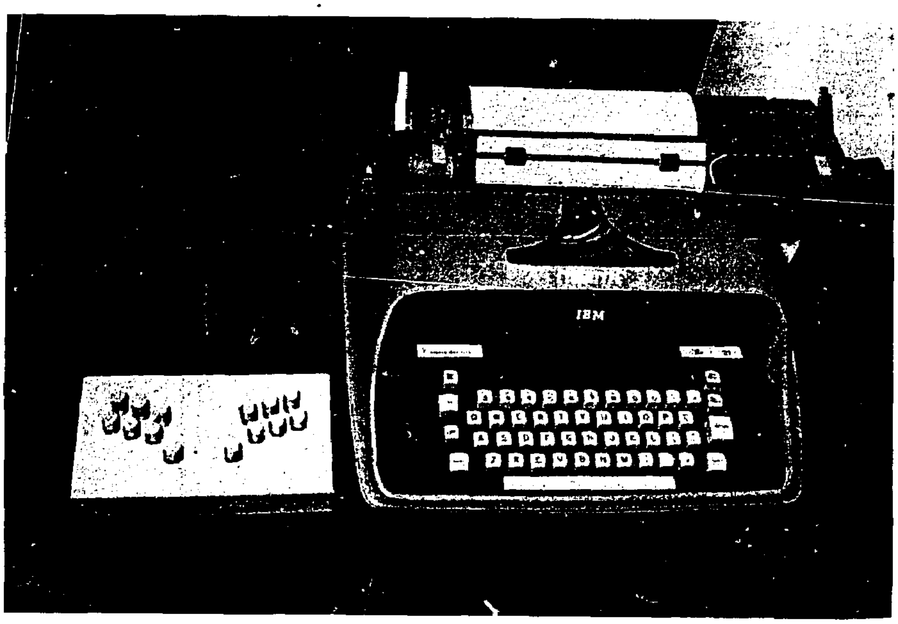


Plate 4. Portable "Cybertype" 14-Key Interface with a Modified Electric Typewriter

There is no requirement that the number of keys be the same in each group. In fact, to satisfy the special needs of Subject No. 103, a mouth-finger interface was used with two groups, of three and 16 keys. This 3x16 interface thus produces 48 characters and functions (see plate 5). The subject operates a miniaturized bank of eight double-throw switch levers that fit in the mouth, enabling the subject to produce 16 switch closures with her tongue. The other three switch closures required for the bilateral-input are obtained from one fixed and two finger-contact switches arranged so that the subject can operate the latter two with a slight hand movement.

16-position Mouth Switch

3-position Finger Switch

Plate 5. Bilateral-Input Interface (3x16)

III. TRANSFER CODE

The initially assigned code, previously reported, is as shown in figure 3. Each character or function produced by a pair of keys of the interface is shown at the intersection of the two rows defined by the two keys selected, one for

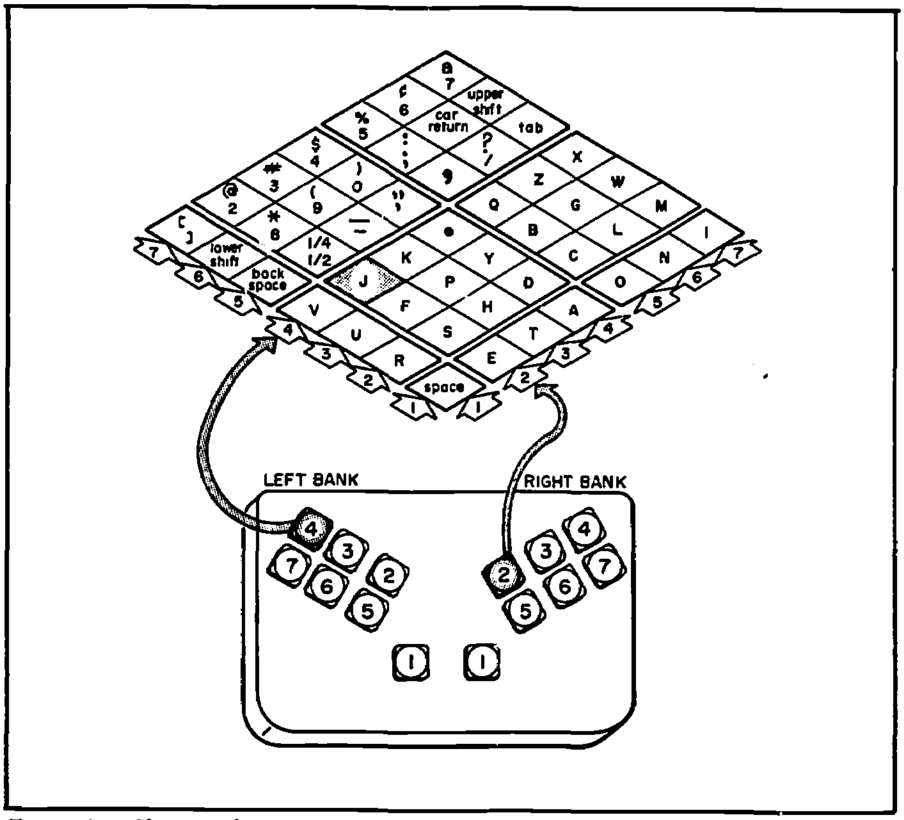


Figure 3. Character/Function Bilateral Transfer Code (Showing keying position for "J")

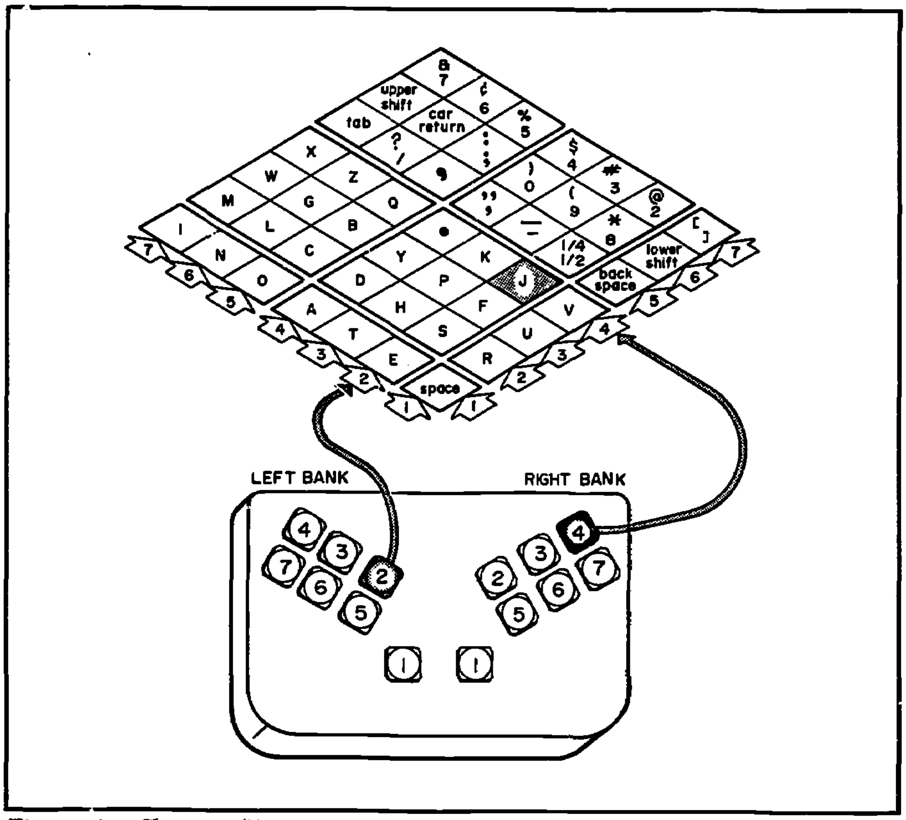


Figure 4. Character/Function Bilateral Transfer Code for Left-Handed Subjects (Showing keying position for "J")

LEFT BANK

4

	Lower	Upper
1	v	V
2	j	J
3	k	K
4	● Period ●	
5	q	Q
6	z	Z
7	x	X

3

	Lower	Upper
1	u	U
2	f	F
3	p	P
4	y	Y
5	b	B
6	g	G
7	w	W

2

	Lower	Upper
1	r	R
2	s	S
3	h	H
4	d	D
5	c	C
6	l	L
7	m	M

7

	Lower	Upper
*1	1/2	1/4
2	2	@
3	3	#
4	4	$
5	5	%
6	6	¢
7	7	&

6

	Lower	Upper
1	Lower Shift	
2	8	*
3	9	(
4	0	)
5	;	Colon :
6	Carriage Return	
7	Upper Shift	

5

	Lower	Upper
1	Back Space	
*2	=	+
3	-	_
4	'	"
5	, Comma ,	
6	/	?
7	Tabulator	

1

	Lower	Upper
1	Space	
2	e	E
3	t	T
4	a	A
5	o	O
6	n	N
7	i	I

RIGHT BANK

2

	Lower	Upper
1	e	E
2	s	S
3	f	F
4	j	J
*5	=	+
6	8	*
7	2	@

3

	Lower	Upper
1	t	T
2	h	H
3	p	P
4	k	K
5	-	_
6	9	(
7	3	#

4

	Lower	Upper
1	a	A
2	d	D
3	y	Y
4	● Period ●	
5	'	"
6	0	)
7	4	$

5

	Lower	Upper
1	o	O
2	c	C
3	b	B
4	q	Q
5	, Comma ,	
6	;	Colon :
7	5	%

6

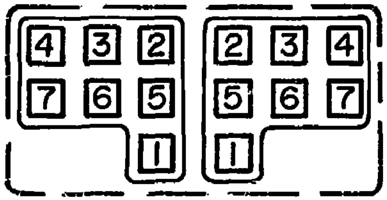
	Lower	Upper
1	n	N
2	l	L
3	g	G
4	z	Z
5	/	?
6	Carriage Return	
7	6	¢

7

	Lower	Upper
1	i	I
2	m	M
3	w	W
4	x	X
5	Tabulator	
6	Upper Shift	
7	7	&

1

	Lower	Upper
1	Space	
2	r	R
3	u	U
4	v	V
5	Back Space	
6	Lower Shift	
*7	1/2	1/4



14-KEY KEYBOARD, SHOWING LEFT AND RIGHT KEYBANKS WITH ASSIGNED NUMBERS.

NOTE:

LOWER=LOWER CASE & LOWER SHIFT POSITION.

UPPER=UPPER CASE & UPPER SHIFT POSITION.

* =VARIABLE, DEPENDING ON TYPEWRITER.

Figure 5. Character/Function Bilateral Transfer Code (For IBM Model C Electric Typewriters)

LEFT BANK

4

	Lower	Upper
1	v	V
2	j	J
3	k	K
4	● Period ●	
5	q	Q
6	z	Z
7	x	X

3

	Lower	Upper
1	u	U
2	f	F
3	p	P
4	y	Y
5	b	B
6	g	G
7	w	W

2

	Lower	Upper
1	r	R
2	s	S
3	h	H
4	d	D
5	c	C
6	l	L
7	m	M

7

	Lower	Upper
*1	]	[
2	2	@
3	3	#
4	4	$
5	5	%
6	6	¢
7	7	&

6

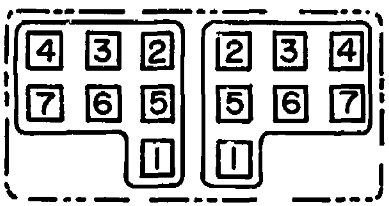
	Lower	Upper
1	Lower Shift	
2	8	*
3	9	(
4	0	)
5	;	Colon :
6	Carriage Return	
7	Upper Shift	

5

	Lower	Upper
1	Back Space	
*2	!	Degree°
3	-	_
4	'	"
5	, Comma ,	
6	/	?
7	Tabulator	

1

	Lower	Upper
1	Space	
2	e	E
3	t	T
4	a	A
5	o	O
6	n	N
7	i	I



14-KEY KEYBOARD, SHOWING LEFT AND RIGHT KEYBANKS WITH ASSIGNED NUMBERS.

RIGHT BANK

2

	Lower	Upper
1	e	E
2	s	S
3	f	F
4	j	J
*5	!	Degree°
6	8	*
7	2	@

3

	Lower	Upper
1	t	T
2	h	H
3	p	P
4	k	K
5	-	_
6	9	(
7	3	#

4

	Lower	Upper
1	a	A
2	d	D
3	y	Y
4	● Period ●	
5	'	"
6	0	)
7	4	$

5

	Lower	Upper
1	o	O
2	c	C
3	b	B
4	q	Q
5	, Comma ,	
6	;	Colon :
7	5	%

6

	Lower	Upper
1	n	N
2	l	L
3	g	G
4	z	Z
5	/	?
6	Carriage Return	
7	6	¢

7

	Lower	Upper
1	i	I
2	m	M
3	w	W
4	x	X
5	Tabulator	
6	Upper Shift	
7	7	&

1

	Lower	Upper
1	Space	
2	r	R
3	u	U
4	v	V
5	Back Space	
6	Lower Shift	
*7	]	[

NOTE:

LOWER = LOWER CASE & LOWER SHIFT POSITION.

UPPER = UPPER CASE & UPPER SHIFT POSITION.

* = VARIABLE, DEPENDING ON TYPEWRITER.

Figure 6. Character/Function Bilateral Transfer Code (For IBM Selectric Typewriters with Prestige Elite, Courier, Letter Gothic, or Delegate Type)

LEFT BANK

4

	Lower	Upper
1	v	V
2	j	J
3	k	K
4	• Period	•
5	q	Q
6	z	Z
7	x	X

3

	Lower	Upper
1	u	U
2	f	F
3	p	P
4	y	Y
5	b	B
6	g	G
7	w	W

2

	Lower	Upper
1	r	R
2	s	S
3	h	H
4	d	D
5	c	C
6	l	L
7	m	M

7

	Lower	Upper
*1	1	±
2	2	@
3	3	#
4	4	$
5	5	%
6	6	¢
7	7	&

6

	Lower	Upper
1	Lower Shift	
2	8	*
3	9	(
4	0	)
5	;	Colon :
6	Carriage Return	
7	Upper Shift	

5

	Lower	Upper
1	Back Space	
*2	!	Degree°
3	–	_
4	'	"
5	• Comma	•
6	/	?
7	Tabulator	

1

	Lower	Upper
1	Space	
2	e	E
3	t	T
4	a	A
5	o	O
6	n	N
7	i	I

RIGHT BANK

2

	Lower	Upper
1	e	E
2	s	S
3	f	F
4	j	J
*5	!	Degree°
6	8	*
7	2	@

3

	Lower	Upper
1	t	T
2	h	H
3	p	P
4	k	K
5	–	_
6	9	(
7	3	#

4

	Lower	Upper
1	a	A
2	d	D
3	y	Y
4	• Period	•
5	'	"
6	0	)
7	4	$

5

	Lower	Upper
1	o	O
2	c	C
3	b	B
4	q	Q
5	• Comma	•
6	;	Colon :
7	5	%

6

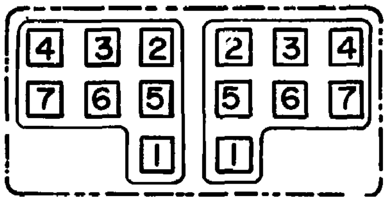
	Lower	Upper
1	n	N
2	l	L
3	g	G
4	z	Z
5	/	?
6	Carriage Return	
7	6	¢

7

	Lower	Upper
1	i	I
2	m	M
3	w	W
4	x	X
5	Tabulator	
6	Upper Shift	
7	7	&

1

	Lower	Upper
1	Space	
2	r	R
3	u	U
4	v	V
5	Back Space	
6	Lower Shift	
*7	1	±



14-KEY KEYBOARD, SHOWING LEFT AND RIGHT KEYBANKS WITH ASSIGNED NUMBERS.

NOTE:

LOWER = LOWER CASE & LOWER SHIFT POSITION.

UPPER = UPPER CASE & UPPER SHIFT POSITION.

* = VARIABLE, DEPENDING ON TYPEWRITER.

Figure 7. Character/Function Bilateral Transfer Code (For IBM Selectric Typewriters with Script, Orator, or Light Gothic Type)

each bank of seven. This code reflects the frequency of letter usage of English. An interface with left and right banks interchanged is available for subjects with left-hand dominance. The corresponding transfer code is shown in figure 4. Figures 5, 6, and 7 represent variations in the standard transfer code which result from using different electric typewriters as output devices.

IV. OUTPUTS

These man-machine communication systems employ a variety of output forms:

1. PRINTED.
   This output form, used throughout the program described in this report, is produced by remotely operated, modified electric typewriters.
2. VISUAL.
   Configurations of "Cyberlex" and "Cyberlamp," word and letter displays serve as important elements of feedback by producing easily read, large letters especially helpful to visually handicapped persons. The displays also permit direct, real time, continuous visual communication between users of "Cyberphone" or "Cyber-Tone" without the need to produce printed text.
3. PUNCTIFORM.
   Modified, electrically operated machines are used to produce braille, HAIBRL, or other punctiform outputs.
4. AUDITORY.
   Several configurations of systems which produce auditory feedback for each character or function typed, are being evaluated.
5. PUNCHED TAPE.
   This output mode is being studied for information storage, transport, and retrieval.
6. TACTILE.
   Several configurations of systems which provide feedback to blind and/or deaf-blind persons by tactile indications, are being evaluated.
7. MAGNETIC TAPE.
   Means of recording on magnetic tape information produced by "Cyber-Tone" and "Cyberphone" for storage, transport and retrieval are being evaluated.

"What are some of the developments that promise solutions of these problems? Two of the most exciting: first, man-machine communications systems that adapt and compensate for sensory and/or motor disabilities; second, a programmatic approach to training. Together, they can demonstrably help people with learning disabilities.

"The objective of one current study of man-machine communications systems for handicapped individuals is to learn how persons with severe physical handicaps and/or minimal brain dysfunctions can be enabled to communicate through the printed, audible, and punctographic word. By employing interfaces which not only match the machine's operational requirements, but also the individual's performance capabilities, individuals who heretofore could not communicate via the written or printed word are now demonstrating otherwise."

Part Three TELEPHONE COMMUNICATIONS FOR THE HANDICAPPED

The deaf, the deaf-blind, and those individuals who are unable to speak or who have severe speech impediments, are denied the use of effective telephone communication. A number of special devices and facilities are in use to restore some measure of telephonic capability for these individuals. Telephone companies provide special devices that augment the normal telephone. Also, automatic typewriters provided by certain organizations are available to deaf individuals for communication to and from fixed installations. One of these units (see plate 6) weighs approximately 275 pounds and requires the use of a special converter such as the Phonetype*. This is a light weight, efficient converter which can easily be installed at any fixed installation which has appropriate receiving equipment. These systems leave much to be desired in situations where handicapped individuals are away from fixed installations or wish to use regular public telephones.

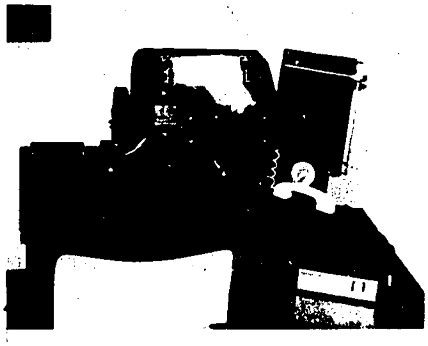


Plate 6. Automatic Typewriter with Special Converter for Telephone Communication

*Proprietary to Applied Communications, Inc., Menlo Park, Calif.

To provide new and necessary capability for these handicapped individuals to communicate by telephone, C/R/I has undertaken to evaluate the "Cyberphone" and "Cyber-Tone," two portable educational telephone communications systems. Many of these new capabilities appear feasible at education centers where use of telephonic devices can be extended to include access to computer library files. This form of information retrieval has been unavailable heretofore to the handicapped student.

The "Cyberphone" is a portable, battery-operated, solid state instrument which permits the deaf, the deaf-blind, and individuals incapable of speaking, or having severe speech impediments, to communicate via telephone over regular telephone circuits. An early prototype unit, weighing about 28 pounds, and portable, but requiring external AC power is shown in plate 7, at the left. A new unit, completely portable, and with battery power included, but weighing only about eight pounds is shown in plate 7, at the right.

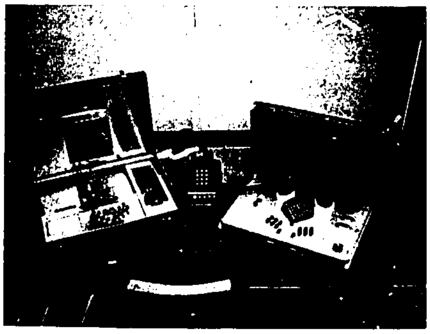


Plate 7. Cyberphones

The use of acoustic coupling for transmission, and magnetic coupling for reception, obviates the need for rental or lease of telephone lines or direct connections between the "Cyberphones" and the telephone lines, thereby eliminating both the cost and inconvenience of fixed location operation. The equipment utilizes a "Cybertype" 14-key, bilateral-input interface with the same transfer code used in all CYBERCOM elements. It provides a miniature, visual, alphanumeric display, and can operate a typewriter or a braillewriter. Thus, typed hard copy and/or braille copy are available at both ends of the communications link to augment the built-in visual display.

In the transmit mode, the equipment encodes each character or typewriter function desired from the 14-key interface into a sequence of six binary data bits. These data bits, along with a start and a stop pulse, are combined to form a sequential eight-bit 'word.' The binary levels, in turn, determine which of two audio frequencies are generated by the transmitter's oscillator. The amplified sequence of binary tones drives a small speaker which is acoustically coupled to the telephone.

In the receive mode, signals from the telephone are coupled inductively to the equipment, amplified, and the eight-bit 'word' is regenerated. The six data bits are then decoded and the decoder output is used to control a bank of matrix drivers compatible with all CYBERCOM devices. The timing sequence is such that "Cyberphone" is capable of operating at speeds up to 150 words per minute. The transmitter is muted and the receiver is activated except when actually transmitting information. Thus, no action by the operator is required in switching from the transmit to the receive mode, and the transmit mode is entered automatically by inputting information through the 14-key interface.

The nature of the signal tones used for "Cyberphone" communication permits use of ordinary low-cost portable-type recorders for temporary or long-term information storage. These recorders have successfully been used to pick up signal tones from either the telephone or the "Cyberphone" speakers. Subsequent playback can be either to the telephone for remote "Cyberphone" decoding and display of the recorded information, or directly to "Cyberphone" for local readout.

Self-contained, rechargeable batteries provide up to five hours of operation between each overnight charging operation. Alternatively, house current power, 110-130 V, 60 Hz, can be used when long periods of operation at fixed locations are anticipated.

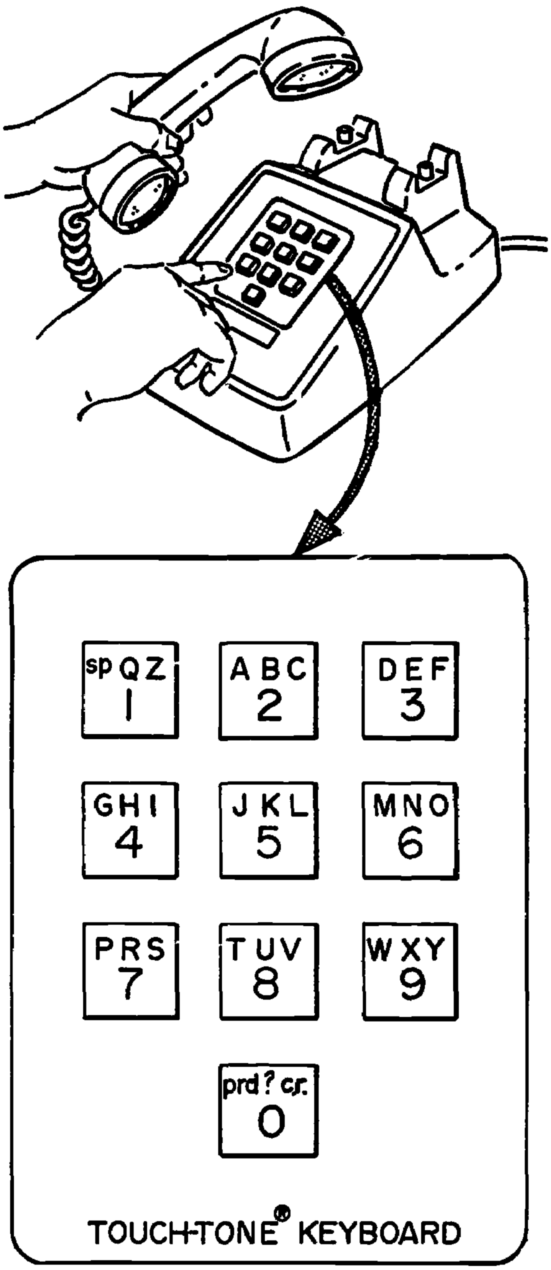
The use of completely solid state circuitry, sequential binary words for the information format, and a two-toned transmitted signal (frequency-shift keying) provide a reliable, lightweight, and portable system. Tape recordings of the system signals have been transmitted over long distance lines on several occasions with 100 percent copy received. These tape recorded signals have been sent over standard transatlantic telephone voice circuits, with about 85 percent copy recorded at the receiving end. In this case, the overseas time-sharing switching circuits introduced transient and hostile signal effects which resulted in occasional erratic performance, but not sufficient to jam the contents of the message.

Continuing activity will be to prepare test procedures, to determine modes of its usage, and to measure its effectiveness in satisfying communications needs for the handicapped.

The second system for use by the handicapped is "Cyber-Tone." It provides an effective and efficient (no equipment is required at the transmitting end) means of telephone communication for the deaf and persons with speech impediments, by using only the push buttons on a standard Touch-Tone® telephone. One readout device is a miniaturized version of the CYBERCOM visual display unit. In addition, a simple code converter provides coupling to any other element of the CYBERCOM system for readout of the communication.

"Cyber-Tone" operates by means of the tones generated by the Touch-Tone®, using a two-element sequential "Cyber-Tone" code, based on the location of the alphanumeric characters as they appear on a standard telephone (see figure 8). A character is transmitted by depressing the button on which the desired character appears, followed by depressing that button which identifies the location of the desired character within its letter group. For example, the letter "G" is transmitted by first depressing (and releasing) the button containing "G", followed by depressing the "1" button, which indicates that the letter "G" is the first letter in the three-letter group (GHI) appearing on the button. Numerals are transmitted by considering them as the fourth character of the group on their respective buttons; i.e., a numeral 6 would be transmitted by first actuating the "6" button followed by actuating the "4" button.

Thus, 24 letters of the alphabet and the digits zero through nine can be encoded for transmission simply by referring to the information printed on the telephone dial. The other two letters (Q and Z) and the space character are encoded by simply considering the "1" button to be imprinted with the characters: "space", "Q", "Z" and "1", in that order. Hence, "Z" is transmitted by actuating the "1" button followed by a "3". Additional encodings are used



sp = space
prd = period
c.r. = carriage return

upper shift = 8,7
lower shift 5,7

CYBER-TONE™ CODE

CHARACTER/ FUNCTION	KEYING SEQUENCE
A	2,1
B	2,2
C	2,3
D	3,1
E	3,2
F	3,3
G	4,1
H	4,2
I	4,3
J	5,1
K	5,2
L	5,3
M	6,1
N	6,2
O	6,3
P	7,1
Q	1,2
R	7,2
S	7,3
T	8,1
U	8,2
V	8,3
W	9,1
X	9,2
Y	9,3
Z	1,3
1	1,4
2	2,4
3	3,4
4	4,4
5	5,4
6	6,4
7	7,4
8	8,4
9	9,4
0	0,4
carriage return	0,3
period	0,1
question mark	0,2
space	1,1
upper shift	8,7
lowershift	5,7

Figure 8. "Cyber-Tone" Transfer Code

with the prototype unit to expand the utility of the system, especially when coupled to typewriter readouts of the CYBERCOM family. The prototype code is tabulated in figure 8. With the 10-button keyboard and a two-element sequential code, the unit has a potential encoding capability of 100 characters or functions.

The simplicity of this encoding process allows a totally inexperienced operator to achieve speeds of eight to ten words per minute after only a few minutes of practice. The practical upper limit of speed is approximately 15 words per minute, although higher speeds can be achieved with practice.

A portable ¼-cubic foot battery-operated decoder unit providing visual readout weighs less than 5 pounds. This decoder equipment is necessary only in receiving Touch-Tone® encoded communication, and not for transmitting. Thus, a person with hearing, but with a speech impediment, would not require any equipment for his end of the communications link, but those with whom he desired to communicate would require the portable decoder.

"Today, it is well within the state of the art dramatically to help many learning-disabled and/or physically handicapped individuals. How? By means of economical, electro-mechanical aids that compensate for their congenital or adventitious deficiencies, and use of systems that may even enhance development of their intellectual, sensory, and motor potentialities. Man-machine systems, designed for the individual's requirements, are beginning to demonstrate significant improvements in the operational and communication skills prerequisite to intellectual development.

"One of our goals is to allow individuals to express themselves through the printed word, thereby stimulating the development of otherwise dormant intellectual and motor potentialities. This goal is based on the assumption that our handicapped children must communicate via the written word if they are to be educated.

"We expect that by studying the attainable efficiency of communication possible in such unusual and multimodal communications arrangements, new insights into the neurophysiological control of movements and the man-machine communications and coding processes will emerge—insights of theoretical, as well as practical, interest. Our goals are also aimed particularly at a better understanding of such considerations."

Part Four | HAIBRL

HAIBRL, an experimental punctographic communications system, was conceived and developed at C/R/I during the present program. The principal objective of this tactile system is to enhance the capability of blind individuals who have not been successful in learning standard braille. HAIBRL has the potential to serve not only totally blind individuals, but also those with marginal vision, as well as some with no visual impairments who may need a tactual augmentation in communicating. HAIBRL could lend itself well for use in scientific and technical work, music, and foreign languages because of its richness in unequivocal patterns, adaptability to international phonemes, and its use of a minimal number of dots per character, function, or symbol. Its richness in unequivocal patterns suggests applications even for sighted people in environments where tactile inputs are needed, for example, where there is no light and written instructional information is needed or, where the user may not refer visually to informational cues.

HAIBRL is free of the principal shortcomings of braille (Nolan and Kederis, 1969), which are the following:

1. Braille patterns are difficult to recognize when there is a high multiplicity of dots.
2. In braille, too few different character patterns are available.
3. Of the 63 possible dot configurations of the six-dot braille cell, 31 are equivocal (see Section 1.13 on HAIBRL, page 20 of the C/R/I Interim Report, Kafafian, 1968).

This ambiguity in braille patterns, combined with the high multiplicity of dots per character, causes confusion to beginners, and requires highly concentrated reading for many users. The braille reader who lacks tactile discrimination, or the beginner, errs frequently because of the complexity of the configurations presented. Since whole-word recognition is an important element in successful reading, and since multiplicity of dots in a whole word impedes easy recognition (Nolan and Kederis, 1969), standard six-dot braille has serious shortcomings.

HAIBRL, on the other hand, as analyzed and described in the Interim Report, offers an opportunity to overcome the deficiencies cited above. First, along with its reference bar (which is present in all HAIBRL cells), it uses only one or two dots for normal language, reserving three dots for special applications. Second, it has numerous different character patterns, all unequivocal. Finally, its number of available patterns far exceeds present demands on a punctiform system; thus, this system's constraints might be only the memory capability of the user.

Studies have continued on one HAIBRL cell configuration having 16 dot positions (see figure 9).

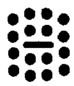


Figure 9. Experimental HAIBRL Cell

Eight of these positions are arranged above and eight below a horizontal reference bar. Essentially, there are four quadrants, each with four dot positions. The sizes and center-to-center spacing of the dots correspond identically to those of standard braille (see figure 10, area A).

One experimental, upward-writing slate with the above HAIBRL cell configuration was made and is being tested (see plates 8 and 9). The actual dimensions within the cells of the slate differ slightly from those described above. Other experimental slates, with slightly varying dimensions, also have been constructed (see plate 10). Observations made by experienced braille readers on samples embossed by these preliminary slates have suggested that experimental testing proceed on the 16-dot experimental HAIBRL cell configuration illustrated in figure 9.

The HAIBRL cell provides 16 unambiguous one-dot and 120 unambiguous two-dot patterns. The use of the reference bar alone as a character thus makes a total of 137 unequivocal patterns (see figure 11).

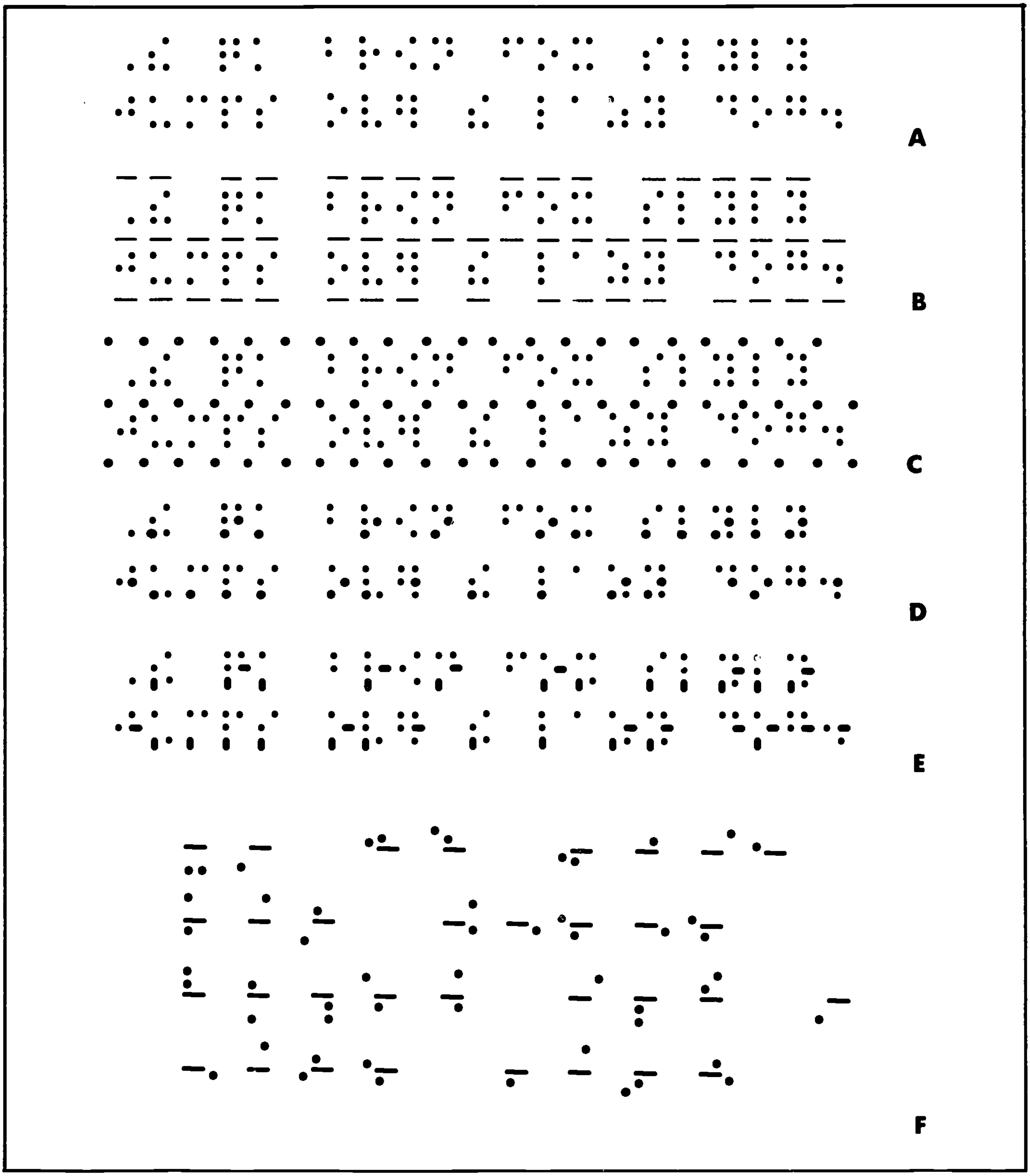


Figure 10. Examples of Punctograph Text; Braille with Variants, and HAIBRL

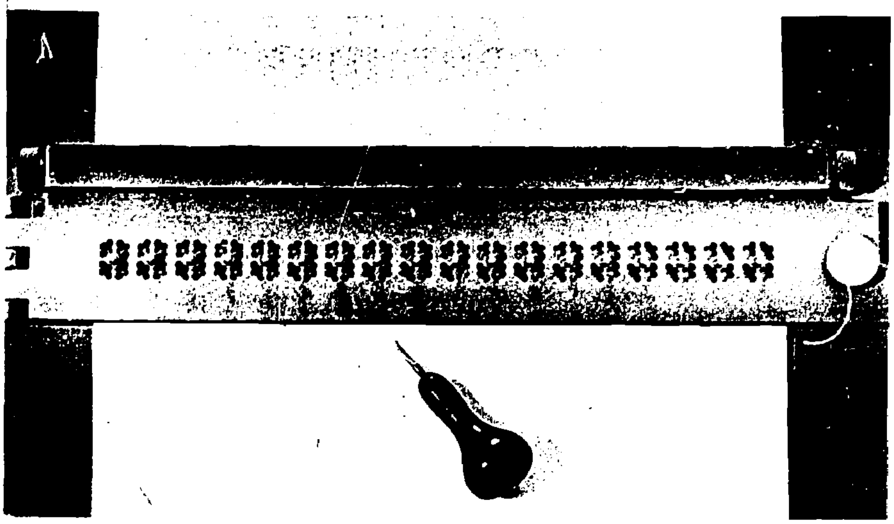
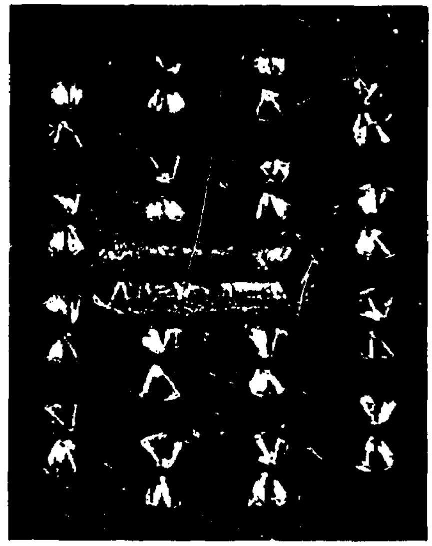
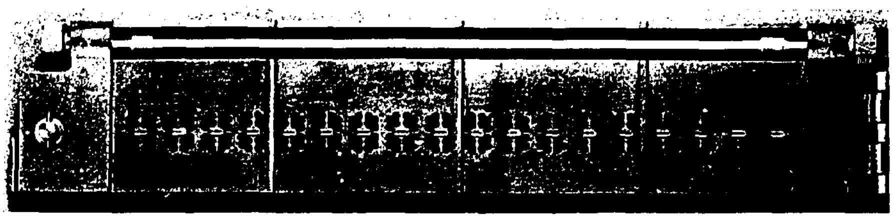


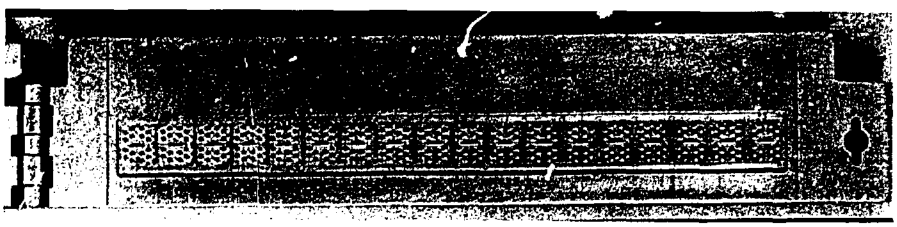
Plate 8. HAIBRL Slate, Upward Writing, and Stylus



Scale 7:1



Cover Plate, Inside View

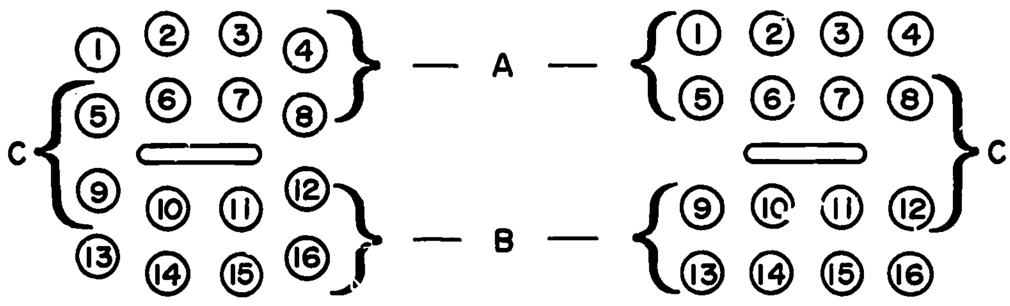


Bottom Plate

Plate 9. HAIBRL Slate, Upward Writing

Early indications are that for beginners, a dot pattern or character made from a cell with 16 dot positions with its reference bar should not have more height than the standard braille cell. Excessive height in a single character may impose difficulty on certain readers, requiring tactile searching over the character area, a process sometimes called "scrubbing." To preclude scrubbing, a height constraint is placed on HAIBRL characters.

Plate 10. HAIBRL Slate with Magnified View of Single Cell



Experimental Cell X1 (Not to scale) Experimental Cell X2

[E: Extended (not shown), with less than or equal to three dots but more than the three-dot height of a standard braille cell.]

Class		"No-Dot"	1-Dot	2-Dot	Sub-total	3-Dot	Total
Less than	A	–	8	28	36	56	92
3-Dot	B	–	8	28	36	56	92
Height	*C	1	–	16	17	48	65
3-Dot Height	D	–	–	8†	8	24‡	32
Sub-total		1	16	80	97	184	281
More than 3-Dot Height	E	–	–	40	40	376	416
Total		1	16	120	137	560	697

*Number in class C do not include configurations already counted in A and B.
†1-9, 1-12, 4-9, 4-12, 5-13, 5-16, 8-13, 8-16
‡1-5-9, 1-5-12, 1-8-12, 1-8-9, etc. . . .
Data are for style X1. For X2 combine figures in line D with line E.
Combination 1-5-10, and some others in class E are .030" higher than 3 Dots.

Figure 11. Summary of HAIBRL Cell Combinations

A legend has been assigned to the experimental HAIBRL cell (see figure 11) wherein each of the four rows of dots are numbered from left to right: the top (first) row contains dots 1, 2, 3, 4; the second row contains dots 5, 6, 7, 8; similarly, the third row has dots 9, 10, 11, 12; and the bottom row 13, 14, 15, 16. The reference bar is between the second and third rows (directly beneath dots 6 and 7 and directly above dots 10 and 11).

Referring again to figure 11, it can be seen that, in the two upper rows of dots (1-8), there are thirty-six one and two-dot characters which are less than the three-dot height of standard braille. These are called HAIBRL A characters ("A" meaning *above* the reference bar). The bottom two rows (dots 9-16), or HAIBRL B characters ("B" for *below* the bar), yield an additional 36 permissible dot patterns.

The second and third rows, or HAIBRL C ("C" for *center),* produce 16 new two-dot patterns. Eight additional dual-dot combinations, HAIBRL D ("D" for *duplex,* since it uses dots above and below the reference bar), are from three-dot high pairs taken only from the outer columns (dots 1, 4; 5, 8; 9, 12; 13, 16).

Thus, the number of permissible characters whose height does not exceed three dots is sixteen one-dot, eighty two-dot, and one reference bar only, or 97. Yet even with this height restriction, the 97 unequivocal HAIBRL patterns provide a richer basic tactile alphabet than the total 63 functions of standard braille.

With this same height constraint, and with three dots per character, HAIBRL offers 184 additional dot patterns. This new total of permissible HAIBRL characters is 281, giving HAIBRL a valuable and necessary versatility as a punctiform writing system.

In the event Experimental HAIBRL Cell X2 is used, the total combination of characters with the three-dot height constraint is reduced, but not significantly, as is indicated in figure 11, which reveals that 32 HAIBRL characters must be excluded, leaving 249 instead of 281 combinations.

In figure 11, HAIBRL E ("E" for *extended*) refers to combinations which have not more than three dots, but which exceed the constraints of a three-dot height pattern.

The full code, HAIBRL F ("F" for *full*) includes every possible configuration and yields a total of 65,536 functions available in the HAIBRL system.

At C/R/I and at the Department of Psychology Perceptual Alternatives Laboratory of the University of Louisville, preliminary evaluations of HAIBRL are being conducted by researchers. Continuing research on configurations of HAIBRL will involve controlled programs to measure the relative tactile discriminability of characters in HAIBRL X1, X2, and other forms. Subsequently, individual dot characters will be assigned meanings in terms of graphemes, letters, symbols, or phonemes for a research study of the communications effectiveness of HAIBRL. Figure 10, area A, shows the visual appearance of a written phrase in grade two braille; area F thereon shows a possible arrangement of this same phrase using HAIBRL.

In addition to studies of the 16-dot HAIBRL cell, the following are being considered:

1. Standard six-dot braille cell, but modified by the inclusion of a reference marker consisting of a bar or enlarged dots placed internal or external to the cell (see figure 10, areas B and C), to remove ambiguities of characters entirely.
2. Standard six-dot braille cell, but modified by increasing the diameter and/or height of dots 3 and 5, thereby reducing the number of 31 ambiguous braille characters to eight (see figure 10, area D).
3. Standard six-dot braille cell, but modified by elongating dots 3 and 5 (see figure 10, area E), to reduce the number of ambiguous braille characters to only four. (No special stylus will be required.)
4. Other configurations.

Preliminary studies to date show great promise that HAIBRL based on a 16-dot cell, and some of the other configurations examined, will provide new and useful capability in punctiform writing for tactile communications. It should be noted that, as a punctographic system for beginners with its present language utility, HAIBRL will have a constraint in that more space is required to communicate a message. In the experimental cells being tested, a space ratio between HAIBRL and braille of approximately 1.85 to 1.00 prevails on a horizontal scale, and a ratio of 1.33 to 1.00 exists on the vertical scale. This constraint will not impede or alter the planned usefulness of HAIBRL.

"Sensory feedback is essential in most learning processes; in the acquisition of reading skills, it is critical."

Part Five SENSORY AIDS FOR THE VISUALLY HANDICAPPED

Studies made at C/R/I on devices employed as sensory aids for the visually handicapped are introduced in this section. Visually handicapped individuals may have reached a reasonably balanced situation between their various activities concerned in communicating with their environment. However, when their capability in one phase of their activity is suddenly enhanced, as it may be through the main aspects of the present program, other phases fall out of balance and require new enhancement to permit taking full advantage of the benefit that may result. Thus, these sensory aid devices seek to provide collateral support to the main thrust of the work at C/R/I.

CANES

The standard nylon tip of a tubular, aluminum Hoover cane for blind individuals was replaced by a rounded steel alloy tip. The cane with the new tip has been subjected to strenuous preliminary tests by a regular user of this type of cane who had been displeased by the rapid wearing of the nylon tip. Furthermore, the worn, sharp, pointed end of the nylon tip presented potential danger according to its user because it could tear clothing or accidentally scratch furniture. The new, lightweight steel alloy tip has shown negligible wear in a 6-month period of hard usage (see plate 11). The user of the cane with the steel alloy tip was pleased with its performance, wearing, and safety properties.

Plate 11. Hoover Cane with Experimental Steel Tip

A newer design of a carbide tip, which is smaller and lighter, should have greater wear capabilities. It can also be easily replaced. Its design has been completed (see plate 12).

Loss or an impediment in a person's visual system limits navigation and imposes serious constraints when ambulating. Hence, the invention of radio direction finding by Marconi in 1906, and subsequent development of more sophisticated radio navigational aids over the past few decades, brought hope to blind individuals who envisioned use of these systems for personal navigational purposes. C/R/I has begun to investigate the utility of a low-cost radio guidance scheme employing commercially available, broadcast-band radio receivers as the means of guidance for the blind. With information derived from an error signal, a blind person may use existing radio systems to navigate in an orderly manner under certain conditions. One constraint of the navigational system (and there may be others) is that it would not actually detect objects, but would serve as a guidance instrument, providing direction in the azimuth plane. Other means would serve to warn the blind person of obstacles. Investigations are underway at C/R/I to ascertain the extent of the utility of radio networks for use by blind individuals.

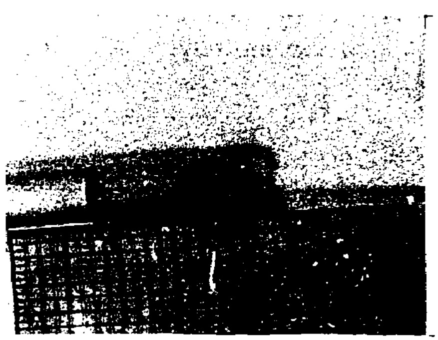


Plate 12. Hoover Cane with Experimental Carbide Tip

SONIC OBSTACLE DETECTORS

Experimental low-cost sonic devices that emit a continuous stream of audible pulses, variable in rate, have been obtained. C/R/I is working with two sightless subjects for a preliminary evaluation of the effectiveness of these sonic detectors.

COMMUNICATIONS FOR THE DEAF-BLIND

No well-established, satisfactory pattern exists for communicating with the deaf-blind. Teachers for the deaf-blind use individual but differing methods. The problem of providing the deaf-blind with practical and valuable means for communicating and navigating represents a fertile field for study and research. C/R/I is exploring man-machine systems within its area of special skills and experiences to find relatively simple and low-cost systems that will satisfy this essential need. For example, the use of overhanging mobile ribbons that can be activated by simple motor devices may be an effective means for guiding the deaf-blind in unfamiliar environments and in signalling to them. Already, preliminary success with an electric braille typewriter for use by the deaf-blind using a telephone has been demonstrated.

> "General and special educators are hopeful that these and other man-machine systems may be added to this growing list of educational aids. Educators hope that these innovations will improve the communications capabilities of learning-disabled and/or physically handicapped individuals so that they too can develop into independent and productive citizens."

Part Six | COLLATERAL STUDIES

I. LANGUAGE ECONOMY

Conventional English has high redundancy in its informational content. Numerous researchers have made extensive measurements to establish quantitative values of this redundancy. It is found to be present in the language both morphologically and orthographically. It is the nature of conventional English that the informational content permits anticipating with high probability of accuracy what the next word, morpheme, or letter (grapheme) will be in a normal sequence. Thus, every word, or morpheme, or grapheme, does not contain meaningful information, but is in the normal language as part of its natural adornment.

In the area of communications for handicapped children, where effecting written communication presents a severe physical burden, it should be possible to take advantage of the redundancy in normal English to reduce the physical burden on the severely handicapped to write, thus reducing mental and emotional stress.

For some categories of the multihandicapped, it has already been shown that the use of the 14-key, dual-input interface reduces the physical burden of producing graphemes in communicating. However, it is possible to go further in reducing this burden by reducing the number of graphemes required to convey a given amount of information in a written communication.

Based on the above precepts, studies have been started in two specific areas. One study concerns the use of phonemes, instead of the graphemes that are the conventional letters of the alphabet; and the other is in the area of abbreviated language. These two will be discussed separately.

A. PHONEMES

The nonphonetic spelling of normal English aggravates the learning and reading difficulty of those children who are handicapped in the area of specific learning disability. The additional step of converting the graphemes in a nonphonetically spelled word into proper sounds, then going to the word, and finally into meaning, often is enough of an additional hardship that it impedes or blocks learning altogether. Thus, it may be possible, by going the route of writing with phonemes, that children with specific learning disabilities may find new relief. Only preliminary studies have been undertaken in this area. The relative efficacy of the use of phonemes as the grapheme, in place of the familiar Initial Teaching Alphabet (ITA), has yet to be analyzed.

The phoneme used as the grapheme offers even greater promise for those who have a severe visual handicap. Those whose writing shall always be tactile and who will never need to effect a transition from a modified spelling of normal English (phonemic, ITA, or other) to normal spelling may find strong gains resulting from the use of such modified spelling. Thus, grade two braille (which is a modified form of spelling, but in punctiform writing), or phonemic writing, or other modified form of spelling, can be regarded as the matured form of spelling for that class of handicap.

An additional potential for the use of phonemes in writing for the handicapped, especially for the blind, is in the area of international communications. The phoneme has a strong character as an international alphabet. Thus, in an internationally adopted convention for punctiform writing, the phoneme becomes a more universal grapheme.

The benefits to be derived from a phonemic structure in punctiform writing may be greater in a new basic character other than the standard six-dot braille cell. HAIBRL, with its very much greater number of unambiguous and easily recognized characters, may provide considerably greater potential for its use in writing with phonemes. Studies on HAIBRL are reported separately in Part Four.

To support the continued study of the potential for the use of phonemes as the grapheme for various categories of handicapped children, a separate study has been made of the total number of phonemes comprising the English language as well as a large number of foreign languages. The results of this analysis are set forth as a separate report in Volume II, Appendix I: Phoneme Study.

B. ABBREVIATED LANGUAGE

The inherent redundancy in normal English has permitted exploiting this characteristic to advantage in a number of areas. Grade two braille, used as the standard abbreviation in punctiform writing for the blind among English-speaking peoples, has effectively reduced both the burden and bulk of punctiform writing. Telegraphic language used for economy in high-speed telecommunications is another form of abbreviated language. Popularly taught and extensively used in stenography are ABC Shorthand and Speedwriting, again, well-known forms of abbreviated language, in these cases, abbreviated spelling. The commercially available system known as Sténotype* also represents a kind of abbreviation in the language, in a somewhat different form.

Abbreviation in language, in either morphology, orthography, or both, reduces the total work in producing the written communication. This economy in producing a written communication is of extremely high value for handicapped persons. Whether a severely handicapped person is to write by hand, on an electric typewriter, or on a 14-key interface, the economy that comes from using an abbreviated language, in effect, uses the brain to reduce the burden on the motor capabilities of physically handicapped individuals. By learning the code for an abbreviated language, thus reducing the number of separate physical actions that must be taken to write out a given message, a distinct gain results. In this case, the fullness of the written sentence is in no way compromised. It appears in the full fluency or eloquence of which the writer is capable.

In the second form, a minimal alphabet is considered. Here, the emphasis is on reducing the number of graphemes necessary to communicate. In this concept, being studied presently, the approach is more particularly adapted to typing with bilateral-input interfaces. One type of interface consists of two groups or banks of seven keys each (for a total of 14 keys). The dual-keying input produces the approximately 90 distinct characters/functions of a standard typewriter. In the concept of the use of a minimal alphabet, it may be possible to require fewer characters/functions and thus use an interface with less keys.

The potential benefit of such a use of a minimal alphabet with a reduced keyboard is tremendous for the individual who is extremely handicapped in several categories. Some ways in which the required number of characters/functions may be reduced so greatly are, for example:

- Eliminating a number of letters of the alphabet by letting other letters or letter combinations serve.
- Being content with only the simplest punctuational structure.
- Modifying spelling.

The development of useful abbreviated languages or minimal alphabets requires analysis of a number of factors. These factors would be, among others:

- Related to existing forms of abbreviated language.
- Effective in reducing the bulk of a given message.
- Easy to learn by the writer.
- Easy to use by others who may not be handicapped, but who must communicate with the handicapped.
- Easy to recognize by others who have had no training in the abbreviated form of the language.

Only preliminary studies have been undertaken to the present.

II. CORRELATION OF VISUAL DEFECTS AND SPEECH DEFICITS

The degree to which visual impairment affects communication—both the receiving of an oral message and the articulation by a handicapped individual—was the object of a small preliminary study undertaken by three students at the University of Illinois. Their report is included as Appendix J in Volume II.

The results of this study provided no evidence of any significant correlation between visual defects and speech deficits. However, the small number of subjects involved in the study, and the preliminary nature of the experimental method, require further research to substantiate or refute these findings.

*TM and Proprietary to Stenographic Machines, Inc., Skokie, Ill.

Part Seven STUDY OF POSSUM* SYSTEM

In its study of man-machine communications systems for the handicapped, C/R/I is studying the Patient-Operated Selector Mechanism systems, a man-machine communications system manufactured by and proprietary to P.O.S.M. Research Project of Aylesbury, England. The system was developed by The Electro-Mechanical Laboratory for Aids to the Disabled, National Spinal Injuries Centre, Stoke Mandeville Hospital, Aylesbury, England.

One P.O.S.M. ("Possum") was obtained for extended evaluation. It operates by puffing and sucking at the open end of a hollow tube placed in the operator's mouth. Another mechanism, a word-store device, was examined but not evaluated; it appears to have numerous merits and should be studied further.

The system evaluated at C/R/I, identified as "Possum" Typewriter Control System Type 6A, permits the user to control the operation of an electric typewriter and tape recorder in all their functions, but in a digital sequential manner. A coded system of maintaining blowing and/or sucking pressure, with pauses, on a mouthpiece, controls the mechanism. A counting out of the timing tone beeps emitted by the mechanism permits the user to employ the code. A microphone for the tape recorder also is positioned near the operator's mouth to permit recording of any spoken communications. Thus, the value of this system is great for a totally paralyzed individual who does have control over his mouth. The complete unit is shown in plate 13.

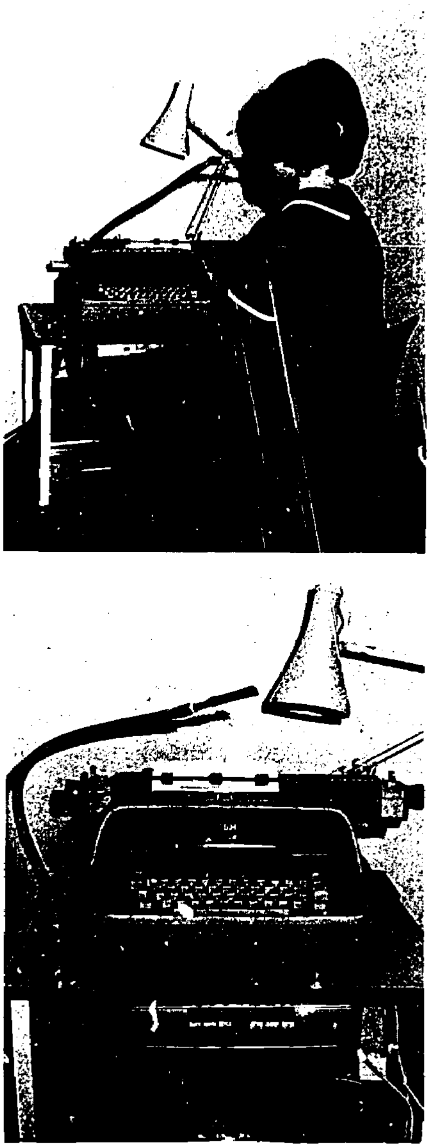


Plate 13. "Possum"

C/R/I investigators have suggested that a visual lamp—in addition to the tone signal used for subjects depending on audio feedback— be provided for feedback of the timing to subjects with hearing impairment. This visual feedback is now available for "Possum."

The equipment has been used in preliminary examination and in training of staff personnel (its operation has been totally reliable).

A second subsystem of "Possum" equipment that was examined is the Word Store. It consists of an electric typewriter and a magnetic core memory in which about 400 words and short phrases are stored. No failures were experienced during the demonstrations or at any other time.

In the configuration examined, the coding consisted of paired numbers in sequence, identifying which of a system of momentary-contact switches are to be operated. By selecting the appropriate code, either through the switch-closure input or the alternate breath-controlled input, each separate character or function of the typewriter, or any of the whole words or phrases that have been stored in the memory system, may be produced.

Numerous configurations of the "Possum" equipment are possible. Systems can be synthesized using various combinations of type-

Proprietary to P.O.S.M. Research Project, Aylesbury, Bucks, England. U.S. Patent 3.241,115 writer, tape recorder, Word Store, calculator, telephone connection, switch-closure input, breath-operated pneumatic control input, etc.

More appropriate instructional material for children is required for the "Possum" so that it will be as effective as the full capability of the device itself. In the opinion of the principal investigator, this is a remarkable system. C/R/I is presently investigating the preparation of appropriate instructional materials for these systems thereby permitting these mechanisms to be used by handicapped children.

The following is a chart (figure 12) of the "Possum" transfer code. Subscripts denote the number of inhaling, exhaling, or waiting time-signals required to produce a character or function. For example

$$I_2W_3O_1$$

means inhale (I_2) for two units of time (each time unit corresponds to one audible click emitted by the control mechanism), then wait (W_3) three units of time (three clicks), and finally exhale (O_1) for one unit of time (one click). Note that the final breath function is either an inhale or exhale function with a duration of one unit of time.

A	= $I_1W_1O_1$	W	= O_3O_1	. .	= $O_1W_3I_1$
B	= $O_1W_3O_1$	X	= $I_3W_1O_1$	? ,	= $I_1W_3I_1$
C	= $O_1W_2O_1$	Y	= O_3I_1	: ;	= $O_3W_1I_1$
D	= $I_2W_1O_1$	Z	= $I_4W_1O_1$	- -	= $I_2W_2I_1$
E	= O_1I_1	1	= $O_1W_2I_1$	" '	= $O_3W_2I_1$
F	= I_3O_1	* 2	= I_4I_1	+ =	= $I_3W_2I_1$
G	= $I_1W_3O_1$	/ 3	= O_4I_1	Shift	= $O_1W_1I_1$
H	= $I_1W_2I_1$	@ 4	= I_4I_1	Carriage Return	= $I_2W_1I_1$
I	= $I_1W_1I_1$	£ 5	= O_4O_1	Space	= I_1O_1
J	= $I_3W_1I_1$	$ 6	= $I_1W_4O_1$	Back Space	= $O_2W_3I_1$
K	= $O_2W_2I_1$	& 7	= $O_1W_4I_1$	Tabulate	= $I_3W_2O_1$
L	= $O_1W_2I_1$	¾ 8	= $I_1W_4I_1$	Repeat	= $I_4W_1I_1$
M	= I_3I_1	(9	= $O_1W_4O_1$	On / Off	= $I_2W_3I_1$
N	= O_2O_1	) 0	= $I_2W_3O_1$		
O	= O_1O_1	% ½	= $O_3W_2O_1$		
P	= $O_2W_1O_1$	⅝ ⅞	= $O_4W_1O_1$ †		
Q	= $O_3W_1O_1$	⅛ ⅜	= $O_4W_1I_1$		
R	= $I_1W_2O_1$				
S	= $O_1W_1O_1$				
T	= I_1I_1				
U	= $O_2W_1I_1$				
V	= $I_2W_2O_1$				

LEGEND

I = Air In (Suck)
O = Air Out (Puff)
W = Wait (No Action)

† This code also activates tape recorder

Figure 12. "Possum" Transfer Code

*The amount of air the "Possum" system requires is less than one cubic centimeter and therefore, is more a mouth-operated than a respiratory one. Hence, even though the subject may have respiratory problems or assists, the "Possum" control can still be operated effectively by mouth control.

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"We must remember that the beneficiaries of these programs for the learning-disabled include their families, members of their communities, and society in general. Certainly, a fertile field is open here for exploration, a field that demands more, by many magnitudes, than is required of industrial and space technology; a field that will yield beneficial aids and provide knowledge and communications skills for our children with specific learning disabilities."

C/R/I

C/R/I Second Report

Project No. 18-2003

Grant No. OEG2-7-070533-4237

STUDY OF MAN-MACHINE COMMUNICATIONS SYSTEMS FOR THE HANDICAPPED

VOLUME II

APPENDIXES

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The research reported herein was performed pursuant to a grant with the OFFICE OF EDUCATION, U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE. Grantees undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official OFFICE OF EDUCATION position or policy.

February 19, 1970

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF EDUCATION
BUREAU OF EDUCATION FOR THE HANDICAPPED

PREFACE

"As no man is an island unto himself, and no event emerges unrelated to other events, so every cause is in itself an effect, and every effect a cause that moves sometimes forward but oftener backward to alter the course of change."

Professor V. Lawrence Parsegian *
Rensselaer Polytechnic Institute

The Appendixes which follow contain detailed data supporting the summary information on the several studies set forth in Volume I of this report.

*Parsegian, V. Lawrence; Meltzer, Alan S.; Luchins, Abraham S.; and Kinerson, K. Scott, *Introduction to Natural Scie ice, Part One: The Physical Sciences.* Academic Press, Inc.: New York, 1968, p. 185. Permission to reproduce this copyrighted material has been granted by Academic Press (copyright cwner) to Cybernetics Research Institute, Inc. Reproduction by the users of any copyrighted material requires permission of the copyright owner.

CONTENTS

VOLUME II

Figures.

Appendix A TRAINING PROGRAMS WITH MAN-MACHINE COMMUNICATIONS SYSTEMS

This Appendix is an account of five special education studies conducted during the period of this program. These studies focused on the efficacy of the bilateral-input writing system in improving verbal communicative ability, rates of learning the character/function keying code, development of teaching procedures tailored to needs and capabilities of individual subjects, and integration of man-machine systems into the total educational program of the subjects.

These studies were intended to be preliminary and exploratory, for the purpose of developing teaching techniques and materials and generating hypotheses for later experimental validation. To assure valid and reliable results, future research must incorporate improved experimental control and standardization procedures and deal with unresolved problems of defining and equating classes of sensory, motor, cognitive and other disorders. These problems are always present in research with multihandicapped subjects and are intrinsically worthy of serious study.

Preliminary results from the studies in this report have been most rewarding and have reinforced the principal investigator's conviction that bilateral-input systems provide a channel of graphic communication for handicapped children who have no other means of writing. Experiments developing from these exploratory studies are being initiated and are described in the "Future Plans and Programs" section in Volume I of this report.

I. COMPARISON STUDY

A. INTRODUCTION

This initial exploratory study was performed to compare typing speed and errors for one typing system employing a 14-key, bilateral-input interface and a second system consisting of the 49-key interface of a standard electric typewriter. Typing performances were compared for motor handicapped and nonhandicapped children.

This section of the report combines results of two studies separately planned and executed. The first study dealt with a sample of physically handicapped children, and was identified as the "Comparison Study" in C/R/I's Quarterly Report for February 19 to May 19, 1969. The second study, completed later, consisted of nonhandicapped subjects.

B. METHOD

Subjects: The handicapped subjects consisted of 14 boys and 10 girls, ages 6 to 12, selected from the Belle Willard School in Fairfax County, Virginia; the Edison School in Arlington County, Virginia; and the Sharpe Health School in Washington, D.C. These 24 subjects were divided into 12 pairs roughly matched according to physical disabilities, age, sex, reading level, visual and auditory impairments, and IQs from school records. One member from each matched handicapped pair was assigned to the bilateral-input interface group (Group A), the other member to the 49-key keyboard group (Group B), for a total of 12 subjects in each of the two groups. The physical disabilities of the subjects were classified as follows: 14 cerebral palsy, two muscular dystrophy, two poliomyelitis, one alleged thalidomide, one nephrosis, one brain damaged, one congenital malformation, one Crouzon's disease, one dermatomyositis.

The nonhandicapped subjects consisted of 20 boys and 12 girls, ages 6 to 12, selected from the Key School, Arlington, Virginia. These 32 subjects were divided into 16 pairs roughly matched for age, sex, reading level, and IQs from school records. Again, one member from each matched pair was assigned to a bilateral-input interface group (Group C), the other member to a 49-key keyboard group (Group D), for a total of 16 subjects in each of the two groups. Subjects and interfaces used for Groups A, B, C, and D are shown in Table I.

TABLE I
Subject Composition and Interfaces Used by Four Experimental Groups

	14-Key Bilateral-Input Interface	49-Key Single Sequential-Input Interface
HANDICAPPED CHILDREN	GROUP A (N = 12)	GROUP B (N = 12)
NON-HANDICAPPED CHILDREN	GROUP C (N = 16)	GROUP D (N = 16)

APPARATUS

The equipment for Groups A and C consisted of 14-key, bilateral-input interfaces operating electric typewriters. Children with left-hand dominance used a reversal code box to interchange functions ordinarily performed by left and right sets of seven keys. Equipment for Groups B and D consisted of standard 49-key electric typewriters.

Subjects in Groups A and C, using the bilateral-input interface, were taught the letter-keying code using associative principles based on the Cyber-Circus Story$_{TM}$, developed by Anna Mae Gallagher and described in the C/R/I Interim Report (Kafafian, 1968). Subjects in Groups B and D, operating standard keyboards, were instructed using "Keyboard Town Story" (Gallagher, 1965). None of the keyboards in these experiments had letters or other coding on key tops.

A different series of typing performance tests was developed for each group of subjects, because sequences in which letters were taught differed between groups using bilateral-input interfaces and groups using standard keyboards, and because nonhandicapped subjects would be expected to progress at a faster learning rate than handicapped subjects. Each series of tests required mastery of increasing numbers of typed letters, symbols, and functions.

PROCEDURE

Four special education teachers on the C/R/I staff served as instructors. These teachers collaborated with other members of the staff in developing instructional materials and techniques in an attempt to equate treatment across groups of subjects.

Each of the handicapped subjects was given about 20 training sessions lasting 30 minutes, twice a week, over approximately a 3-month period. Testing began at about the fifth training session, with each test being administered for a timed 3-minute period. Most subjects had received practice with some test materials in previous training sessions. Each test was scheduled for a specific session, but tests were sometimes rescheduled if necessary to accommodate the child's learning pace.

Nonhandicapped subjects were given about ten training sessions of 30 minutes each, twice a week. The 3-minute timed tests were administered starting at about the fourth training session and continued through the tenth session.

At the end of training, appropriate final tests were given to the handicapped groups (A and B) and the nonhandicapped groups (C and D). Performance on these timed tests was determined by counting the number of letters, symbols, and functions and the number of errors produced in the 3-minute period.

C. RESULTS

Table II presents median numbers of characters (letters and symbols) and functions produced in three minutes on nine tests given to Group A (handicapped subjects, 14-key interface) and eight tests given to Group B (handicapped subjects, 49-key keyboard). Errors were recorded as a percentage of the number of characters and functions produced by each subject in each of his 3-minute tests. Median percentage

TABLE II

Median Number of Characters/Functions Produced
by Handicapped Subjects
Using Bilateral-Input and 49-Key Interfaces

		Test Number								
		1	2	3	4	5	6	7	8	Final
Group A (14-Key) (N = 12)	Median	47	35	36	36	44	47	54	53	47
	Quartile Deviation	13	14	17	16	20	22	21	34	25
Group B (49-Key) (N = 12)	Median	51	57	48	46	46	46	66		40
	Quartile Diviation	32	41	18	12	20	23	22		13

TABLE III

Median Errors as Percent of Characters/Functions Produced
by Handicapped Subjects
Using Bilateral-Input and 49-Key Interfaces

		Test Number								
		1	2	3	4	5	6	7	8	Final
Group A (14-Key) (N = 12)	Median	11	8	5	11	5	2	2	6	6
	Quartile Deviation	7	6	3	5	3	3	2	1	2
Group B (49-Key) (N = 12)	Median	14	10	14	9	6	14	10		14
	Quartile Deviation	14	13	6	7	5	8	6		11

errors are presented for Groups A and B in Table III. Medians and quartile deviations were calculated rather than averages and standard deviations to correct for skewed data distributions.

Training tests for Group A differed from those for Group B. To improve comparison of typing performance on these tests between groups, median performance scores were averaged across tests for each group. Since the same final test was given to Groups A and B, performance on this test can be compared directly between these two groups. These data are shown graphically in the upper part of figure 1 for number of characters and functions produced, and in the upper part of figure 2 for percentage errors.

A similar treatment was applied to data for nonhandicapped subjects in Group C (14-key interface) and Group D (49-key keyboard). Median numbers of characters and functions produced in training tests and final test for these groups are presented in Table IV; median percentage errors are shown in Table V. Data are presented graphically in the lower parts of figures 1 and 2.

D. DISCUSSION

Examination of data for handicapped subjects in figures 1 and 2 reveals that Group A subjects using the bilateral-input interface on the training tests typed on the average slightly fewer characters and functions, but with a smaller percentage of errors, than did the handicapped, Group B subjects using the 49-key keyboard. On the final test, however, subjects in Group A typed a somewhat greater number of characters and functions with a smaller percentage of errors than subjects in Group B. Although these differences are small in relation to intra-group variability (Tables II, III, IV, and V), they suggest at least a small post-training facilitative effect of the bilateral-input system for handicapped operators.

These results and interpretations may be qualified by recognition of improvements that should be made in experimental control procedures. To compare communicative performance for the bilateral-input and standard typewriter systems, factors affecting typing performance, other than typing interface configuration (the primary independent variable), must be equated across subject groups. This includes equating groups in terms of subject age, sex, IQ, dexterity, sensory-motor capabilities, and clinical diagnosis, as well as equating instructional materials and techniques as much as possible. Attempts were made to attain these objectives in this pilot study. However, improvements in control procedures are essential in future research to determine more validly the relative efficacy of various systems for written communication by handicapped subjects with certain sensory-motor capabilities and limitations.

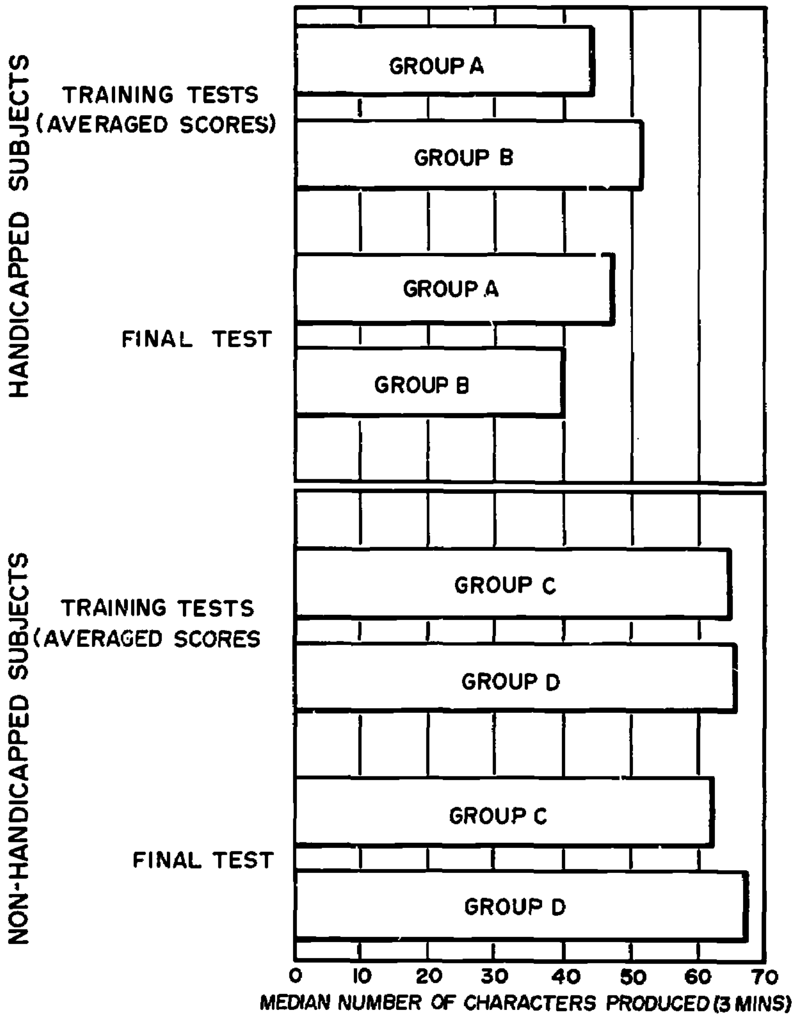


Figure 1. Median Number of Characters/Functions Produced by Handicapped and Nonhandicapped Subjects Using Bilateral-Input System (Groups A and C) and 49-Key Electric Typewriter (Groups B and D)

TABLE IV

Median Number of Characters/Functions Produced by Nonhandicapped Subjects Using Bilateral-Input and 49-Key Interfaces

		Test Number 1	2	3	Final
Group C (14-Key) (N = 16)	Median	61	54	78	62
	Quartile Deviation	14	17	26	23
Group D (49-Key) (N = 16)	Median	63	63	70	67
	Quartile Deviation	9	11	14	13

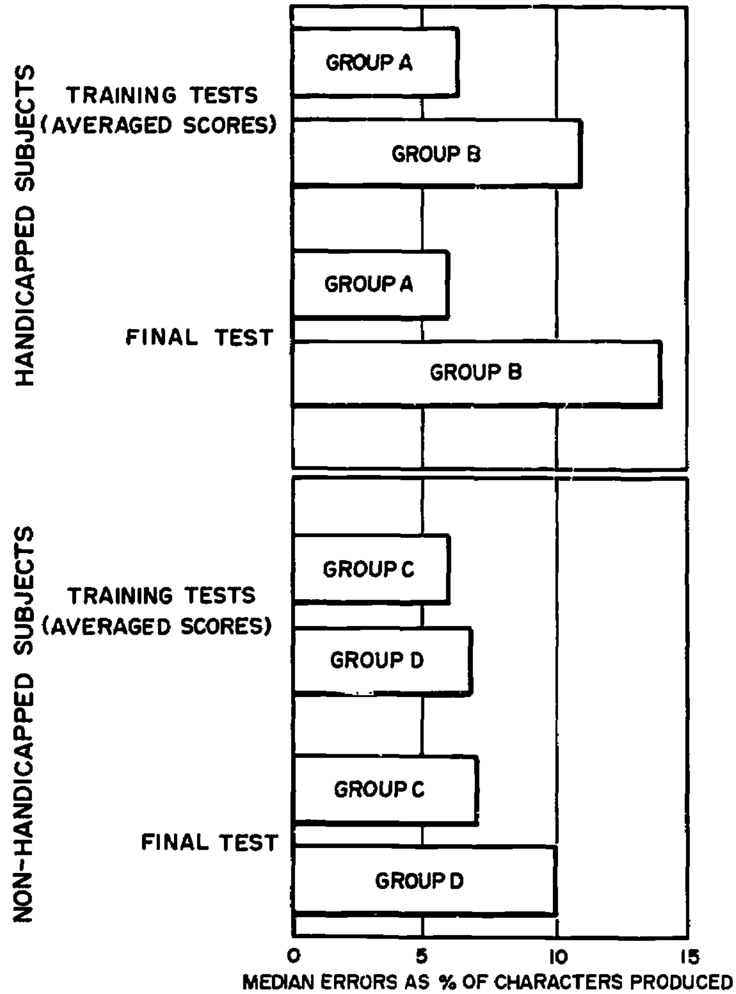


Figure 2. Median Errors as Percent of Characters/Functions Produced by Handicapped and Nonhandicapped Subjects Using Bilateral-Input System (Groups A and C) and 49-Key Electric Typewriter (Groups B and D)

TABLE V

Median Errors as Percent of Characters/Functions Produced by Nonhandicapped Subjects Using Bilateral-Input and 49-Key Interfaces

		Test Number			
		1	2	3	Final
Group C (14-Key) (N = 16)	Median	7	8	3	7
	Quartile Deviation	6	6	3	8
Group D (49-Key) (N = 16)	Median	8	5	7	10
	Quartile Deviation	3	4	5	8

Examination of data for nonhandicapped subjects in figures 1 and 2 reveals negligibly small differences betweem Group C (14-key interface) and Group D (49-key keyboard) in terms of numbers of characters and functions typed and percentage errors. These preliminary results suggest that for nonhandicapped persons, the 14-key bilateral-input system is no more difficult to use than the standard, 49-key electric typewriter. This finding provides some assurance that a handicapped child using the bilateral-input system is operating an interface which is not intrinsically more difficult to control than a standard typewriter keyboard. This assurance, combined with the adaptability of the bilateral-input interface to match the handicapped operator's limited performance capabilities, reinforces the value of the system for severely disabled individuals.

Keyboards used in this study had no letters or other coding displayed on key tops. Since individual keys on the 14-key, bilateral-input interface produce multiple outputs, depending on pairing of keys, one from each group, no symbols or markings are normally inscribed on key tops. Accordingly, keys of the 49-key typewriter were masked for equivalence with the unmasked keys of the 14-key interface. This procedure is supported by arguments for equating instructional and information-display conditions for the two typing systems. Alternatively, letters or other coding information might be provided for key tops on the bilateral-input interface for equivalence with information usually displayed by letters inscribed on key tops for the standard typewriter. Another alternative would be to employ the bilateral-input interface with blank key tops, while leaving the key tops of the standard typewriter unmasked. In this procedure the information provided by spatial positioning of bilateral pairs of keys would be compared to the information provided by letters displayed on key tops of the standard typewriter. Good arguments can be presented supporting each of these alternatives, and the most defensible procedure remains to be determined.

It is the strong belief of the principal investigator that for typewriter operation by handicapped children, bilateral-input spatial positioning of two or more fingers with the 14-key interface is more advantageous for acquisition and retention of the character/function keying code than the single-input touch-typing method used with the standard 49-key keyboard. Each letter, symbol, or function to be typed on the 14-key interface requires a concurrent, bilateral response by the operator, which may enhance formation of a "cognitive map" linking graphemes and typing functions to motor responses in a 'tactile-kinesthetic space' which includes a frame of reference provided by the fingers themselves or other parts of the body used to operate the keys. This system, then, enables an individual to practice or rehearse the typing code using a phantom keyboard defined by the positions of his fingers or other parts of his body engaged in the operation. This capability is not readily provided by the 49-key keyboard interface of standard typewriters.

A unique contribution of the bilateral-input system lies not only in its small number of keys and a major reduction in the area of the keyboard, but in its interface flexibility which permits modification to match the performance capabilities of the handicapped operator. This adaptability is demonstrated by some of the modifications of the basic bilateral-input system, described elsewhere in this report, such as the 'control-stick' interface, the foot-operated pedal interface, and the single-bank interface. Thus, it has been demonstrated in this program that a person whose physical disability precludes or greatly impedes his operation of a standard typewriter keyboard is able to communicate more successfully with a bilateral-input system matched to his remaining sensory-motor capabilities.

The principal investigator recognizes that this research is preliminary and exploratory in nature, and additional, more carefully controlled experimentation is required for a definitive comparison of bilateral-input and standard typewriter systems for handicapped persons. The present study strongly suggests the efficacy of the bilateral-input system for certain categories of handicapped persons, and it provides a foundation of subject data and teacher experience from which further experimentation may progress.

II. DIAGNOSTIC EXPLORATORY STUDY

A. INTRODUCTION

During the first phase of the Comparison Study with handicapped subjects, many questions arose concerning the materials and methods used in presenting bilateral-input typing. The instructors observed that while the Comparison Study was successful in teaching mastery of the bilateral-input code, it did not prepare subjects to make maximum use of the system as a communications tool within the classroom setting. Accordingly, this exploratory study was initiated to try new teaching procedures for future projects. An attempt was made to assess subjects' physical and intellectual capabilities for the purpose of developing instructional procedures appropriate for each child.

B. METHOD

Eight children (see Table VI) served as subjects, ranging in age from 6 to 13. Four were diagnosed as having cerebral palsy, one post-encephalitis syndrome, one arthrogryposis, one post-polio, and one muscular dystrophy. These subjects, Nos. 25 - 32, were initially screened for the Comparison Study, but were chosen instead for this study to provide a group heterogeneous in age and in type of physical disability.

The subjects attended about twenty 30-minute sessions in the hallway of the Sharpe Health School, Washington, D.C. The initial evaluation period proceeded according to the following:

1. The instructor introduced the "Cybertype", and made a first assessment as to the general type of interface configuration needed to match the subject's performance characteristics.

TABLE VI

Data on Subjects Included in Exploratory Study

Subject No.	Sex	Medical Diagnosis	CA	IQ	MA	C/R/I Dexterity Score	Functions Learned by End of Session 5	10	Final	Total Number Sessions
25	F	Post polio	13-8	101	13-10	15	39	39	43	15
26	M	Cerebral palsy	13-3	88	11-8	26	29	43	43	18
27	F	Post encephalitis	6-1	*	*	*	11	16	23	14
28	M	Cerebral palsy	8-5	**	*	23	23	26	36	19
29	M	Muscular dystrophy	11-7	84	9-9	29	32	41	45	17
30	F	Cerebral palsy	7-7	71	5-5	27	11	15	23	18
31	F	Arthrogryposis	8-0	88	7-0	15	11	18	29	21
32	M	Cerebral palsy	7-8	86	6-7	17	11	24	18	14

* Not available
** Estimated below 56

Key:
CA = Chronological Age (years-months)
IQ = Intelligence Quotient
MA = Mental Age (years-months)

2. A battery of tests was administered, including the Peabody Picture Vocabulary Test, the C/R/I dexterity test (Appendix C), and informal testing of auditory and visual capabilities.
3. Video tapes were made of each child typing exercises requiring use of a variety of keys, to be used in consultation with the occupational therapist, equipment technician, and teacher.
4. Various types of instructional materials were tried, including block and sandpaper letters, reading exercises, class assignments, creative writing, and poetry.

The three older children (ages 11–13) were taught the letter code without the aid of formal associations. Of the five younger subjects (ages 6–8), one was taught using associations with the "Cyber-Circus Story;" two were taught letter names, and then the "Circus" was used as reinforcement; and two were instructed without formal associations.

For the younger subjects, emphasis was placed on mastery of the letter names, the letter-keying code, and a small vocabulary from the Dolch Basic Word List (Garrard Publishing Co., 1960). Letter cards and blocks with sandpaper letters were used to reinforce letter recognition and word building, in preparation for typing letters with the 14-key interface. The older children were expected to do creative writing and class assignments after learning the code in the first few lessons. Speed and independent use in the classroom were the goals for all subjects. Teaching methods and aids were devised and adapted to these goals and individual needs. Instructional materials and techniques are contained in Appendix C.

Five subjects used the bilateral-input system with lamp display and a standard 14-key interface. Three subjects, because of their particular physical handicaps, used an interface having wider-spaced keys with rubber tops to preclude 'slipping.'

The subjects' classroom teachers and the occupational therapist of four subjects were consulted concerning instructional materials and style of interface to be used. The program of instruction was designed accordingly for each child.

When the two oldest subjects reached the stage of using the machine independently, the equipment was installed in their adjoining classroom for use in their daily work. Their teachers assigned pertinent exercises or language arts work to be done in the subjects' typing sessions.

C. RESULTS AND DISCUSSION

The subjects received between 14 and 21 instructional sessions, with performance ranging from Subject No. 29 who learned 45 letters, symbols, and functions in 17 sessions, to Subject No. 32 who learned 18 letters and functions in 14 sessions. These data are shown in Table VI.

Subject No. 26, a 13-year old boy with cerebral palsy, learned the code easily and tried to work on reading assignments, but had so much difficulty with spelling that these assignments were discontinued. Subsequently he devoted his time to creative writing which he found more enjoyable and easier. This subject had had previous instruction on a 49-key typewriter, but it had been discontinued because of the subject's slowness (2.8 words per minute on a 5-minute test given about 7 months earlier). During the sixteenth 1/2-hour lesson, this subject was given an equivalent 5-minute test on the 14-key interface and on a 49-key typewriter. With the 14-key interface he typed 3.5 words per minute and on the 49-key typewriter he typed 4.7 words per minute, suggesting transfer of training from the bilateral-input system to the 49-key typewriter.

Subject No. 25, a 13-year old girl, with paralysis of both upper and lower extremities as a result of polio, learned the code quickly and used her right index finger and the knuckle of her left index finger to type. At first she showed reluctance to use the 14-key interface; subsequently, she said it was faster and easier to use than the 49-key typewriter on which she had previously learned to type (although so slowly that its use had been discontinued). Her teacher reported that the subject used bilateral-input typing often in class.

Subject No. 29, an 11-year old boy, with muscular dystrophy, learned 45 functions with the 14-key interface and, on the final test, typed 4.9 words per minute.

Four younger subjects, ages 6 – 8, Nos. 18, 30, 31, and 32 learned most of the letters of the alphabet, a number of typing functions, and a few simple words. They typed at a rate of two or three words per minute on the final test. A 6-year old subject (No. 27), who could already identify letters, learned the code and typed at a rate of 4.3 words per minute on the final test.

Case studies of Subjects 29 and 30 are found in Appendix E.

It should be explained that even though typing speed data are being acquired, it is not by any means the measure of success of these communicative, educational systems. The fact that the child can be taught to communicate in printed form with these mechanisms and instructional aids is far more important.

Efforts to integrate the bilateral-input system into the classroom suggested that children can use the 14-key keyboards successfully for production of written responses under these conditions. However, further research is necessary to establish more precisely rates of acquisition of the letter-keying code, effects of instructional experience with bilateral-input systems on verbal and intellectual ability, and academic achievement through use of the systems in the classroom.

III. FOLLOW-UP STUDIES (EDISON SCHOOL STUDY)

A. INTRODUCTION

At Edison School, Arlington County, Virginia, three subjects who participated in the Comparison Study were given concentrated instruction and supervision four mornings a week for a month. The C/R/I instructor, a teacher in the previous study at this school, was well known by the school staff and children. The goal was to integrate the 14-key, bilateral-input interface with school work on a more intensive basis than the twice-a-week schedule used in other studies.

B. METHOD

Objectives for each of the three subjects, Nos. 2, 3, and 7, were different. A 6-year old boy, Subject No. 2, allegedly affected by the drug thalidomide, had severe impairment of arms and legs. He learned to type on the 14-key interface in the Comparison Study with relatively good speed (4 words per minute) and accuracy. At the request of his teacher, he was to use the interface for creative writing and for building his sight vocabulary. Subject No. 3, a 9-year old boy with cerebral palsy and a severe visual impairment, had not mastered the entire code in the Comparison Study. Unable to write or to use the 49-key typewriter effectively (according to his occupational therapist), this subject was given a 14-key interface which gave him writing experience and helped him develop a small sight vocabulary in preparation for reading. A 7-year old boy, Subject No. 7, with Crouzon's disease and very poor dexterity, had used the 49-key typewriter in the Comparison Study with limited success. His visual and dexterity problems as well as his hyperactivity and short attention span were the reasons for his selection as a subject for the 14-key interface. The objective for this child was to improve his attention span as well as to develop a means of written communication.

Lessons directed toward these objectives were planned with the classroom teacher. The 14-key interface and alphanumeric lamp display were used in the classroom or in a resource room depending upon the structure of the class for the day. The 14-key interface was used by each child for an average of 30 minutes per day, 4 days a week.

C. RESULTS AND DISCUSSION

Subject No. 7 had been instructed on the 49-key typewriter in the Comparison Study. His progress had been disappointing in view of average, or above average intelligence and rather good motor coordination, although his surgically formed fingers lacked dexterity. Hyperactivity plus multiple visual abnormalities were considered his major problems. Fascination with the intricacy of the 49-key typewriter proved so distracting that the subject was unable to concentrate on the letters typed. For this study, he was transferred to the 14-key interface, with the alphanumeric lamp display for visual feedback. The smaller number of keys on this interface proved less distracting, and the subject's performance improved. Typing exercises included words composed from scrambled letters, timed tests, practice sentences, and work given him by his classroom teacher (see figure 3). His ability to type using the bilateral-input interface was especially valuable in view of his nearly illegible handwriting (see figure 4).

Subject No. 3 (cerebral palsy with considerable spasticity, wheelchair-confined) was the most severely impaired child in the Comparison Study; he had auditory encoding problems in addition to visual difficulties. This subject's visual discrimination abilities were limited and he had extreme difficulty in following written material. Two one-half hour sessions per week resulted in only slow progress. He needed much repetition and a multisensory feedback approach to learning. To reach the interface, the subject had to stretch his arms from his shoulders so that he could place his hand on the keys.

```
          TODDAY  IS  FRIDAY.

                         BRETTLIKES BEES.

          TODAY IS SUNNY.

          BRETT LOVES A KITTEN.ROTSBUM

                          234567890 1019 1124 31 Buy 12 eggs.

     Isee 4 g cats.atei

  FAT FFUN BELL BAT BIRDS ATE THE CRUMCS IT IS FUN TO DANCE
                                             trrn it off
```

Figure 3. Typing Samples – Subject No. 7

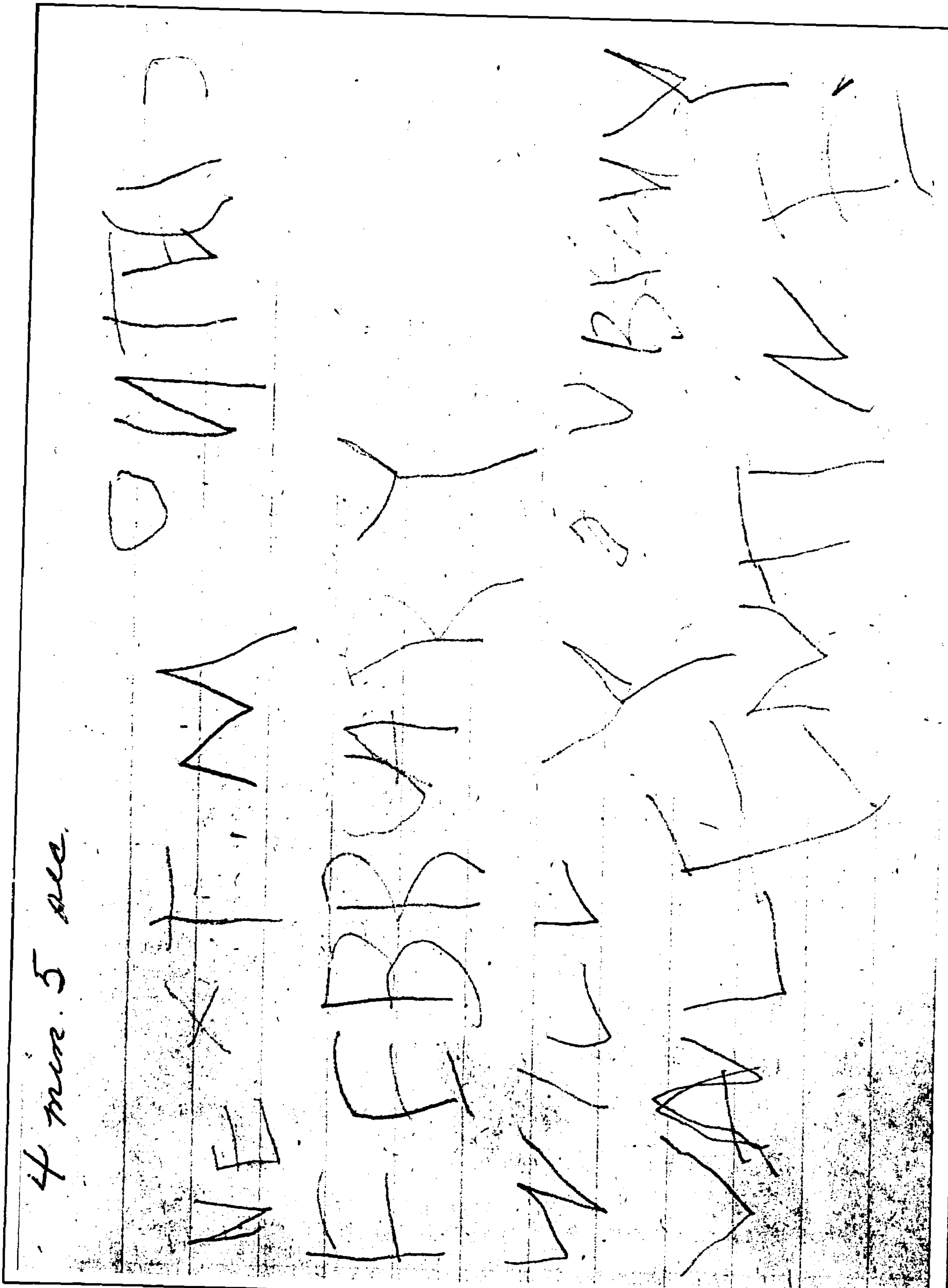


Figure 4. Handwriting Sample – Subject No. 7

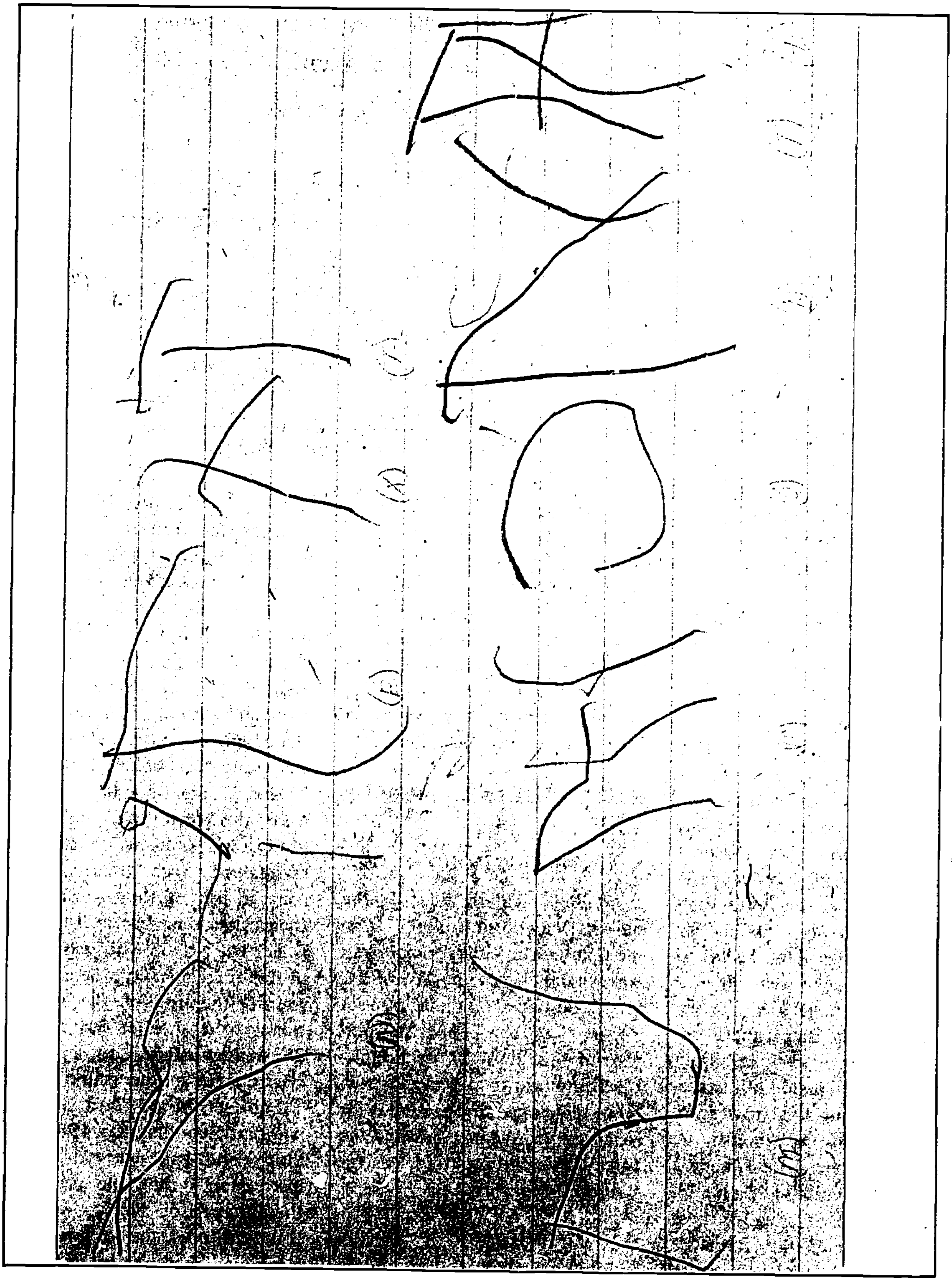


Figure 5: Handwriting Sample — Subject No. 3

His elbows flared out to bring his fingers into position. His handwriting was extremely labored and illegible (see figure 5), and attempts to type on a 49-key typewriter before this study were slow and difficult. However, with the aid of a modified bilateral-input interface, to the satisfaction of the subject and his teachers, he was able to type 27 characters and functions per minute by the last session, as compared to 12 characters per minute illegibly handwritten.

Instructional exercises for Subject No. 3 included timed test sentences and words on cards, original letters and teacher-supplied lists of words which posed difficult visual discrimination problems for him (see figure 6).

```
               THE MEOUNTY PPOLICEMAN

HIS SUIT IS RED  AND BLUE. --

HE HAS A GUN ANDRE HANDCUFFS.


            HELLO MRS. JANE

      WW& WHAT ARE YEOU DOING?THAIS AFTERNOON?

WILL YOU COME TTO SEE ME.

           COME WITH ME.

           DANNY WENT WITH CBRETT.

           HELLO WMALLK
```

Figure 6. Typing Samples – Subject No. 3

Subject No. 2 was a child with his right arm underdeveloped and with short legs, allegedly caused by the drug thalidomide. He was introduced to the 14-key interface code in the fall and learned it quickly and well. He typed slowly and deliberately but with few errors. The code reversal box was employed to make better use of the strength of his left hand. As his reading skills were on a first-grade level and his verbal ability on a much higher level, he found it a real challenge to write his own stories. This subject had been given the Spache Diagnostic Reading Scale in April 1969 and again after the 4-week period of instruction. His reading level rose from 1.8 to 2.3. In this month, he typed original stories and made a booklet of his work (see figure 7).

The period of training for these subjects with the 14-key interface took place during the last month of school, making it difficult for the investigators to measure results effectively. The machines were used successfully in the classroom with the subjects showing marked improvement in ability to communicate in writing. All three subjects used the equipment independently of the instructor and, by the end of the study, appeared to enjoy operating the system.

BELLE WILLARD SCHOOL STUDY

A. INTRODUCTION

At Belle Willard School, the subjects were four children from the Comparison Study sample and two children from the 1968 Pilot Study described in the Interim Report (Kafafian, 1968). The purpose of this phase of the Follow-Up Study was to develop instructional techniques and materials for achieving proficiency in using the 14-key, bilateral-input system for classroom operation.

B. METHOD

Subjects: The four children from the Comparison Study (Subjects 9, 14, 15, and 16) and the two children from the 1968 Pilot Study (Subjects 36 and 38) had all received instruction with the bilateral-input interface but had not developed independent proficiency in operating the equipment due to the severity of their physical handicaps. A summary of characteristics of these six subjects is presented in Table VII. Subjects 34 and 37, identified in Table VII, were also from the 1968 Pilot Study, and sporadic contact was maintained with them to encourage use of the interfaces in their classroom. Also in Table VII is Subject No. 35 who was scheduled for regular typing sessions toward the end of the instructional program after Subject No. 36 was transferred to a regular classroom in another school.

Subjects 34, 35, and 37, who had participated in the 1968 Pilot Study, and had received further instruction during the period of the Comparison Study, were encouraged to use the equipment for classroom work since they had achieved mastery of the letter-

Judy's Wedding

On Friday April 11, Judy and George got married. They are married now, and they live in an apartment, a whole hour away from us. Judy wore a white wedding gown, and it looked pretty ån her. Nan was a bridedmaid. I wore a blue and green suit. I also wore a tie. I looked very nice.

By

Jimmy

Today I Am Captain

I hold the flag, and I choose what record I want. Mrs. Noble gets the record, and I pat it on the record player. I am the leader going to lunch. I work the puppet Pebo during song time. I wear a round red captain's badge.

Everyone in the class gets to be captain sometime, but you have to do something good to be captain. This morning I had to try to get that silly class quiet, but they wouldn't listen to me.

By

Jimmy

Figure 7. Typing Samples -- Subject No. 2

keying code and requisite speed. These three subjects were also tested for code retention during the course of the Follow-Up Study.

Subjects came to the instruction room once or twice a week for ½-hour periods with a single instructor.

C. APPARATUS

The apparatus was a normal 14-key, bilateral-input interface and a close-coupled (one hand) interface which operated an electric typewriter. "Cyber-Circus" toys were set up in the room for reference and play. Between instructional periods, the equipment was available in classrooms where usage was not scheduled but was encouraged whenever possible.

D. PROCEDURE

Since subjects differed widely in performance, a variety of teaching materials and techniques was required to aid each child in developing requisite communications skills for producing academic work. Techniques employed in this study included use of visual feedback from alphanumeric lamp displays and from typed pages, coupled with auditory feedback from the instructor to provide information about letters and words typed; use of two interfaces on a multiple junction box into a single typewriter to encourage cooperation and competition by two children working alternately on the equipment; practice with spatial positioning exercises involving placement of fingers on a table top or even in the air into positions corresponding to pairs of keys needed to type a letter, symbol or function; and use of background music to aid subject morale.

TABLE VII

Summary Chart of Subjects, Follow-Up Study (Belle Willard School)

Subject Number	Diagnosis	CA (years-months)	IQ	Reading Level	Number of Sessions
9	Cerebral Palsy	7-5	78	1.8	9
14	Cerebral Palsy	10-2	90	5	25
15	Cerebral Palsy	9-9	89	2.3	13
16	Residual Traumatic Brain Damage	12-9	78	5	6
36	Cerebral Palsy Hemiplegia	11-3	93	3	17
38	Congenital Cerebral Palsy Hemiplegia	8-3	Average	2	21
34	Cerebral Palsy Hemiplegia	14-4	115	8	5
35	Thalidomide	9-1	73	*	7
37	Congenital Deformation, Bilateral Amputee	*	93	3	2

*Not available

The instructor maintained close contact with the school principal and, where possible, with classroom teachers. Teachers were encouraged to view instruction on the 14-key interface as an extension of classroom work and to advise the instructor of each child's needs which might be met during the instructional sessions.

E. RESULTS AND DISCUSSION

Initial testing revealed that subjects had retained all the letter-keying code learned during experience in previous studies, in spite of a lapse of at least four months. There was, however, a decrease in speed and accuracy.

All subjects achieved full mechanical use of the equipment and generally increased their typing speed above the level attained in the earlier Comparison Study (or 1966 Pilot Study).

Figure 8 shows median numbers of characters/functions, and errors typed by subjects in the present Follow-Up Study and in the earlier Comparison Study. For example, in timed, 3-minute tests requiring knowledge of 24 different letters, symbols, and functions, subjects in the Comparison and Pilot Studies produced a median number of 17 letters, symbols, and functions, while in the present study their performance improved to a median level of 35. Median errors remained at an approximately constant low level between one and five errors per test. It can be seen that the curve for number of characters and functions typed in the Comparison Study slopes downward, suggesting a decrement in performance as increasing numbers of different letters, symbols, and functions were introduced. The performance curve for the Follow-Up Study, however, slopes slightly upward, suggesting greater mastery of the function and letter-keying code.

Subject motivation was found to be an extremely important determinant of performance. Subjects 9 and 36 who were anticipating transfer to other schools and who could type, though inadequately, with a standard 49-key typewriter, showed some decrement in performance over time. However, Subject No. 14 who was highly involved in creating her own book of original fairy tales showed considerable improvement in typing speed on

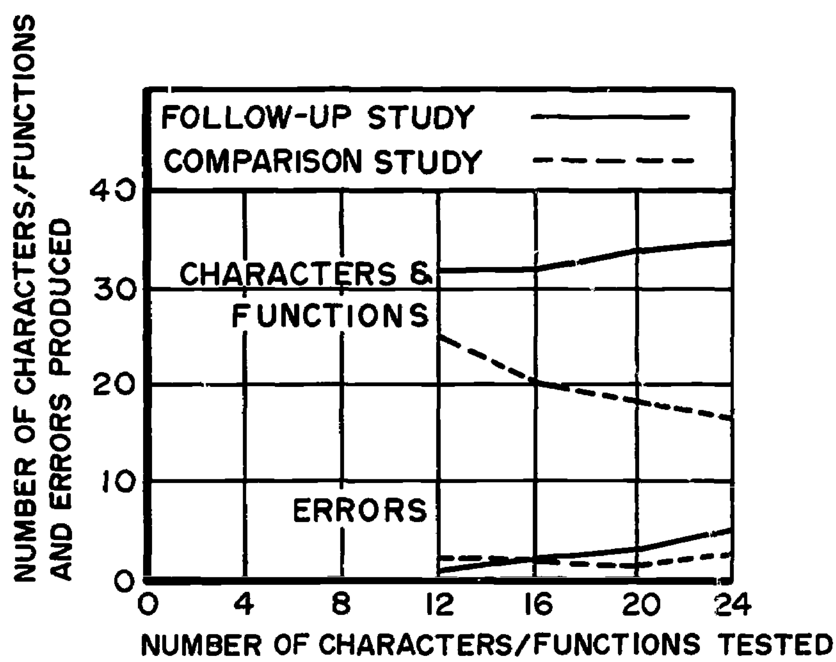


Figure 8. **Medium Number of Characters/Functions and Errors Produced by Subjects in the Comparison Study and by the Same Subjects in the Follow-Up Studies**

the 14-key interface. The researchers observed generally that the subjects who enjoyed using words for communication made the greatest progress in this study.

Exercises during instruction consisted of, in order of decreasing output, writing original compositions, copying word cards, typing timed tests and practice sentences, copying rhymes, and finishing school work. Original compositions were the most popular exercises and produced the greatest word output because the children became personally committed to their work and were proud of their results. Copies of these compositions were often made for children to take home, and two subjects each produced a booklet of their compositions, one of which was an extended fairy tale (Subject No. 14) and the other a collection of fanciful essays (Subject No. 38).

The effects of background music on typing performance varied between subjects. Some children enjoyed the music and found it conducive to performing their exercises. Others found the music distracting and were better able to concentrate on their exercise in a quiet room. The role of background music and its interaction with the individual personalities of subjects in affecting performance on typing tasks is a topic the researchers thought deserved further consideration.

Results with two 14-key interfaces coupled to a single typewriter suggested that subject interaction and competition may favorably affect attitude and performance. During teaching and testing sessions where children worked with the 14-key interfaces and other interface configurations, they could work together on the same typewriter, taking turns operating their own keyboards (see plate 1). At other times, the instructor could operate one keyboard interface and reinforce or correct the performance of a child at the other interface (see plate 2).

Spatial exercises were used to clarify and reinforce key-position relationships. Some students found it valuable to approximately reproduce key positions in the air to clarify the bilateral movement relationships between letters. This was especially helpful to Subject No. 16, a brain-damaged child whose movements were slow but whose spatial relations were good.

The variety of techniques and materials designed for an individual subject's needs and characteristics generally resulted in improved typing performance. However, unless the material produced was of high value to the subject, performance deteriorated through time, especially in cases where use of the bilateral-input system satisfied no specific physical or cognitive requirement.

Experience in applying the operation of 14-key interfaces to the production of classroom exercises has revealed that instructor supervision is usually required to help the child achieve independent use of the communications system in a classroom environment. In addition, the teacher must provide classroom assignments which are adapted for completion with a typewriter.

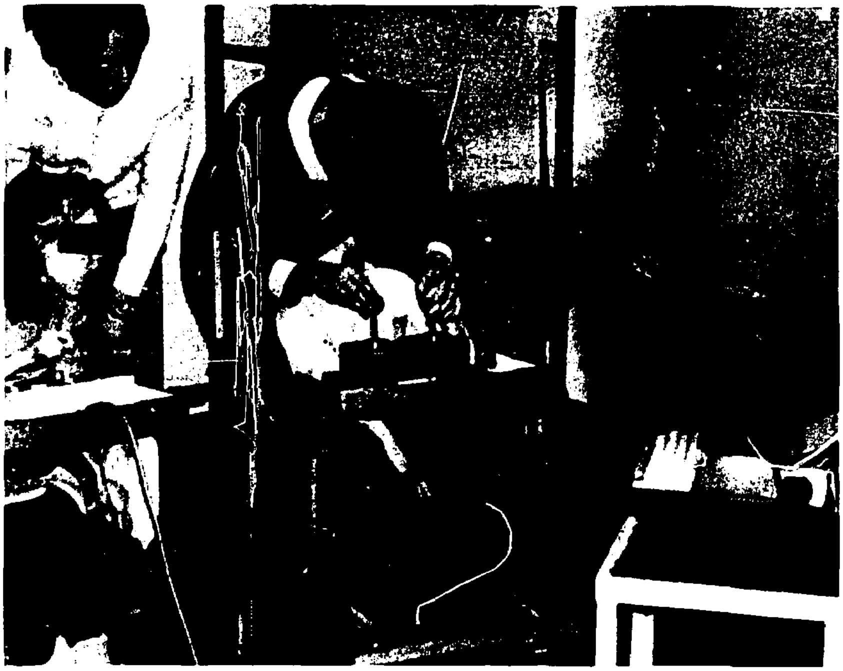


Plate 1. Members of Research Staff Testing with 14-Key and Control-Stick Interfaces

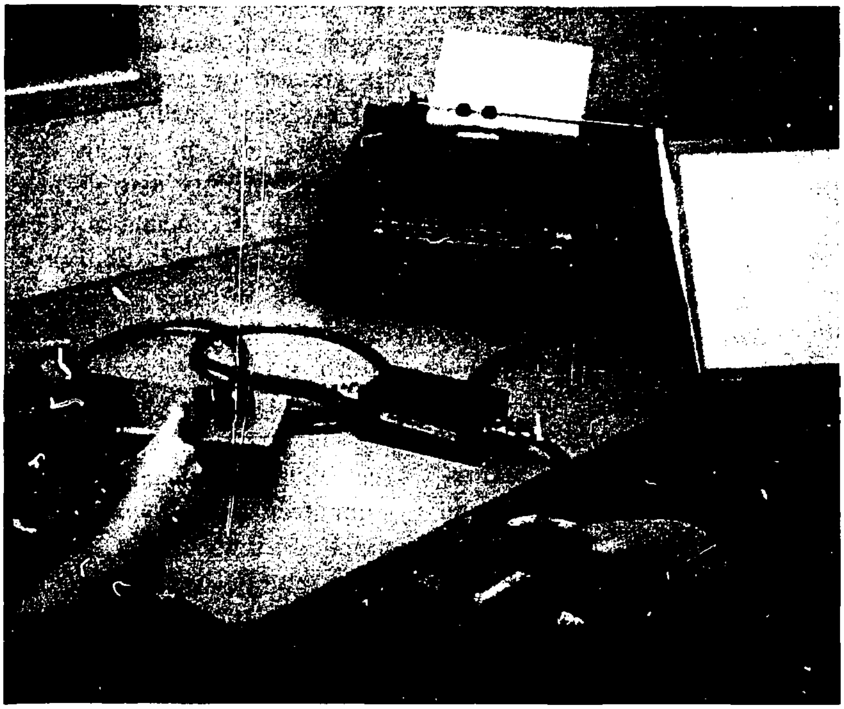


Plate 2. Teaching Session Using Two Keyboards and One Typewriter

IV. LEARNING DISABILITIES STUDY

A. INTRODUCTION

The acquisition of reading skills may be facilitated by tactile, kinesthetic and auditory feedback provided by tracing or writing a word, speaking it, and listening to it being spoken (Fernald, 1943). This multisensory approach to reading development is now generally adopted in programs of reading instruction.

Children with specific learning disabilities (SLD) often demonstrate poor motor coordination caused by underlying physiological or central nervous system deficiencies. According to Fernald's theory, when poor motor coordination or other factors interfere with the acquisition of cursive writing skills, the development of reading ability may be impeded. However, this reading impediment may be mitigated by providing the handicapped child with a simpler method of writing than cursive handwriting. Campbell (1968), in a study of reading acquisition by children with severe learning and motor disabilities, employed an electric typewriter with a standard 49-key keyboard to simplify the task of writing. She found that children using such keyboards to produce written exercises, showed significantly greater improvement in vocabulary than did a comparable group of children using cursive handwriting.

Since the bilateral-input keying interface may be adapted to utilize the limited motor capabilities of various types of handicaps, many disabled youngsters are finding the dual-input keyboard easier to operate than the standard 49-key keyboards. Accordingly, children with severe learning and accompanying motor disabilities should demonstrate improvement in reading skill as a result of writing experience with the bilateral-input system.

The purpose of this Pilot Study was to observe the performance of children with learning and motor disabilities when being trained to use the bilateral-input system for the production of written communications. It is expected that these observations will lead to experimentation on the use of bilateral-input communications systems by children with specific learning disabilities.

B. METHOD

This study employed eight subjects, ranging in age from 6 to 14, with a variety of clinical diagnoses. Of the eight children, four had severe learning disabilities, two had cerebral palsy (CP), one was congenitally deaf, and one demonstrated congenital dyslexia. Although clinical diagnosis varied between subjects, all showed evidence of learning impediments with accompanying sensory or motor disorders. A summary chart outlining subject characteristics is provided in Table VIII.

Subjects were given the following tests of cognitive functioning: Peabody Picture Vocabulary Test, Wide Range Achievement Test (reading, arithmetic, and spelling), Wechsler Intelligence Scale For Children (digit span, block design, vocabulary, coding) and the C/R/I Dexterity Test (see Appendix C).

In addition to this battery of tests, subjects were given typing instruction using (1) a standard electric typewriter with 49-key interface; (2) variations of the

TABLE VIII
Summary Chart of Subjects

Subject No.	CA (years)	IQ	Diagnosis	Reading Level	Speech
55	14	107	SLD; Emotionally Disturbed	3	Mumbled, low amplitude
56	8	Not Known	Cerebral Palsy	Not Known	Unintelligible
57	11	127	Congenital Dyslexia	3.3	Normal
58	8	100	SLD	1	Articulation problems
59	10	Not Known	Cerebral Palsy	Not Known	Unintelligible
61	6	69	Congenital Deafness	2	Rudimentary
62	7	140	SLD	1	Normal
63	11	98	SLD	5	Rough vocal quality

14-key, bilateral-input interface (standard, pedal, and control-stick keyboards); and (3) a "Cyberlamp" display to provide visual feedback for each letter, symbol or function typed. Children used separate work tables, and those not in wheelchairs used swivel chairs. Testing and typing sessions were evenly divided in 1-hour periods held twice weekly. Subjects worked both individually and in small groups in the C/R/I instruction room which is equipped with a two-way mirror for observers.

In the initial session, subjects were introduced to a color-coded, 14-key, bilateral-input interface and were taught the first six letters of the code (e-t-a-o-n-i), the 'space,' and the 'carriage return' functions. Once the concept of bilateral-input was understood, color-coded fingering charts (figure 9) were mounted on the wall, and children searched the charts to learn the fingering for different functions. Emphasis from the beginning was on combining letters and words for self-expression, rather than on code mastery alone.

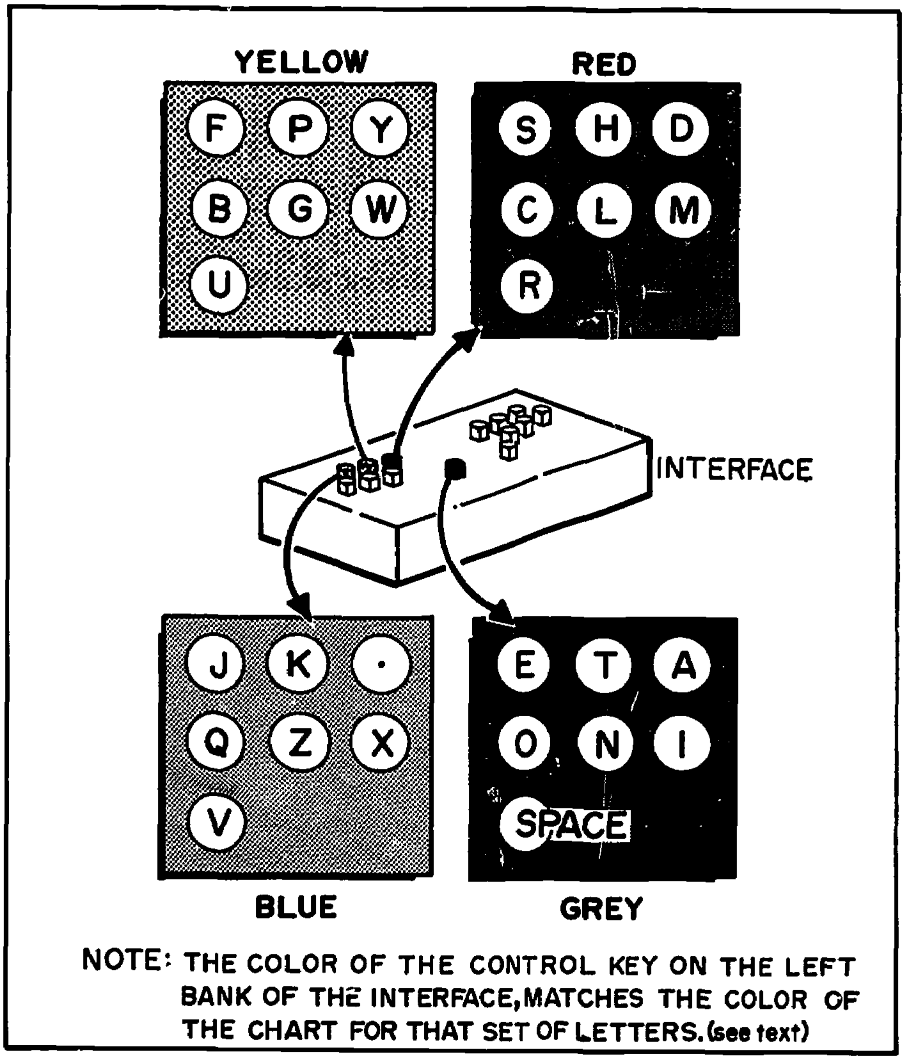


Figure 9. Color-Coded Fingering Charts

A number of instructional techniques and typing materials, described in Appendix C, were used in both individual and group sessions. Instructional procedures varied with group size. In individual sessions, the child used an interface which activated a typewriter or lamp display or both. With two children, each worked with a separate interface connected to a single typewriter, and the two alternated typing the same word, or shared typing of phrases and sentences. When the group was expanded to four, each child had an interface which activated a typewriter or lamp display. (Thus four keyboards plus the teacher's were being used with only one typewriter.) Specific letters or letter combinations were used for drill, and were typed rhythmically by all the children.

At the onset of this study, the two CP children were unable to control arm movements, to depress keys, or to produce speech intelligible to the instructor. To facilitate typing, a special technique was used for each child. Subject No. 59 practiced bilateral typing responses with her fingers on the instructor's hands until her apraxic spasm was practically overcome; then her hands could be manipulated to produce bilateral-inputs to the interface. Subject No. 56 typed with her right index finger hooked over her thumb for support, and the instructor provided the left-hand input.

To develop independent control, the CP subjects used the control-stick interface for part of most sessions. This interface produced the functions of the upper row of the 14-key interface by pushing the stick forward, and the lower row by pulling it back. This mechanical arrangement thus provides more letters with a pushing motion. Since the CP subjects could pull the control-stick more easily than they could push it, their interface was rotated so that their natural pull motion would produce the greater number of letters. While the children typed on this interface, the instructor announced each typed function to enhance feedback.

The CP subjects also required postural attention. When necessary, the children were "propped up" with pillows on one side, but were not supported in front. Interfaces were on a table adapted for wheelchairs and adjusted in height to ease hand control and reduce fatigue. Work to be copied, and an alphanumeric display were placed in a direct line of vision to optimize the presentation of feedback information. Also, stimuli in subjects' peripheral fields of view were minimized to reduce distraction.

All subjects were encouraged to experiment with different interface configurations in learning letter arrangements and in deciding which interface was easiest to operate. Children used the standard 49-key keyboards as just another interface and developed their own 'hunt-and-peck' methods to operate the keys. At the end of each session each child was provided with a copy of his paper to take home. For a permanent record and future analysis, video tapes were made by the investigators, of the subjects using the apparatus at the beginning and end of an 8-week period. Subjects diagnosed as SLD were given the same final performance tests used in the Comparison Study.

C. RESULTS AND DISCUSSION

The testing program included the Peabody Picture Vocabulary Test (PPVT), from which IQ scores were derived, the Wide Range Achievement Test (WRAT), and the Wechsler Intelligence Scale for Children (WISC). Due to time limitations, not all tests were given to all children. However, PPVT IQs ranged from 69 to 140, with a median of 103. In spite of the predominance of average or above average IQ scores, all subjects, except one, tested below their school grade levels in basic academic skills (reading, spelling, arithmetic), reflecting learning or cognitive disabilities.

Significantly, the flexibility of varied keyboard interfaces coupled together in various arrangements was a major asset for both SLDs and CPs in terms of enhancing the ability to produce written material. Many combinations were used: two interfaces into one typewriter, one interface into two typewriters, one interface into a typewriter and an alphanumeric lamp display, and the pedal interface into a lamp display with the interface being hand-actuated while the subjects were lying on the floor in a darkened room.

No objective measures of the effects of visual feedback were obtained. However, there was a definite increase in clarity and volume of speech for CP subjects in the presence of auditory feedback from the instructor, and further enhancement when a microphone, amplifier, and loudspeaker were used.

Group instruction was also explored. Two SLD subjects, brothers, provided each other with mutual support and learned code patterns more rapidly together than individually. After four sessions, an attempt was made to expand this excellent relationship for learning by the addition of another set of brothers, also SLDs. Among the four, however, the areas of disability were too diverse, ages too varied, and competition too fierce to permit this particular group to work together effectively. Other children working together in groups showed performance improvement from interpersonal cooperation and motivation.

The subjects used a number of available interfaces and lamp displays to produce a variety of materials, including scribbles, individual and group letter drills, lists of words and phrases, and original stories and pictures. "Scribbles" or random typing periods allowed the child to act a role in imitating the skilled adult. Scribble was observed in all cases to move into words and back to scribble. It was also observed that the sound of scribbling by one child was often distracting to another child who was typing copy.

Drill in two, three, and four-letter frequently-used combinations instead of in single letters, which helped to define keyboard spatial relationships, was more effective in code acquisition. High-interest word cards from which subjects could make phrases or sentences enabled older SLD subjects, ages 10-14, to work independently and produce a satisfactory volume of work. Younger

SLD subjects could not scan or shift visual fixation to copy adequately from word lists.

Original stories dictated to the teacher and read back to the subjects for typing proved to be an effective instructional technique, especially for younger subjects. Pictures to accompany these stories were drawn with pens and crayons to augment typewriter printing.

Feedback from parents revealed that there was general improvement in their children's finger dexterity, speech, posture, and confidence. The investigator's observations of subjects' verbal performance suggest that improvements in reading and writing ability might be expected to develop from an intensive program of instruction with the bilateral-input communications system.

While this study was designed to be exploratory, indications are that a 14-key, bilateral-input interface may be used effectively by many children with learning disabilities. It was especially helpful to children who did not have the motor control or facility to operate the 49-key keyboards. Although some assessment was made to determine areas of dysfunction, problems involved in specific learning disabilities are obscure, and continued research is essential to determine any ameliorative effect of the bilateral-input typing system.

V. GROUP INSTRUCTIONAL PROCEDURES (See Appendix F.)

VI. SPECIAL PROJECTS AND CASE STUDIES

A number of handicapped subjects have received individual training at C/R/I for the purposes of studying bilateral-input interface configurations which would utilize their strongest motor capabilities, and of providing preliminary evaluation of research equipment and materials.

From time to time individual inquiries are made of C/R/I regarding possible help that may be given to a handicapped person. Parents, medical advisors, or school officials, having heard of the work being done at C/R/I, have requested an examination of a handicapped individual to determine if "Cybertyping" can be helpful. In general, these handicapped subjects are believed to have greater potential in their academic training than they are showing in their present environment.

Such subjects are welcomed to the laboratory at C/R/I where, after a study of records available and an initial interview with parents or medical advisor, the subject is allowed to try appropriate interfaces under the direction of a special educator. A videotape record is made, and researchers can also observe the subject through one-way observation windows, if desirable. Individual subjects so observed provide additional experience in assessing the effectiveness of the interfaces and their numerous configurations in providing a means of written communication for the several categories of handicapped individuals. Such observations also provide insight into new variants of interfaces for special needs of individuals with unique handicaps.

Special case studies and visitors of particular interest are described below.

A. DEAF ADULTS

Subjects 47 and 48, two deaf and speech impaired adults, aged 61 and 59, were engaged as research subjects. They were trained on various bilateral-input keyboards for use with the Cyberphone$_{TM}$ telephonic communications system, for the purpose of learning the extent of training required and determining whether these subjects could subsequently assist special educators in developing instructional materials to be used with these man-machine systems.

PROCEDURE

The subjects had learned the basic bilateral-input code prior to the period of this report. They worked about 2 hours twice a week to develop speed and accuracy. They also learned to transmit and receive simple messages via alphanumeric displays. Initially, the content of materials typed consisted solely of typewriter exercises; subsequently, they typed paragraphs from current magazines. These messages, reflecting their personal interests, were prepared on cards prior to transmission.

Attention was given to the subjects' communications problems, some of which were peculiar to their hearing loss and speech impairments. Since the subjects were being trained, in part, for evaluation of "Cyberphone" and Cyber-Tone$_{TM}$ communications systems, it was observed that telephone language includes characteristic colloquialisms with which deaf persons are unfamiliar. Such components of speech as "Uh huh," "Yeah," "Hello," "This is

Rose," or "Hello, Haig here," are not part of ordinary correspondence, face-to-face vocal or lip reading conversations, or other daily nontelephonic communications. Thus, deaf persons, learning to communicate by phone with "Cyberphone" or "Cyber-Tone" systems, should either become familiar with these colloquialisms used by regular telephone users or perhaps they may adopt equivalent expressions when communicating between themselves via telephone.

An investigation revealed that the educational background of both subjects was not appropriate for further development of their communications ability in the present program. Their educational environment had been patterned after that school of training, so severely discredited by Alexander Graham Bell in his famous paper, "Fallacies Concerning the Deaf and the Influence of their Condition," first published in 1833 (A.G. Bell Association, 1969). Both subjects had, in addition to gesture and sign language, some training in speaking, but it was apparent that shortcomings in their speech and reluctance to vocalize resulted from a lack of appropriate training rather than of their potential to speak. At times, both subjects would generate minimally modulated sounds when they wished to attract the investigator's attention.

RESULTS AND DISCUSSION

In producing written material from printed copy with the 14-key interface, the average speed for Subject No. 47 was 13 words per minute for a 5-minute test, with an average of five errors per test. Average speed for Subject No. 48 for a 5-minute test was 11 words per minute with an average of eight errors per test. Both subjects later increased their speed to about 17 words per minute. Subject No. 47 generally had a larger average output than Subject No. 48 and made fewer errors. The most common mistake made by the subjects was the omission of letters from words. Extra letters and double letters occurred in correcting errors.

Two-way communication using the lamp display revealed that both subjects could transmit straight messages at speeds up to about 17 words per minute. Subject No. 48 produced letters faster than Subject No. 47, but was less clear and made more errors, which slowed down reception of information.

These subjects exhibited problems arising from the characteristic language deficits of deaf-mutes in translating from gestures to written language, as evidenced by the following observations:

1. Their spelling was affected by the manual sign language with which they customarily communicate.
2. They often failed to understand the full meaning of a transmitted message, responding to a sentence fragment containing a single word or phrase cue, rather than comprehending and responding to the complete sentence.
3. They had difficulty in following detailed written directions.

These subjects successfully demonstrated the use of the "Cyberphone". between remote points. (For example, when scientists representing the Bureau of Educaction for the Handicapped visited C/R/I, these two subjects transmitted and received messages via "Cyberphone", using 14-key interfaces and alphanumeric displays.) Although they eventually learned a pattern of a "spontaneous" telephone conversation and were able to improvise short messages, it was evident that they felt more at ease when the message to be transmitted was written in advance. In fact, when demonstrating they insisted on typing from copy.

A separate study was undertaken to determine whether they could learn another bilateral-input transfer code and to reveal the extent of constraints, if any, of having previously learned a different code. The subjects were first shown the experimental code by means of a matrix chart and an explanation of the letter-key equivalences. Subject No. 48 tried first, exploring the code independently, and after three sessions could produce intelligible copy at a slow rate. When Subject No. 47 tried, she quickly understood the equivalences, and after one-half hour of exploration, typed a form letter, with only occasional, rapid references to the chart for fingering positions.

CONCLUSIONS

Two deaf-mute subjects have mastered the dual-input keyboards, developing a speed which permits a person to visually scan an alphanumeric lamp display and record the transmitted message. They have suggested procedures by which coded signals can be more readily identified when communicating via telephone. They pointed out to the investigators that signalling the correction of an error was critically important for clear communication. The necessity of coding signals to indicate the beginnings and endings of messages was also suggested by the subjects. It was found that the flashing light of "upper shift" and "lower shift" on the lamp display, which indicated capitalization, introduced "noise" in their communicating system, especially when the pronoun "I" was typed. This observation suggests that differentiation between upper and lower cases should not necessarily be made for the transmission of information to be presented by alphanumeric displays. Preliminary investigation also indicates that transmitted information may be more easily read when certain punctuation marks, e.g., commas, hyphens, and even question marks, are omitted. An investigation of literature related to research in telegraph transmissions as it may apply to transmission of "Cyberphone," "Cyber-Tone," and other related equipment is being made prior to determining a procedure anent capitalization, punctuation, correction, and start and end of messages.

The value of having typewriters in which the carriage returns automatically at the end of a line was also apparent. The carriage-return signal itself does not need to be monitored because it has little information value and appears to disrupt the flow of meaning.

Deaf-mute persons who do little writing and who have minimal contact with people who can speak and hear, need special training in the "normal" format of telephone transmission, and may even require a new communicating format consisting of letters and whole words appropriately displayed. Two-way communications with these new man-machine systems presents a fertile field of exploration especially where used in educational environments equipped with central computers from which instructional materials may be retrieved via telephones.

B. SPASTIC QUADRIPLEGIC SUBJECT

A 17-year old student, Subject No. 42, was selected in order to explore how a spastic quadriplegic with limited arm and hand control would benefit from working with these man-machine systems. His school curricula did not meet his reading and writing needs, hence the investigators directed their efforts towards learning whether typing experience and assistance from special educators and man-machine systems would improve his reading and writing competence.

His assets included excellent verbal ability, a good vocabulary and sentence structure, and an especially cooperative spirit when working with the research team. Approximately 11 months prior to his contact with his tutor, this subject had been taught the finger positions of the space function and six letters on a dual-input keyboard by the principal investigator. His tutor noted that he had retained all of the fingering positions and executed them without error or review.

PROCEDURE

Initially, this subject was instructed twice weekly for 1 hour at his home. His first exercises were typing common digraphs and trigraphs that were spoken to him, and writing sentences about his own experiences. After eight sessions, he began to write his own "newsletter," which he dictated to his tutor. She then spelled the dictated words to him in three and four-letter clusters, indicating space and punctuation.

The subject had been placed in a school, new to him, shortly before the onset of this instruction. Reading lessons were given at the new school during the first semester but were abandoned during the second semester in favor of a sheltered workshop program. Attempts at enrolling him in a regular school system proved futile. Hence, his experience in learning to write with the dual-input keyboard and the introduction of associated learning aids became his principal academic inputs during this period. After 6 months of home tutoring, the subject received instruction at the C/R/I laboratory, where researchers learned a great deal about matching interfaces and the spacing of keys and controls for this quadriplegic subject. This information proved to be of value for other children similarly afflicted. Sessions were discontinued during the summer and resumed in the fall of 1969.

RESULTS AND DISCUSSION

The project's special educator reported that the subject showed marked improvements in the later instructional sessions. His hand and finger control had improved and his typing effectiveness increased to about two words per minute. It must be noted that effective, meaningful communication and not speed, was the important result of this subject's training. Progress was noted in reading; phonics skills previously acquired, emerged and facilitated his spelling; and more importantly, this subject was able to read stories he had created and typed. Changes were also noted in the appropriateness of verbal expression and in his speech structure. His former pattern of stringing together standard expressions had diminished.

The subject learned the bilateral-input code in five sessions. A major improvement in fluency occurred with the introduction and use of a color-coded interface; as a result, the subject ceased producing double letters. An unfavorable effect was caused when large type was replaced by standard pica type. After this substitution, he rarely typed the practice sentences, partly because his visual feedback was considerably reduced and he was unable to manipulate a magnifying glass provided for his use.

The researchers observed that feedback played an important role in his educational motivation and behavior, and they resumed use of the typewriter with large type which the subject could more easily see. Subsequently, reading of other materials by this subject indicated that the improvement in fluency was primarily due to visual feedback of large letters and not the style of the letters.

By January 1970, the subject had developed the confidence, verbal ability, and motor coordination necessary to compose and type (using a 14-key interface) original stories in response to pictures shown to him (see figure 10; the picture was selected and cut out by the subject).

The question of long-term benefits from typing with the dual-input interface remains to be learned. This subject will be followed-up in a future program. It is of significance to parents who have children similarly handicapped and who have been told by examiners that there is little hope for their children, that with appropriate interfaces and instruction these children can develop intellectually.

C. TEN-YEAR OLD MULTI-HANDICAPPED GIRL

A special program of instruction was undertaken at Belle Willard Elementary School with one subject, No. 50, who, because she had no intelligible speech, was receiving little instruction in the classroom, but gave the impression of being able to learn and to communicate, if she had the means to do so. The purpose was to determine whether the bilateral-input interface would in any way facilitate communication for this child.

PROCEDURE

For 1 hour twice a week this subject received instruction with the bilateral-input system. Since she had use of only the right hand, the instructor initially provided either the left-hand input or manipulated the subject's left hand.

The instructional sessions were enriched with the use of puppets and musical instruments to stimulate speech and to encourage use of both hands. The Cyber-Circus$_{TM}$ toys were available for play and code reference. A song about "Cyber-Circus" characters was devised.

Group conferences, prior to and after instruction, were held with the subject's parents, a participating classroom teacher, an occupational therapist, a tutor, and the school principal to coordinate goals and materials.

RESULTS

This subject was taught most of the letters of the alphabet in a total of 17 sessions. Using the knuckle of her right index finger she could type reasonably accurately with her right hand on the 14-key interface. Her left hand was very weak, and though improvement was noted in its use, it had not attained strength and sufficient control to operate the keys independently. The subject moved her left hand from key to key as required, but the teacher had to assist her to depress the key.

The child's speech increased noticeably and became clearer. In addition, her use of the bilateral-input interface and increased exposure to printed words led to an acquisition of a sight-reading vocabulary of several words.

This program was terminated by the parents after 17 sessions, though it was strongly supported by members of the school staff. While the child was making rapid progress and moving toward accomplishment and independence in many performance areas, in-

SUMMER HARVEST

THF MEN WERE A KIND OF PEOPLE

WHY WOORKING VERY HARED TO MAKE

A LIVING . TPEY MADEED A LIVING::

TOO LIVE OFF OF THE LAND . T

CULTIVATE THE RICE.

ONE MAN IN WEARING A WOVEN

STDAW HAD. FOR THE SUN. HE

LIKES IT TOO.HE IS IN WET.

GARY

Figure 10. Original Story Produced by Subject No. 42 in Response to Picture

cluding walking, the parents felt that she was not happy. The investigators were subsequently informed by the administration of the school that this sort of action was not uncommon for parents of multi-impaired children, many of whom develop their own behavior patterns which at times adversely affect their decisions and overview.

The administration at the school, however, recognizing the development potential, took new interest in the subject and began to provide new services. She began speech therapy and made progress in language development. This subject was then seen as a child who could use her own words and was learning to talk. Her image at school, as a direct outgrowth of her participation in this program, shifted from one defined by what she could not do to what she could do. Here again, the broad scope of tasks and responsibilities of the special educator is highlighted.

D. THREE SHARPE HEALTH SCHOOL CHILDREN

The occupational therapists at Sharpe Health School requested evaluations concerning the usefulness of the 14-key, bilateral-input interface for Subjects 39, 40, and 41. The three subjects were seen by C/R/I teachers and came to the Institute for video taping.

Subject No. 39, age 6, had no arms and had special gas-powered prostheses. The operation of the prostheses and the bodily movements required for the bilateral-input keyboard proved to be a more difficult task than the single sequential input of a 49-key keyboard. This child was able to strike a typewriter key with one prosthesis.

Subjects 40 and 41 were observed as candidates for future study. Subject No. 40 could use one finger which she was unable to use on the 49-key keyboard. However she could operate one side of the dual-input keyboard which was equipped with widely spaced keys. In order to operate the other half of the dual-input keyboard she was given a mouth stick. This is a difficult case but the investigator felt that the dual-input interface would significantly reduce the workload required by this child. Subject No. 41 has no functional use of her hands but has excellent tongue and mouth control and will be considered as a future subject on the "Possum" machine.

E. FOURTEEN-YEAR OLD CP

Subject No. 101 (cerebral palsy, age 14, high IQ) attends a private school for normal children. He has an electric typewriter and can use it with difficulty. His parents want to keep him in a regular school and seek help to allow him to compete with other children.

Since this subject was able to use a standard typewriter, it was not regarded as desirable to have him learn to use the other kinds of interfaces for his school work.

F. MATURE SUBJECT

Subject No. 103 (mature woman, age 36) is almost totally paralyzed, but is capable of slight head movements and use of the tongue. The subject, under rehabilitative care of the Bio-Medical Engineering Facility of the Rancho Los Amigos Hospital, of Downey, California, has been using a ganged mouth switch developed by Los Amigos, and consisting of a number of separate, small switches to be operated by her tongue. She was accepted as a candidate because of her not uncommon handicap, her high motivation and her cooperative attitude towards making a contribution which would someday help other handicapped children. The subject can control the movements of her wheelchair with her mouth switches. In addition, using her arm with the aid of a prosthesis, she can use a standard 49-key keyboard.

Presently the investigators are studying the utility of a "Cybertype" in order to ascertain what advantages, if any, will be attained through use of a special, two-bank interface. One bank consists of three switches operated by the fifth finger of her right hand and the other consists of a mouth keyboard with 8 double-throw toggle switches. This interface has been separately described in Appendix G, and in Volume I, Part Two of this report.

G. Four subjects, 45, 56, 49, and 60, participated informally in "Cybertype" instruction for their interest and for further preliminary experience at C/R/I with normal subjects. No formalized data collection was undertaken.

Appendix B MASTER LIST OF SUBJECTS

C	Comparison Study
D	Diagnostic Exploratory Study
F	Follow-Up Studies
G	Group Instructional Procedures
L	Learning Disabilities Study
P	Pilot Study
SPC	Special Projects and Case Studies
W	D. T. Watson Home for Crippled Children Study

Subject Number	CA (yrs-mos)	Diagnosis	Study
1	10-2	CP (Cerebral Palsy), Athetoid	C
2	6-5	Alleged Thalidomide	C,F
3	10-1	CP, Spastic	C,F
4	8-9	CP	C
5	11-8	CP, Left Hemiplegic	C
6	6-2	Dermatomyositis	C
7	6-10	Crouzan's Disease	C,F
8	10-8	CP	C
9	7-6	CP	C,F
10	9-3	Post Polio	C
11	9-11	CP	C
12	6-4	CP	C
13	10-3	Muscular Dystrophy	C
14	10-2	CP, Rigidity	C,F
15	9-9	CP, Birth Accident	C,F
16	12-9	Brain Damage	C,F
17	6-7	Congenital Malformations of Foot and Hip	C
18	8-10	Post Polio	C
19	7-2	CP, Spastic	C
20	9-4	CP, Athetoid	C
21	12-7	CP, Athetoid	C
22	10-9	Nephrosis	C
23	10-11	CP	C
24	10-6	Muscular Dystrophy	C
25	13-8	Post Polio	D
26	13-3	CP	D
27	6-1	Postencephalitis	D
28	8-5	CP	D
29	11-7	Muscular Dystrophy	D
30	7-7	CP	D
31	8-0	Arthrogryposis	D
32	7-8	CP	D
33	Adult	Bilateral Amputee	SPC
34	13-10	CP	P,F
35	9-1	Thalidomide Syndrome	P,F
36	11-2	CP	P,F
37	8-3	Congenitally Armless	P,F
38	8-3	CP	P,F
39	6	Bilateral Amelia, Femoral Deficiencies	SPC
40	15	CP, Athetoid Quadriplegic	SPC
41	13	Quadriplegia, Polio	SPC
42	17	CP, Spastic Quadriplegic	SPC
43	9	Polio, Scoliosis	SPC
44	9	CP	SPC
45	9		

Subject Number	CA (yrs-mos)	Diagnosis	Study
46	9		
47	Adult	Deaf	SPC
48	Adult	Deaf	SPC
49	16		
50	10	CP, Spastic, Quadriplegic	SPC
51	11	Rubella	SPC
52	15	Retrolental Fibroplasia	SPC
53	16	Retrolental Fibroplasia	SPC
54	16	Retrolental Fibroplasia	SPC
55	14	SLD (Specific Learning Disorders)	L
56	8	CP	L
57	11	SLD	L
58	8	SLD	L
59	10	CP	L
60	14		F
61	6	Congenitally Deaf	L
62	8	SLD	L
63	11	SLD	L
64	6-3	(See footnote 1.)	C
65	7-0		C
66	9-7		C
67	10-0		C
68	7-5		C
69	7-3		C
70	10-8		C
71	10-0		C
72	5-10		C
73	10-8		C
74	12-6		C
75	7-3		C
76	10-4		C
77	9-7		C

[1]Subjects 64-99 used in the Comparison Study are nonhandicapped.

[2]Subjects 106-114 used in Group Instructional Procedures are nonhandicapped.

Subject Number	CA (yrs-mos)	Diagnosis	Study
78	10-5		C
79	7-6		C
80	10-7		C
81	9-0		C
82	5-11		C
83	10-7		C
84	7-6		C
85	10-8		C
86	10-2		C
87	10-5		C
88	12-10		C
89	10-1		C
90	7-8		C
91	9-10		C
92	10-0		C
93	10-2		C
94	9-9		C
95	7-3		C
96	12-11		C
97	11-9		C
98	6-8		C
99	7-2		C
100	16	Congenital Glaucoma	SPC
101	Adult	Blind Amputee	SPC
102	14	CP	SPC
103	Adult	Totally Paralyzed	SPC
104	10	Minimal Cerebrai Dysfunction	G
105	12	Torticollis	G
106	10	(See footnote 2.)	G
107	11		G
108	13		G
109	14		G
110	14		G

Subject Number	CA (yrs-mos)	Diagnosis	Study
111	19		G
112	8		G
113	14		G
114	6		G
*			
122	12	CP	W
123	14	CP, Rigidity	W
124	19	CP, Spastic Ataxic Quadriplegic	W

Subject Number	CA (yrs-mos)	Diagnosis	Study
125	13	Arthrogryposis multiplex congenita	W
126	11	CP, Spastic Paraplegic Flexion contractures of hips and knees	W
127	12	CP, Athetoid Quadriplegic	W
128	8	CP, Spastic legs	W
129	7	Osteogenesis Imperfecta (weighs 23 lbs.)	W

*(Subjects 115 through 121 are in current studies not included in this report.)

Appendix C INSTRUCTIONAL MATERIALS AND TECHNIQUES

Studies at C/R/I involving bilateral-input systems require that subjects be taught appropriate keying codes and operation of the interfaces in communicating. This teaching is accomplished with a variety of instructional materials.

Needs of individual subjects and teaching styles of C/R/I instructors vary. Some instructors emphasize teaching aids to clarify and reinforce learning; others emphasize techniques of manipulating equipment and copy materials to accomplish the same end. While in a closely controlled research study, an attempt may be made to standardize materials and/or techniques, there are many ways to assist the handicapped child in the creative pursuit of learning. If one of the goals is to facilitate communication through use of man-machine systems, then the teaching goal is not only keyboard mastery, but also integration of the use of these devices into the school curricula in full functioning with the child's other academic skills.

The following are techniques and materials that have been developed by the C/R/I staff to facilitate attainment of these goals. They suggest new ideas for creative teachers. The flexibility and usefulness of communicating with bilateral-input interfaces encourages creative innovation of both techniques and materials to enhance the learning process.

SPEED DRILLS:

A number of techniques have been helpful in developing speed and accuracy. These are concentrated exercises on digraphs, common letter combinations, clusters of similar words, rhyming words for repetition of endings, words with double letters and words with common-key letter sequence for developing speed. Common-key letters are those pairs or sequences of letters that require changing keys with only one hand on the bilateral-input interface.

Some of these techniques are designed to clarify the physical act of key depression, and some are designed to clarify the code system to make learning of fingering positions quicker.

POEMS AND GAMES

Such materials often have considerable repetition within their structure which is helpful for exercise, but there is also a rhythmic organization to the word flow which helps to modulate the typing. The children were especially delighted with funny poems, 'autograph-book' jingles, and games.

SCRAMBLED LETTERS AND SENTENCES

Letter cards and word cards were used to construct words and sentences. The children particularly enjoyed seeing how many words they could form from a single base word. For example, "ear" can become "hear," "fear," or "tear."

SONGS

Songs were used to organize code information for children with hearing. These songs, which provided the sequence assigned to letters in the code, were helpful in the same way that the "Alphabet Song" organized the alphabet sequence.

ORIGINAL COMPOSITION

It was observed that some children composed stories and typed them directly while other children could not. Those children who could not, required assistance from the teacher to record their story and feed it back to them in a manner that facilitated their writing.

The role of the teacher in the production of original work can be vital. What appears on the child's paper can be the work of the child, but the instructor can support this work in several ways.

Sometimes the teacher simply records, completely and accurately, the words as the child says them. At times the teacher helps the child start the composition by suggesting topics or even beginning a sentence. The teacher helps maintain the narrative flow by supplying missing or cue words.

Letter writing is another facet of original composition which has been used in this program.

CLASSROOM PAPERS AND ASSIGNMENTS

Often these papers are in a format for handwriting and special techniques are needed to convert them to typewritten form. Assignments to prepare compositions are difficult to complete in half-hour instructional periods unless the compositions are short or the student can continue the work on the assignment from session to session. The duration of teaching sessions is being extended.

USE OF ASSOCIATIONS

This involves teaching the code through the use of associations with characters in "Cyber-Circus"; e.g., ETA, ONI: Eva, Tom and Ann went to the circus; Eva took Oatmeal cookies, Tom took Nuts, and Ann had Ice cream. The "Cyber-Circus Story," (Kafafian, 1968) developed by Mrs. Anna Mae Gallagher at C/R/I in 1967, is comparable to "Keyboard Town," a story of associations for the 49-key typewriter, also developed by Mrs. Gallagher (1965). In some studies, these stories were used to provide associations as an instructional method; in other studies, reference to these stories was made only to help a child remember what he had learned already.

BACKGROUND MUSIC

In our work, some students increased typing speed and volume of output when any kind of music was played. Others were selective about the kind of music that was presented and still others could not tolerate music at all.

MULTIPLE INTERFACE HOOK-UPS (INPUT)

The "Cybertype" permits the use of many keyboards on one typewriter. Since the interfaces attach to the typewriter via a cable and connector through a junction box which has multiple plugs, it is possible to have several interfaces connected to the same typewriter. A master switch is provided on interfaces for control by the teacher. This allows for alternation between teacher and student or between students. It was found that the speed of some slow students could be improved by having the teacher or another student type along with the slow student, alternating words or letters.

DUAL DISPLAYS (OUTPUT)

For reinforcement, a lamp display provides visual feedback augmenting the child's tactile and kinesthetic feedback. It has been found that the visual feedback is unnecessary with the D.T. Watson Home subjects.

AUDITORY FEEDBACK

If visual feedback from typing is not available to the student, the teacher announces the letter as it is typed by him.

LARGE TYPE FONT VISUAL FEEDBACK

Type fonts normally available on standard electric typewriters are too small for the visually impaired student. Some typewriters allow a choice of type style by changing the type element. The Orator style of type provides large letters, but the available letter spacing of ten to the inch produces a crowded text when all capital letters are used. The spacing rack (12 characters to the inch) of one model typewriter was modified by removing its alternate teeth. This resulted in a spacing of six characters to the inch. A sample of the text produced is shown in figure 11 beneath the work before modification.

GROUP INSTRUCTIONAL PROCEDURES

A separate phase of the program was conducted to develop effective group procedures for teaching handicapped and nonhandicapped children to communicate using the bilateral-input interfaces. The results are reported separately in Appendix F.

TYPING AND DEXTERITY TESTS

As part of the Comparison Study, C/R/I administered typing tests to handicapped and nonhandicapped subjects in order to compare performance on the standard electric typewriter and the dual-input keyboards. Each subject was tested on either the 49-key or the 14-key keyboard; these performances were compared. Separate comparisons were made for the handicapped and for the nonhandicapped groups. The typing tests follow.

THE USE OF PROPERLY PROPORTIONED LARGE TYPE AND APPROPRIATE SPACING FOR CHILDREN WHO ARE VISUALLY IMPAIRED HELPS SOME OF THEM TO READ MORE EASILY. THIS TEXT IS WRITTEN ON A TYPEWRITER WHOSE SPACING HAS NOT BEEN MODIFIED. IT HAS 10 CHARACTERS PER INCH. NOTICE THE DIFFERENCE IN LEGIBILITY OF THIS TYPING SAMPLE AND THE ONE GIVEN BELOW.

THE USE OF LARGE TYPE WITH CORRESPONDINGLY LARGE SPACING IS BENEFICIAL TO INDIVIDUALS WITH IMPAIRED VISION. THIS TEXT WAS WRITTEN ON A TYPEWRITER WITH MODIFIED SPACING RACK TO GIVE 6 CHARACTERS TO THE INCH. MODIFICATION REQUIRED OF THE TYPEWRITER IS MINIMAL AND EASILY ACCOMPLISHED.

Figure 11. Comparison of Large Type with and without Increased Spacing

DUAL-INPUT INTERFACE TYPING TEST
for Handicapped Subjects
Comparison Study
(Group A)

1. TONI ATE AT NINE
I ATE IN A NEAT TENT
NO ONE ATE AT NOON
AN ON NO NOT
I ATE AN ONION

2. SEE WAS AS SEED
A CASE
WE SAW DAD
ED WAS SAD

3. HAT CALL LET HILL
HE SELLS HATS
ALICE IS LITTLE
HE LOST HIS CAT

4. MEN DID DOOR HAM
DAD CAME HOME
MOM MADE DINNER
LET ME SEE THE DOLL

5. FAT FUN BELL BAT
BIRDS ATE THE CRUMBS
IT IS FUN TO DANCE
TURN IT OFF

6. POP PULL GUM GO
I DROPPED THE CUP
MOM TOLD ME TO GET UP
GOATS EAT GRASS

7. YELL WE YARD WEED
WILL YOU SIT DOWN
MARY WAS HAPPY
WE WILL TRY TO WIN

8. JELLY JAR JAM JOB
JUMP QUIET VERY JOY
THE QUEEN WAS VERY PRETTY
JILL DROPPED THE VASE
SHE SAID TO BE QUIET

STANDARD ELECTRIC TYPING TEST
for Handicapped Subjects
Comparison Study
(Group B)

1. AS WAS ED AXE
DEED ADD SAD
DAD SAW A SEED
WE SEE SEAWEEDS

2. SEE WAS AS SEED
A CASE
WE SAW DAD
ED WAS SAD

3. TAG BED GRASS SAVE
TED RACED FAST
GET DAD A BAG
ED SAVED A CAT

4. MANY JAR NURSE THEY
DADDY SAYS WE CAN
FRED ATE THE JAM
JANE MET ANN BY THE GATE

5. INK KING KISS KICK
MIKE FLIES A KITE
KIM RIDES A BIKE

6. OIL COLOR OLD ONLY
YOU LOOK COLD
SALLY WANTS A COLT
SOL SOLD A CLOCK

7. HOP SKIP JUMP PAW
WAS PEPE HAPPY
WILL YOU PAY A PENNY
DID YOU LIKE THE PARTY

Final Test: (Groups B and D)

NEXT MONTH IS FEBRUARY
WILL YOU BE MY VALENTINE

DUAL-INPUT INTERFACE TYPING TEST
for Nonhandicapped Subjects
Comparison Study
(Group C)

1. NO ONE ATE IT.
RICE IS NICE.
HE SELLS HATS.
MOM MADE DINNER.

2. BAT THE FAT FLIES.
GREGG GOT UP.
BOB DROPPED THE CUP.
WE WILL TRY TO WIN.

3. DOES KIM HAVE A JAR OF JAM.
THE QUEEN WORE VELVET.
SEE THE LAZY DOG SNEEZE.
MR. CURT FIXED MY BIKE.

4. JUDY QUIT JUMPING.
JILL HAS A VERY QUIET VOICE.
THE MONKEY KICKED THE ZEBRA.
THE FOX WAS NOT IN A BOX.

STANDARD ELECTRIC TYPING TEST
for Nonhandicapped Subjects
Comparison Study
(Group D)

1. DAD SAW A SEED.
GET FRED A RED RACER.
TED GAVE REX A BAG.
A BEAR EATS AT A CAVE.

2. THE NURSE FED MEG JAM.
HAND MARY A JUG.
HARVEY NEVER CAME.
JUDY MET ANN BY THE GATE.

3. MIKE KICKED A BLUE BALL.
THE QUEEN WORE VELVET.
SEE THE LAZY DOG SNEEZE.
CAROL, THERE IS YOUR DOLL.

4. JUDY QUIT JUMPING.
JILL HAS A VERY QUIET VOICE.
THE MONKEY KICKED THE ZEBRA.
THE FOX WAS NOT IN A BOX.

All subjects were also given a finger dexterity test. Recently a new tapping test of finger dexterity has been developed by C/R/I. It was put into use in January 1970. Both of these dexterity tests follow in the text.

DEXTERITY TEST

This initial test of finger dexterity, developed at C/R/I in 1969, was part of the battery of tests given to subjects in studies described in this report. The test provided an objective measure of hand and finger dexterity in relation to typing potential, in terms of the speed and accuracy with which handicapped and nonhandicapped subjects could strike the keys of a standard electric typewriter.

DEXTERITY TEST*

(To be given on standard electric typewriter)

I. SEQUENTIAL ORDER TEST

Left Hand Test:

Cover all keys except F, D, S, A.

Keys to be hit in order, right to left beginning with index finger:
index = F; middle = D; ring = S; little = A.
Demonstrate hitting all keys in order.
Directions to child: "Do this as quickly as you can."
Time:

Right Hand Test:

Cover all keys except J, K, L, ";"
Keys to be hit in order, left to right beginning with index finger:
index = J; middle = K; ring = L; little = ";"
Directions to child: "Do this as quickly as you can."
Time:

Directions to teacher: If subject is not able to use individual fingers, note which fingers used and any problems.

Teacher's Notes:

*Form No. 107 (June 1969)

II. CONSECUTIVE KEY DEPRESSION TEST

Do not cover keys.
Demonstrate with same placement of fingers as in test I, hitting each key five times consecutively. Point to key; say name of letter. Direct child to hit five times as quickly as possible. Count for child as he depresses keys.

Time: If task is completed in 5 seconds per key, check for those passed. If subject is very slow and time exceeds 5 seconds, note time task required and reasons for slowness.

Left Hand Test:

index =	F
middle =	D
ring =	S
little =	A

Right Hand Test:

index =	J
middle =	K
ring =	L
little =	;

III. DIGITAL AIMING ABILITY TEST

Cover right side of typewriter (beginning with Y,H,N). Direct child to hit key named, using designated finger. Do not place fingers on keys; child should find and depress keys from starting point, hands in lap or on table; return to start position after key depressed. Teacher should point to key, say letter, and designate finger to be used.

Time: Same as Test II. Check if passed, if missed; note letter struck and why designated letter was missed.

Left Hand Test:

index =	T
middle =	D
ring =	X
little =	Q

Right Hand Test:

index =	B
middle =	U
ring =	K
little =	P

Teacher's Notes:

DEXTERITY TEST – SCORING KEY

I. SEQUENTIAL ORDER TEST – POSSIBLE SCORE 20

Left Hand Test:

No. of Seconds	Score
11+	0
10	1
9	2
8	3
7	4
6	5
5	6
4	7
3	8
2	9
1	10

Right Hand Test:
(Same as Left, above)

II. CONSECUTIVE KEY DEPRESSION TEST – POSSIBLE SCORE 8
One point for each check

III. DIGITAL AIMING ABILITY TEST – POSSIBLE SCORE 8
One point for each perfect response

TOTAL POSSIBLE SCORE 36

DEXTERITY TEST

This test developed at C/R/I was adapted from "The Tapping Test" by John C. Flanagan, 1959 (Psychometric Techniques Associates, Pittsburgh, Pennsylvania). It provides an objective measure of dexterity for each finger, as an indicator of potential for typewriting and other tasks requiring finger manipulation, and was effective January 1970.

TAPPING TEST OF FINGER DEXTERITY

Instructions

Materials needed for each test subject are:

- 1 test booklet
- 10 finger-tip pads
- 1 container of paint or ink
- 1 applicator or brush

The test of dexterity requires that an inked pad be attached to the subject's finger tip. Two types of exercises are provided for each finger, both of which involve tapping a single spot of ink or paint inside each of a series of circles inscribed on the test page. In the first exercise, the subject must tap a spot of ink or paint within each circle, working across rows from left to right for a timed 15 second period. In the second exercise, the subject taps a spot in only those circles which do not contain an "X", again working across rows from left to right for a timed 15 second period.

Practice Sessions. Preceding the test series, the subject should be given practice with each finger of each hand. The first two pages of the test booklet are used for this purpose. Begin with the circles on the first page. For this practice session, do not use the fingertip pads. Tell the child:

"THIS IS AN EXERCISE TO SHOW HOW WELL YOU CAN USE YOUR FINGERS. WE WILL START BY GIVING YOU PRACTICE IN USING YOUR FINGERS."

(Show child first page of test booklet.)

"HERE YOU SEE CIRCLES ARRANGED IN ROWS. START WITH THIS FINGER (THUMB) OF YOUR RIGHT HAND AND TAP ONCE INSIDE EACH CIRCLE FROM LEFT TO RIGHT ACROSS EACH ROW."——— (Demonstrate)———"I WILL TELL YOU WHEN TO START AND WHEN TO STOP."

Allow subject about 5-10 seconds with each finger for these practice trials.

If the subject has full use of all fingers, begin with the thumb and proceed to index, middle, ring, and little fingers of the right, then the left hand. If the subject has no use whatsoever of one or more fingers, make note of this and omit these fingers in the test series.

After giving practice with both hands, turn to the second page of the test booklet. Tell the child:

"THIS TIME I WANT YOU TO TAP ONLY THE EMPTY CIRCLES. DO NOT TAP THE CIRCLES CONTAINING AN "X". START WITH THIS FINGER (THUMB) OF YOUR RIGHT HAND AND TAP INSIDE EACH EMPTY CIRCLE UNTIL I TELL YOU TO STOP."

Allow subject about 5-10 seconds with each finger for these practice trials.

On this practice page, omit finger(s) found to be unusable during the preceding practice session. Otherwise, proceed with each finger of right and left hands as before.

Test Session. There are twenty test pages, two for each finger. Begin with the right hand, testing in the order thumb, index finger, middle finger, ring finger, and little finger; then test the left hand using the same finger order. Omit any fingers found to be unusable during the practice session.

Attach a finger-tip pad to the surface of the first finger to be tested (usually the thumb) by peeling off the protective backing to expose the adhesive side of the pad. If the pad does not stick firmly to the skin, scrub the subject's finger with alcohol to remove skin oils, and dry thoroughly. Attach a finger-pad to the skin surface near the finger tip. Locate the pad in the most convenient and comfortable position for each child. For the thumb, the child may find it more comfortable if the pad is positioned on the outside edge of the thumb. Tell the subject:

"IN A MOMENT, I WILL PUT INK (PAINT) ON THIS FINGER PAD AND ASK YOU TO TAP A SPOT INSIDE EACH CIRCLE ON THE PAGE. TRY TO TAP INSIDE EACH CIRCLE WITH THE PAD, LIKE THIS."——— (Demonstrate by guiding child's hand and finger).———"NOW I WILL PUT INK (PAINT) ON THE PAD."

Apply ink or paint to the pad using a brush applicator. The pad should be moist but not saturated, so that no liquid will be squeezed onto the child's finger during testing. Tell the child:

"NOW I WANT YOU TO TAP A SPOT INSIDE EACH CIRCLE. WORK FROM LEFT TO RIGHT ACROSS EACH ROW. GO AS FAST AS YOU CAN, BUT TRY TO MAKE EACH SPOT FALL INSIDE EACH CIRCLE. I WILL TELL YOU WHEN TO START AND STOP."

Using a stop watch, time the subject for exactly 15 seconds, then stop. Turn to the next page. Apply a little fresh ink or paint to the pad if necessary. Tell the subject:

"THIS TIME, TRY TO TAP A SPOT INSIDE EACH EMPTY CIRCLE. DO NOT TAP CIRCLES CONTAINING AN 'X'. I WILL TELL YOU WHEN TO START AND STOP. IF YOU FINISH THE ROWS ON THE LEFT SIDE OF THE PAGE, CONTINUE IMMEDIATELY TO THE TOP ROW ON THE RIGHT SIDE OF THE PAGE AND KEEP WORKING UNTIL I ASK YOU TO STOP."

Again, time the subject for 15 seconds.

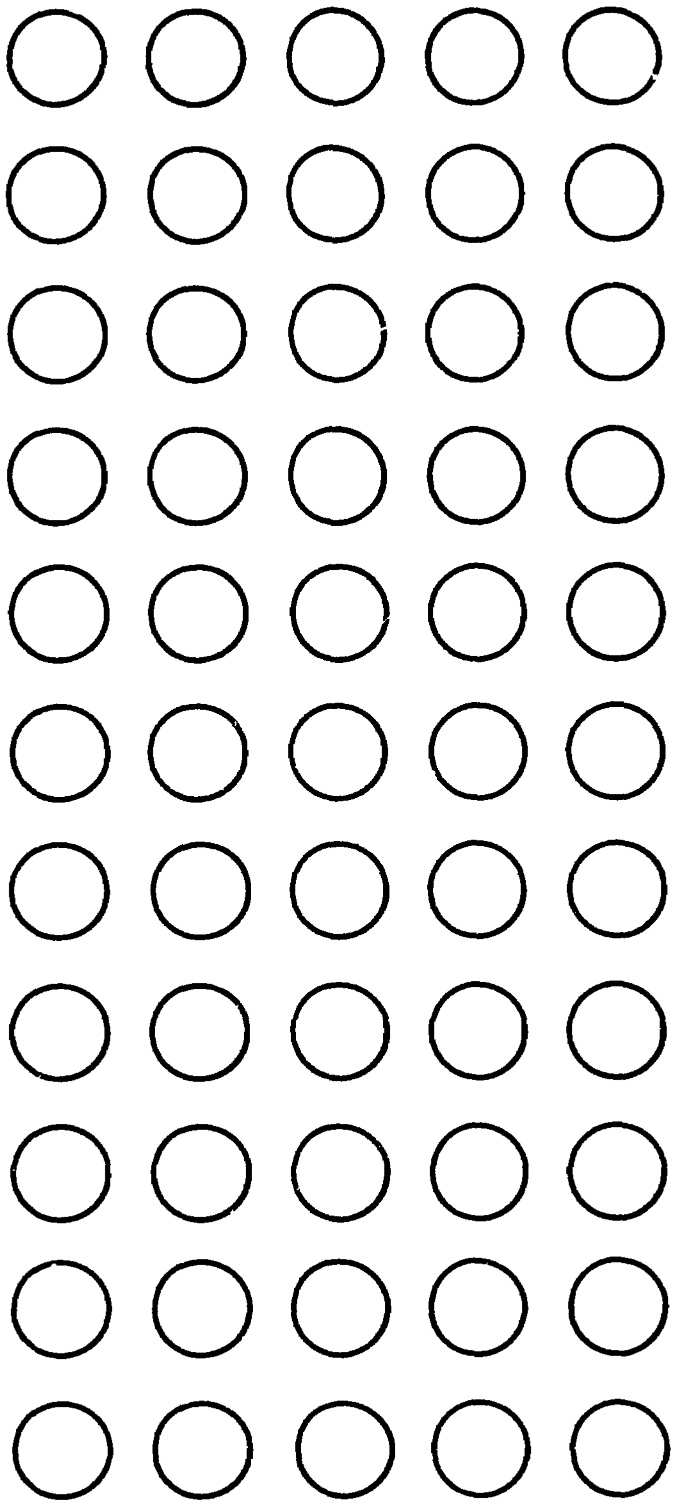
Remove the finger pad and discard it. Scrub with alcohol the next finger to be tested, apply a new finger pad, and proceed as before. Continue until all fingers have been tested.

At the top of each test page, write in the spaces provided the hand (right or left) and finger being tested. Write the child's name, the experimenter's name, the date, and the testing location in the spaces provided on the front page of the test booklet. Also, record any comments about the test procedure, fingers omitted from testing, procedural errors or changes, etc., in the space provided for that purpose.

Scoring. For each test page, count the number of circles containing a spot and record that number in the space at the top of the page. Do not count circles for which less than half of the spot lies inside the circle.

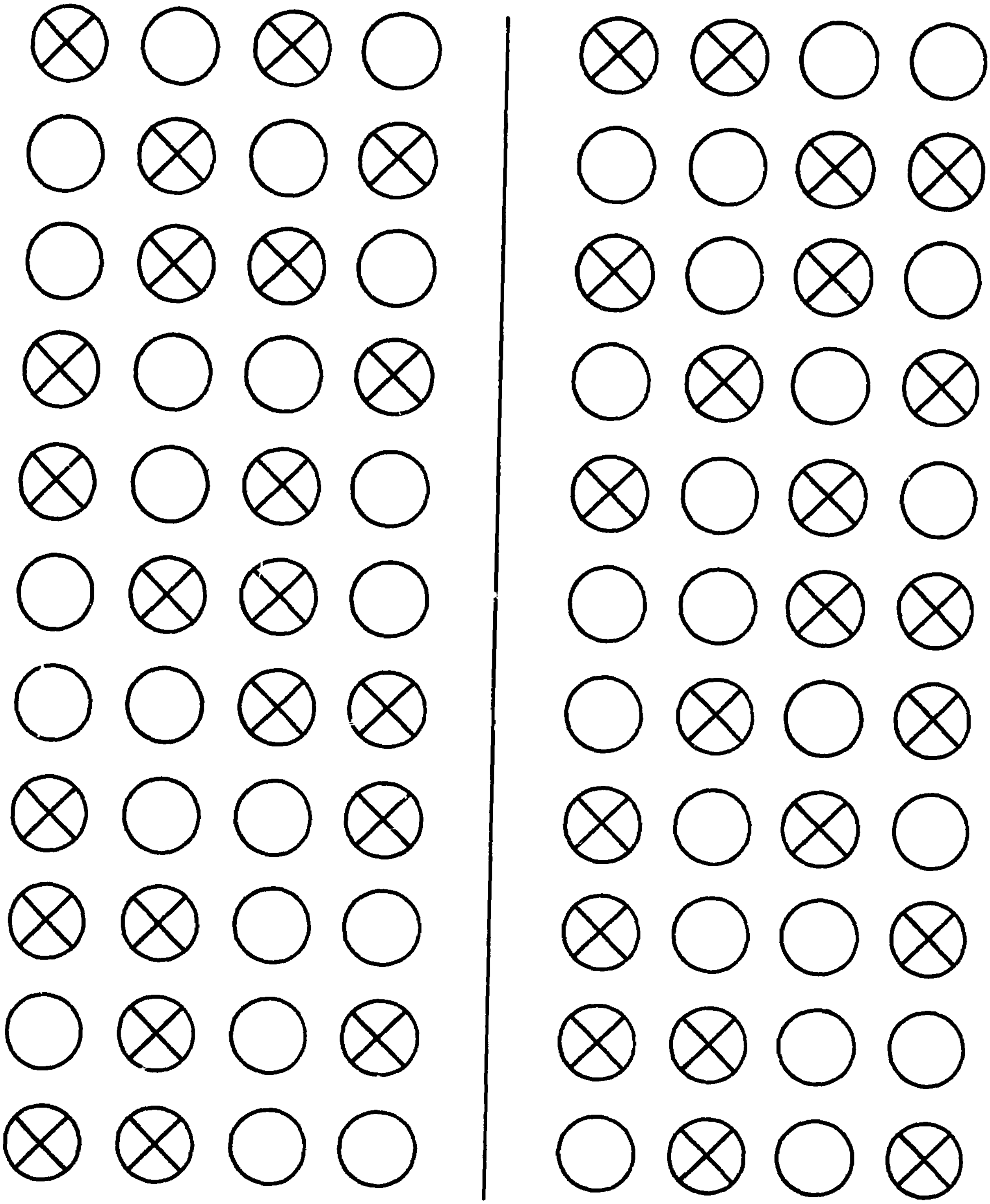
C/R/I
Tapping Test of Finger Dexterity

Hand **Finger** **Score**



C/R/I
Tapping Test of Finger Dexterity

Hand **Finger** **Score**



Appendix D CHILDREN'S HANDWRITING AND TYPING SAMPLES

This Appendix contains several samples of handwriting and daily typing papers taken from files at C/R/I for about 80 subjects in the studies described in the C/R/I Second Report.

Typed samples of work (figures 12-20) in this Appendix were produced on 14-key, bilateral-input interfaces. They have been included to illustrate the effectiveness of these man-machine communications systems in the education of the handicapped.

2345678902345678902345678 90,

Will you be my valentine

NEYXN SMEO

TODD

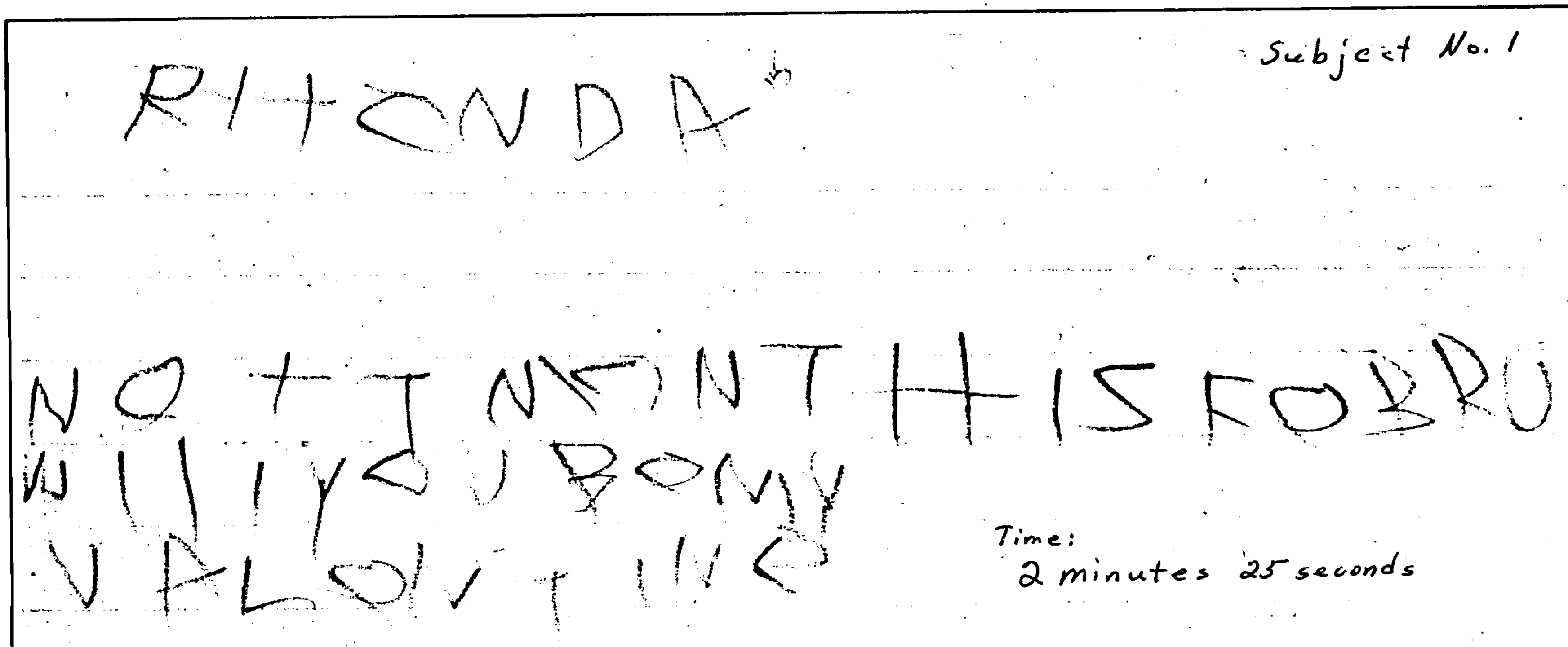
TOADAY I GOT MY TROPHY.

I AD. HAPPY THAT I HAVE IT.?

AN ANT ATE AN ONION. A RAT
THE CAT CHASES A RAT.
HELLLLO HELLO HELEN CCALLS.

THE MELN RODE HOME.
RUTH INSURED HSHER COAT.
SFABLLE FOOTOOBALL

Figure 12. Typing Samples – Subject No. 15



RHONDA CYBERTYPE

VERY FUZZY JANE JIMMY PAJAMAS
NEXT MONTH IS FEORUARY X WILL YOU OU MY VALENTINE.

Figure 13. Handwriting and Typing Samples – Subject No. 1

Will you be my valentine

Time:
4 minutes 31 seconds

Next Month is February

fbpgpg

MERRY CHRISTMAS
HAPPY NEW YEAR
U
Frances put a bun here.

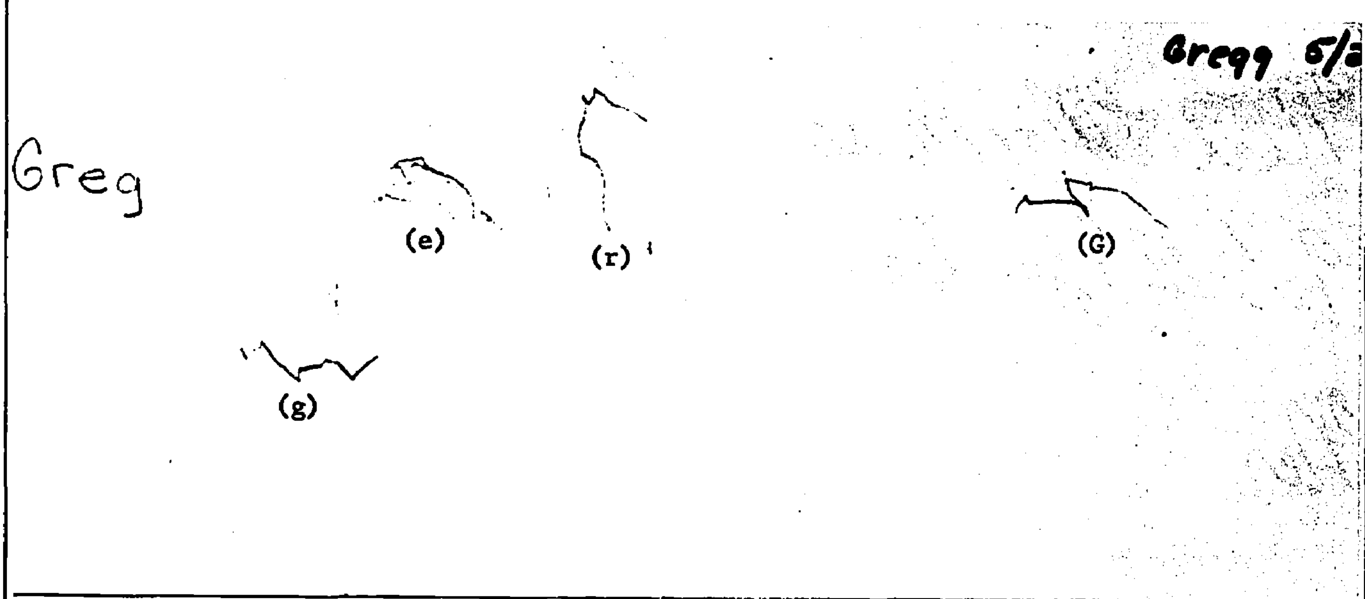
PAUL ATE A GREEN PEAR.

PUFF CAN RUN FAST.

GAIL HIGGER GETS GREEN GRAPE GUM.

PLEASE PASS PAUL THE GRAPES.

Figure 14. Handwriting and Typing Samples – Subject No. 16



(NOTE: Subject was asked to print his name - Greg - within this space)

GREG JOHN
KIK IKIK,I KIK
I KI
IK,ILJ
KITE TAKE ? KATE
KITTEM

T I ANM A KITTEMN

I CAN'T MAKE UP MUY MIND.

1+1=2 ¢c

Figure 15. Handwriting and Typing Samples – Subject No. 19

art

Next Month is February.

Will You Be my Valentine.

Ner

Subject No. 29
Case Study

HANDWRITING SAMPLE

Subject No. 29
Case Study

STUDENT'S PAPER--5/18

aRt

vjqkz.xkz.qjqjk.xzkqzkqzkjjq.xkzruvywfpz

scwxv.u.

S

NEXT MONTH IS B FFEBRUARY.

WCLL FGYOU BE MY VALENTINE.

NEWT MONTH IS FEB

Figure 16. Handwriting and Typing Samples – Subject No. 29

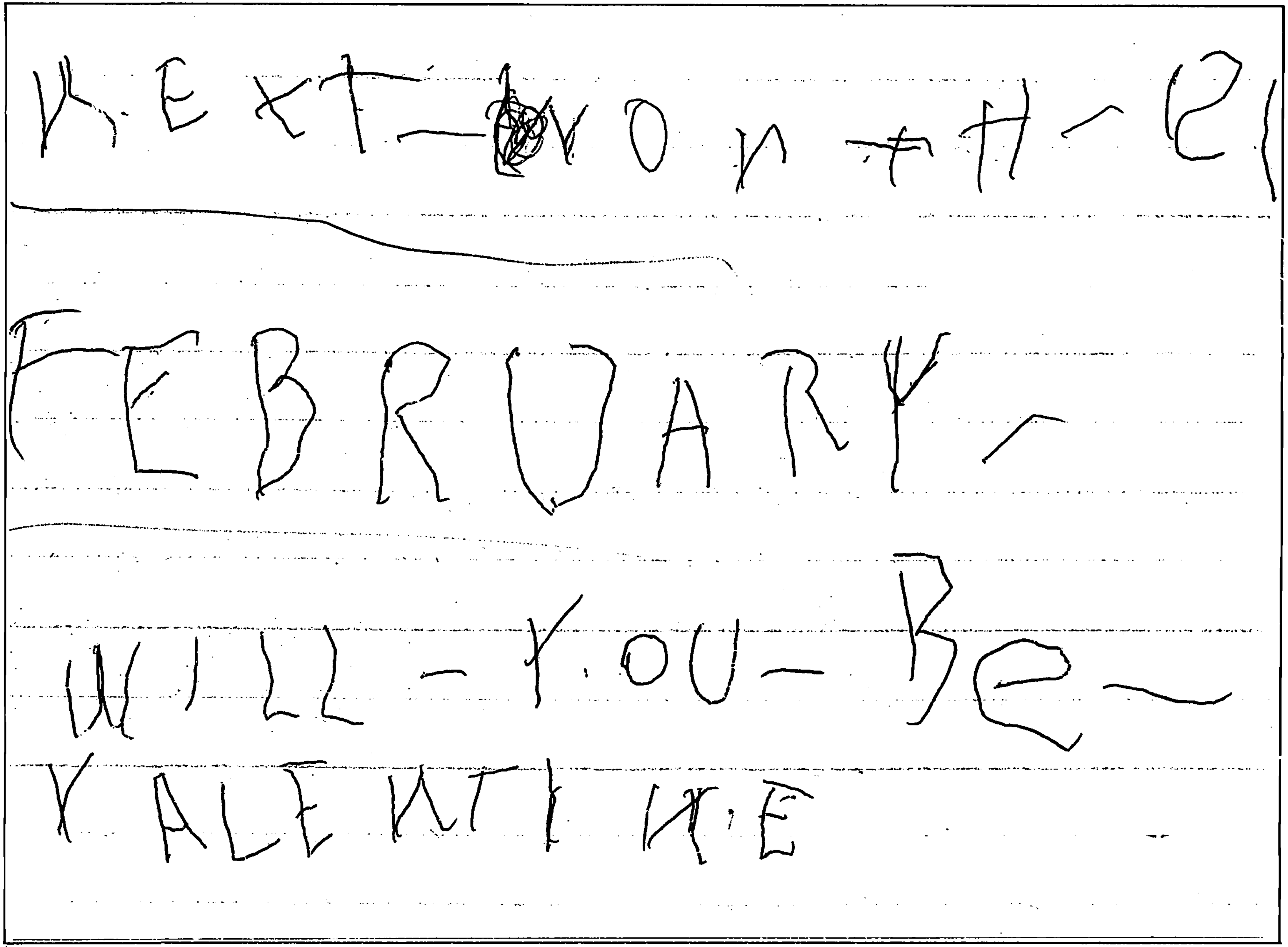


Figure 17. Handwriting Sample – Subject No. 30

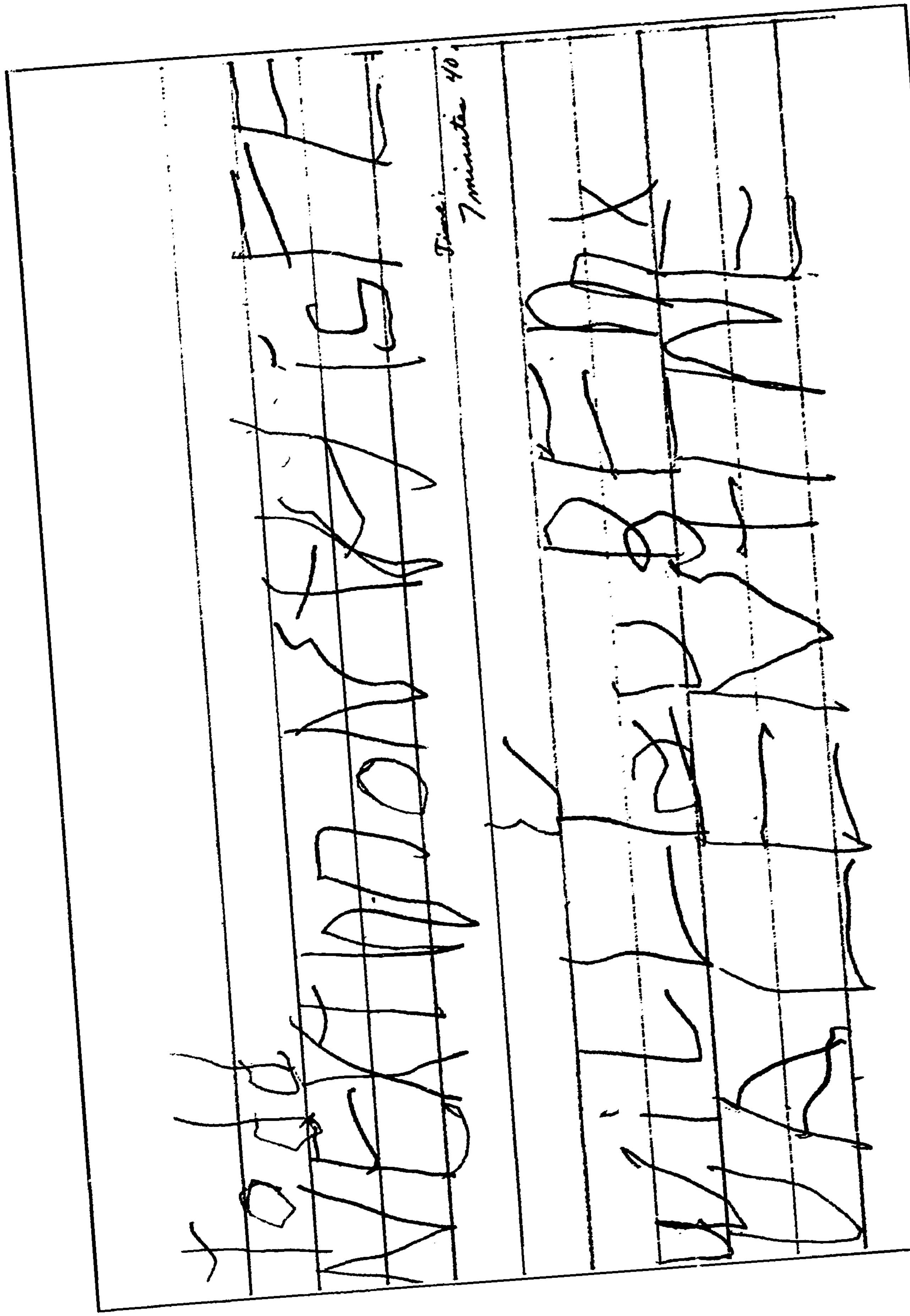


Figure 18. Handwriting Sample -- Subject No. 15

KIM

ONCE UPON A TIME, LONG, LONG AGO, IN A FARAWAY LAND OF PALM TREES AND COCKATOOS, THERE LIVED A // FROG. NOW THIS WAS A SILLY LITTLE FROG. EVERYBODY CALLED HIM KINGPRINCE OF THE FROGS. HE WAS A FAT LITTLE FROG BECAUSE HE ATE TOO MUCH.

AND THE LATTLE COCKATOO WENT FLYING BY.

HI FATSO HAHA! YOU'RE SO FAT, WITH THOSE SHRIMPY LEGS OF YOURS.

AND THE FROG WENT SWIMMING ACROSS THE POND SAYING HAHA, YOU CAN'T SWIM.

Teacher's Note: This clever fairy tale is symbolic of the subject's own diminutive size but spunky nature and pride in what she can do.
The beginning lines (to double bars) were prepared by the teacher. The story was recorded by the teacher and typed by the subject from dictation.

Figure 19. Creative Work – Subject No. 14

BARTEY

THE K
I
N
G MDOESN'T SAY PHLEASE OR THANK YOU

THE
Q
U
E
E
N

G
N
I
K

E
H
T

O
T

N
A
E
M

S
WA

E
H
S

Teacher's Note:

In this paper, a subject with little physical strength used spacing as an expressive device to fulfill the assignment of writing a story entitled "The Funniest Thing". In this way he was able to write a complete and expressive story in only 3 sentences.

Figure 20. Creative Work — Subject No. 38

Appendix E | CASE STUDIES

Case studies including daily reports, an extensive summary, and progress charts and graphs have been kept for about 80 subjects involved in this phase of the study at C/R/I. Two representative case studies are shown; they include summaries, progress charts (figures 21 and 23), handwriting samples, and daily reports (figures 22 and 24) which illustrate the methods and techniques used in teaching children of different ages, in adapting to varying handicaps, in evaluating performance, and in reporting data. For convenience, the graph (figure 25) at the end of this appendix combines data from both case studies.

Case Study: Subject No. 29

Subject No. 29 is an 11-year-old boy confined to a wheelchair with muscular dystrophy; most of his weakness is in his lower extremities. According to the occupational therapist, he has good dexterity with full use of all his fingers, and physical difficulties in typing would be more a matter of arm and finger weakness than of lack of coordination. A recent test score indicated that he was reading at his school grade level. His handwriting is labored (see Appendix D).

During the initial session, the subject appeared to be motivated, interested, and eager to use the dual-input interface as a communications tool. He rapidly learned the transfer code for seven letters and the following typewriter functions: carriage return, space, and period. By the end of the first lesson he was able to type his name. The teacher noted that he preferred to work with the keyboard on his lap rather rather than on a table. The typewriter was on a typing table which was placed in front of him, but he seemed to have difficulty seeing what he had typed. He also showed a preference for using only his index fingers, even though he had use of all of his fingers. (This is not uncommon for beginners.) The instructor advised him that, though it initially might seem easier and faster to type using only his index fingers, he would be able to touch type using the thumb and the second, third, and fourth fingers of each of his hands and surpass the speed he would achieve using only his index fingers.

From the initial session, it appeared that the bilateral-input interface would be useful for this child. The portable, small-area keyboard with just seven keys on each side would be of particular importance considering his arm and finger weakness. Less navigation and movement would be required. The fact that he could use the keyboard on his lap also eliminated the necessity of having to raise his arms and extend them as would be necessary when using a standard electric typewriter keyboard. After the first session, it appeared that the child would be able to master the transfer code quickly and with very little difficulty. For him, speed did not seem to be an important factor. What this subject needed was a communications device that could be used with the least amount of energy possible. Due to the effort required to correct errors, emphasis was placed on accuracy as opposed to speed.

At the outset of the second session, the subject displayed rapid and accurate recall of the first seven letters. He had been taught these code positions with reference only to spatial positions; and since he evidenced no difficulty in recall, it was decided to teach him the remainder of the code in the same manner.

A "split" keyboard was tried with the subject at the second training session. A seven-key section of the keyboard was placed adjacent to each of his knees. The light touch of the keys and the fact that he did not have to raise his arms clearly made it easier for him to operate the keys. Should this subject become progressively weaker, the split keyboard with its light touch keys will be all the more necessary.

The subject continued to show rapid progress in learning the code. By the end of the fifth lesson, he had mastered 32 characters and functions and had developed sufficient skill in using the "Cybertype" to be able to type an English assignment on pronouns during the sixth lesson.

From this point on, most of the lessons were devoted to completing English assignments on the bilateral-input interface. The subject "Cybertyped" his name, the date, and the title of the assignment at the top of the paper and numbered each sentence he typed. In most instances, he corrected his errors with typing correction tape. This correcting served two purposes: (a) it reinforced his memory of the location of the correct key, and (b) it allowed him to produce neat, readable copy. Often his teacher inserted the correction tape while the subject back-spaced, typed over the error, and then typed the proper letter.

By the end of the ninth lesson, the subject had mastered 41 functions, and it was obvious that he was capable of using the bilateral-input interface independently in the classroom.

After mastering the transfer code, the subject was assigned a set of practice sentences and common endings. Some time was spent during each lesson showing him how many of the common digraphs and syllables could be typed by keeping one key depressed, thus requiring less hand movement. The purpose of this was not necessarily to develop speed, but rather to conserve as much of this child's energy as possible.

Since speed was not considered to be an important factor, the subject was not given any timed tests until the 13th session. He was then given the series of timed tests used for the Comparison Study to demonstrate his progress to him and to determine which key combinations were difficult for him to remember. The instructor noticed that he seemed to have most difficulty with the placement of his left hand. Analysis of

TABLE IX

Test Results-Subject No. 29 Case Study

Test No.	Given in Lesson No.	Characters Functions	Errors	Duration of Test (min.)
1	13	69	2	2:30
2	13	52	0	2
3	14	65	5	3
4	14	59	4	3
5	15	67	4	3
6	15	81	3	3
7	16	59	6	3
8	18	70	7	3:20
9	19	76	3	3
Final Test	20	73	7	3
Retest (Final)	20	73	3	3

TABLE X

Rate of Introduction to Cybercode$_{TM}$–Subject No. 29

Lesson No.	Characters/Functions Introduced	Number Learned
1	E,T,A,O,N,I, space, R, carriage return, period	10
2	S,C	12
3	H,L,D,M,2,3,4,5,6,7,8,9,0	25
4	-	25
5	U,F,B,P,G,Y,W	32
6	V	33
7	comma, back space	35
8	K, quotation mark, question mark, upper shift, lower shift	40
9	X	41
10	-	41
11	-	41
12	Z	42
13	-	42
14	J,Q	44
15	-	44
16	-	44
17	apostrophe	45

[Note: At the beginning of each session all previously introduced items were reviewed.]

the tests indicated that this difficulty with left-hand placement was indeed the major cause for his errors. Table IX shows typing performance and errors made on the timed typing tests.

SUMMARY

Subject No. 29 received a total of 17 lessons and mastered 45 functions (see Table X). Emphasis was placed on accuracy and limited finger movement, not speed. On the final typing test, he typed 73 functions in 3 minutes with three errors. He mastered the transfer code and the bilateral-input interface to the extent that he was able to use the "Cybertype" independently within his classroom.

The split keyboard should be more particularly adapted to meet his specific needs either by attaching it directly to a wheelchair that does not have armrests or by developing an adjustable cut-out table with slots on both sides of the cut-out for the split interface. This would enable the subject to type with his arms resting on the table.

DIAGNOSTIC EXPLORATORY STUDY

S. No.	SEX	CA	IQ	MA	RL	SPACHE/	
29	M	11-10	84	9-11	4'	WL 6 Comp 6	Good word attack skills. Good comprehension.

MACHINE Cybertype

SESSIONS 20

MIN/SESSION 29

TOTAL TIME ON MACHINE 460

TOTAL TIME 580

MAXIMUM WPM 5.4 WRITTEN SAMPLE/TIME 90/3

EPM 1 TYPED SAMPLE/TIME 73/3 /ERRORS 7

MEDICAL DIAGNOSES MD

CHART DESCRIPTION MD - weakness mostly in lower extremities. Wheelchair. No hearing or vision problems. Complete use of all fingers.

TEACHERS DESCRIPTION Complete use all fingers - in wheelchair. Tired easily. When tired sometimes used only index fingers. No evidence of visual or auditory impairment.

108/11·9

Figure 21. Summary Progress Chart – Subject No. 29

NAME Subject No. 29

TEACHER Nikkel

DATE 5/18 SESSION # 20

TOTAL TIME 30

TOTAL TIME ON MACHINE 25

NEW SYMBOLS INTRODUCED ----

SYMBOLS REVIEWED All

TOTAL NUMBER OF FUNCTIONS TAUGHT ---

TIMED SAMPLE

2 - Final Test

DATE 5/18 TOTAL FUNCTIONS 73

TOTAL ERRORS 7 TIME 3

L		R	
V	H	V	H
B-F DL-F O-1 P-Y C-Y	O-T W-X		

NOTES #2 of test. 73 functions. 3 minutes. 3 errors. (w-x, s, e-r) Reviewed keys. Typed final test twice. The subject didn't think he'd done his best the first time. Got written sample. Rest of class used for typing English assignment. Every time I have gone to get the machine from the child's room he has been using it. Very excited about having it two days a week instead of one. A child in Project Dual in this boy's room. The other told now that study is over he can use the machine when this subject isn't. Excited about being able to use it but doesn't think he'll get to use it too much since this child is always using it. Left supply of carbon paper. Asked child to make carbon of anything he does on the "Cybertype."

109/7-9

Figure 22. Daily Report Form: Final Test – Subject No. 29

Case Study: Subject No. 30

Subject No. 30 is a 7-year-old girl with cerebral palsy. According to her school file description, she has some visual impairment, difficulty in scanning, and difficulty in perceiving form and position in space. She has a moderate hearing loss and a speech problem. She scored 99 on her last IQ test.

During the initial lesson, it was observed that she was unable to hold her finger on any specific key without depressing many other keys. She originally typed only with her index fingers, but eventually began using her thumbs. She was easily distracted and confused. This child should have been instructed in a small private room instead of in an open hallway with a good deal of traffic and confusion (the only space available at the school).

At the outset of the program, the subject was unable to correctly identify seven consonants and evidenced a great deal of difficulty focusing on a letter or on word cards. She did not seem to hear much of what was said to her, even when directly facing the speaker; often she seemed lost in a world of her own.

For this subject the purposes of instruction were to help her learn to concentrate, develop skill in identifying letters, master the code, and use these skills in building a sight vocabulary. (When first tested on the Spache Word List the subject could not read a single word.)

The subject worked with a large-type "Cybertype," the alphanumeric lamp display, and a 14-key interface. Several versions of the interfaces were tried. A

TABLE XI

Rate of Introduction to "Cybercode"–Subject No. 30

Lesson No.	Characters/Functions Introduced	Number Learned
1	E,T,A,O,N,I, space, carriage return	8
2	-	8
3	-	8
4	R	9
5	S,C,	11
6	D	12
7	-	12
8	-	12
9	H,L,M	15
10	-	15
11	-	15
12	-	15
13	-	15
14	-	15
15	-	15
16	U,F,B	18
17	-	18
18	P,G,Y,W,X	23

[Note: At the beginning of each session all previously introduced items were reviewed.]

TABLE XII

Test Results–Subject No. 30

Test No.	Character/ Functions	Errors	Duration of Test (min.)
1	36	7	4:15
2	44	4	3
3	45	11	2:55
4	45	9	3
5	30	7	3
6	40	4	3
Final Test*			
AM Final	34	5	3
PM Final	32	2	3

*Given twice on the same day

keyboard with large, widely-spaced, rubber-tipped keys, initially designed for use by a bilateral amputee, was found most satisfactory. After trying various placements of the lamp display and the material the subject was copying, it was found that the subject worked most effectively when the lamp display was placed directly in front of her and the cards from which she was working were held at an angle on the desk directly below the lamp display.

The first six letters of the code were taught through association with the "Cyber-Circus" teaching aid. Once the subject had progressed to the "R Tent," the circus character associations did not seem to hold her interest. The subject was unable to grasp the order of the characters and their spatial location. Also, some of the associations in the story confused her; e.g., she kept insisting that the "colt" was not a colt but a "horsey."

As the subject learned the location of a letter she was given a small card with the letter printed on it. The lessons began with the instructor selecting a letter from the pile, naming it, and asking the subject to type a row of that letter. This procedure was later changed so that the subject selected, named, and typed the letter. Once she had mastered enough letters they were combined into words selected from the Dolch Basic Word List. These words were then used in sentences.

The Subject's performance was at times erratic. She was always delighted to come to the lesson, but her attention, concentration, and retention were highly unpredictable. In one lesson she would take the entire period to type her name correctly three times; in another lesson she might have complete recall of the code and type with enthusiasm and accuracy. This specific learning problem could not go unheeded; no machine, no matter how good, would be of any value without a teacher with an understanding of her student and of measures to be taken to help correct his problems. About mid-way through this program, cookies were introduced as an incentive, and a marked improvement was noted in the subject's attention and performance.

As the subject progressed to typing words, phrases, and sentences the lamp display was removed. At this stage of the instruction the display seemed to be more a distraction than an aid.

In the course of her total of 18 lessons, the subject learned the keying positions of 23 characters and functions. By the end of the program, at the close of the school year, she had gained a great deal of confidence and enthusiasm and was progressing much more rapidly than she had at the outset of the program. Table XI indicates the rate at which the letters were introduced. The subject progressed to the point where she neither required nor wanted cuing assistance from the instructor. Results of timed tests are shown in Table XII.

DIAGNOSTIC EXPLORATORY STUDY

S. No.	SEX	CA	IQ	MA	RL	SPACHE/	
30	F	7-11	71*	5-7	Not Tested	WL	Out of entire list knew 4 words - book, come, the, big. Could have been a put-on. Did better reading cards in class. No word attack skills at all. Phonics - given twice, 1st time 2/17* q=p n=v l=one j=g d=b t=x y=h second time 6/2, q=p n=? l=i g=o

*file SB-'65 IQ=99

MACHINE Cybertype

SESSIONS 18

MIN/SESSION 18

TOTAL TIME ON MACHINE 320

TOTAL TIME 470

*first time she didn't know one word.

MAXIMUM WPM 3 WRITTEN SAMPLE/TIME 27/3**

EPM 3 TYPED SAMPLE/TIME 32/3 /ERRORS 2

**Wrote sentence "Turn it off" 47 sec. Typed perfectly in 45.

MEDICAL DIAGNOSES CP

CHART DESCRIPTION CP Athetoid. Disabled foot (extensive surgery rt. foot). Visual impairment(scanning).Moderate hearing loss. Perceptual problem forms and position in space.

TEACHERS DESCRIPTION Used only index finger and thumb on each hand. Couldn't hold hands in proper positions without pushing all keys down. Perception problems. Hearing problem. Very limited attention span. Easily confused. Worked well for cookies. Unpredictable. Up one day, down the next. Distractable.

108/11·9

Figure 23. Summary Progress Chart – Subject No. 30

NAME Subject #30

TEACHER Nikkel

DATE 5/19 SESSION # 18

TOTAL TIME 30 min. (15a.m.--15p.m.)

TOTAL TIME ON MACHINE 10a.m.--10p.m.

NEW SYMBOLS INTRODUCED PG - WY - V

SYMBOLS REVIEWED

TOTAL NUMBER OF FUNCTIONS TAUGHT 23

TIMED SAMPLE
Final test -- twice a.m. & p.m.

DATE 5/19 TOTAL FUNCTIONS 34

TOTAL ERRORS 5 TIME 3 min.

L		R	
V	H	V	H
W-M P-H C-L N-L	CR		

NOTES It was a rainy day and the child was very distracted--took her the first period in the morning and again in the afternoon. She had missed 2 sessions in a row. 1) attended a field trip.

109/7-9

2) Another child was leaving on Friday and I gave her this subject's period. Child is very playful--not at all in the mood to type. Typing part of the time with her thumbs. On the test told her only "x" Wicnl = will Hit carriage return by mistake so 11 on next line. Trouble remembering tents. Kept hitting U for R. P.M. gave test again: 32 functions 3 minutes 2 errors

Writing sample: Got to "Will" in 3 minutes

Figure 24. Daily Report Form: Final Test – Subject No. 30

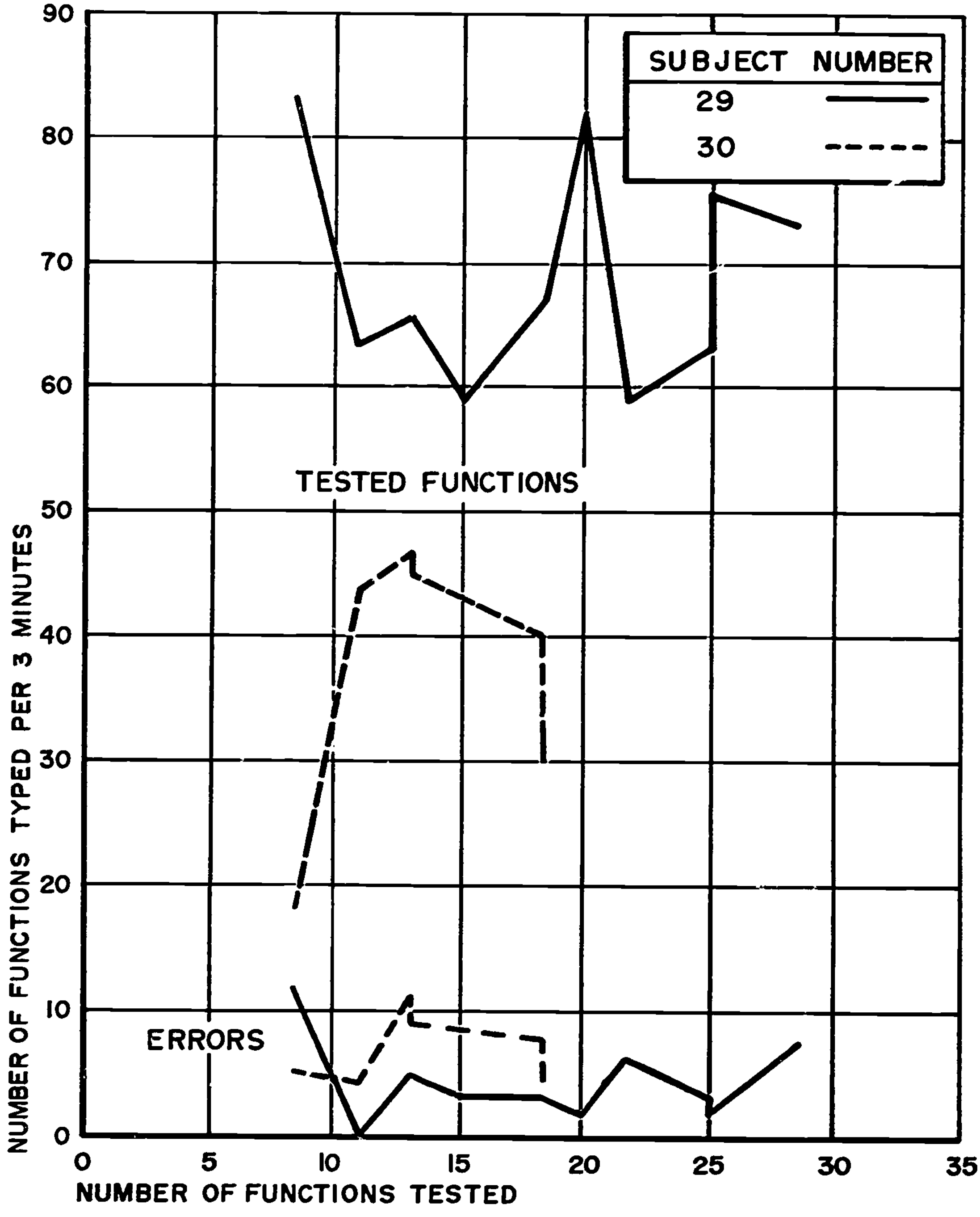


Figure 25. Graph of Characters/Functions and Errors Produced by Subjects 29 and 30

Appendix J GROUP INSTRUCTIONAL PROCEDURES

This Appendix covers the first phase of an exploratory educational program concerned with developing effective group procedures for teaching handicapped and nonhandicapped children to communicate using a dual-input man-machine system. The investigators placed emphasis on applying well-known teaching techniques practiced in many public and private schools to group instruction with man-machine systems. Objectives of this phase of the program were:

1. to teach the entire English alphabet and corresponding code for bilateral-input fingering in the fewest possible training sessions;
2. to devise effective means of group instruction, including gamelike educational materials related to the bilateral-input system;
3. to develop increased interest in reading, and in communicating through man-machine systems;
4. to enrich the vocabulary of the underachievers, improving verbal comprehension and expression; and
5. to develop improved manual skills.

One underlying assumption of this phase of the program was that dual-input typing and the concurrent bilateral motor responses it requires would enhance the child's learning of verbal and manual dexterity skills. This assumption is not systematically studied in this first-phase program, but stands as a hypothesis for future experimental validation.

A second assumption was that the use of only one typewriter with several remote keyboards

TABLE XIII

Characteristics of Subjects

Subject Number	Description
104	Male, age 10, IQ 80; minimal cerebral dysfunction with positive neurological myopia (enrolled in a special education class).
105	Female, age 12, IQ 95; torticollis and other minimal spinal deformity; elongated fingers; severe one-sidedness, with entire body in swinging motion; trained for one year with optometrist to develop skills for one eye—could not track or follow an object moved about 6 inches from her eyes; worked with student of Gesell Institute to improve muscle development; in sixth grade because of size.
106	Male, age 10, IQ 101; enrolled in sixth grade, remedial reading class; grade norm 5.5, reading level 3.4; Iowa Basic Skills, average 5.0.
107	Male, age 11, IQ 110; enrolled in sixth grade, remedial reading class; grade norm 5.5, reading level 4.7.
112	Male, age 8, IQ 93; enrolled in fourth grade, remedial reading class.

The remaining six subjects were nonhandicapped and were evaluated as possessing average to above-average intelligence, with ages ranging from 6 to 19.

connected to it, would lend itself particularly well to group instruction.

The bilateral-input system has been demonstrated to be a valuable educational tool for many children who have severe motor disabilities which preclude their use of standard typewriters, and may also prove to be beneficial for children with specific learning disabilities.

SUBJECTS:

Eleven children participated in this phase of the study. They included physically handicapped and nonhandicapped children, and children with specific learning disabilities. Their IQs ranged from 80 to 123. Summary information provided by parents and school administrators for subjects having physical or learning disorders is given in Table XIII.

APPARATUS AND PROCEDURE:

The basic input mechanism of the man-machine communications system was the interface, a portable, bilateral-input keyboard, which controlled a 49-key electric typewriter. The interface consists of two sets of seven keys, one set for each hand or part of the body used to activate the keys. Each character or function to be typed requires a concurrent bilateral response of two key depressions, one from each set. (For a full description of the equipment, see Interim Report, Kafafian, 1968.)

Subjects were introduced to the identity of their fingers by name and to the fingering code by demonstration and use of a visual aid in the form of a large chart showing keying positions for each character and function. Subjects took turns using two remote keyboards connected to one "Cybertype" unit through a junction box. (More keyboards could have been connnected to the typewriter since the junction box was equipped with six connnections.) The group received practice using a variety of projects and games, described herein, designed to enhance learning of the transfer code.

Imaginary 14-key keyboards were also used for practice. The children were asked to picture a "phantom" keyboard in their minds and to manipulate the appropriate fingers for various characters and functions. Tape recorded voice instructions and musical accompaniment paced for the beginner were prepared for use in the training sessions. The latter are currently being evaluated.

Since most of the subjects ranged in age from 6 to 14, instructions for use of the keyboard interfaces included such labels as "Master Controls," "Space," "Secret Agents," etc., to develop intrigue and maintain motivation. A "play" or "games" concept was utilized in these instances. The investigators felt that terms related to outer space and discussions of man-machine systems used in space exploration would be particularly attractive to the children, since at the time of this phase of the program, our Nation was engaged in the Apollo 11 launching, man's first moon walk, and the successful return of the three astronauts from outer space.

One of the initial procedures was to explain man-machine relationships to the subjects, and the extent to which machines help us perform work efficiently. Hence, in one training session, the children were encouraged to describe the usefulness of machines, e.g. vacuum cleaners, washing machines, electric saws, automobiles, airplanes, and meteorological rockets. During these discussions, the standard electric typewriter with a 49-key keyboard and the dual-input "Cybertype" with one variety of interface, a 14-key portable keyboard, were introduced. The children were taught how to insert and remove paper from the typewriter (this particular machine was not equipped with the automatic paper feed) and were shown how to operate the dual-input keyboard.

For many children, this was their first experience in creating printed words and typing sentences. The teacher explained that "Cybertype" was a new invention to help physically handicapped children who could not operate a standard 49-key typewriter keyboard. With "Cybertype" and its reduced number of keys and smaller keyboard, they would be able to move their fingers about the interface more easily and would be able to communicate through typing. These ideas were reinforced by showing the subjects photographs of physically handicapped children typing through use of various "Cybertype" portable keyboards.

The subjects were also told that using the new machine would help them learn more about letters, words, and sentences, and would improve their ability to communicate. The teachers explained the importance of verbal and written communications in expressing ideas and describing things. It was pointed out that many deaf children can be taught to understand speech by "reading" a person's lips, and that many blind children learn to read through their fingers by touching a punctographic or tactile code known as braille. The purpose of this didactic introductory information for the subjects was to develop understanding of the part words play in meaningful expression and to explain some of the modes of communicating, such as audible speech, lip movements, braille tactile dot characters, and printed words.

Through these introductory comments, the teacher assured herself that the children were well motivated for learning before proceeding with instruction. Thereafter, the responses of the subject were carefully observed. As indicated herein, their responses were good.

The projects and games used by the subjects in practicing fingering codes include:

1. Window Shade Instructional Aid (plate 3): A large chart of a 14-key keyboard, showing seven blue keys on the left side and seven red keys on the right side, was made from a standard window shade (3' x 6'). The dual-input fingering codes were shown by outline drawings of the dual keying positions, below which were printed the corresponding characters and functions. When the window shade was completely pulled down, it displayed the entire dual-input fingering code. As each group of characters and function was learned, the shade could be partially rolled up,

Plate 3. Window Shade Instructional Aid

thereby concealing that group and showing only those characters and functions to be learned. This chart was used only for reference until the fifth session with most subjects, after which it was not required.

2. Beanbag Game (plate 4): A window shade was also used for a game which consisted of large squares arranged to represent the 14 keytops of the keyboard. Seven squares on the left side of the window shade were colored blue and seven squares on the right side were colored red. This keyboard chart was rolled out on the floor of the classroom for use by the subjects. Two teams of children were formed; a Blue Team used a blue beanbag for the left side, and a Red Team used a red beanbag for the right side. One child on the Blue Team would throw his blue beanbag on one of the squares on the left side of the chart, after which his opponent on the Red Team would throw his red beanbag on a square on the right side of the chart and call out the character or function represented by the "key" positions of the red and blue beanbags. If correct, the Red Team would receive a point for that play. The players would continue in turn until one player of the Red Team made a mistake or a time limit was reached. Then the children would switch sides and exchange beanbags. Variations of this game, including a "Hop-Scotch" layout, are being developed.

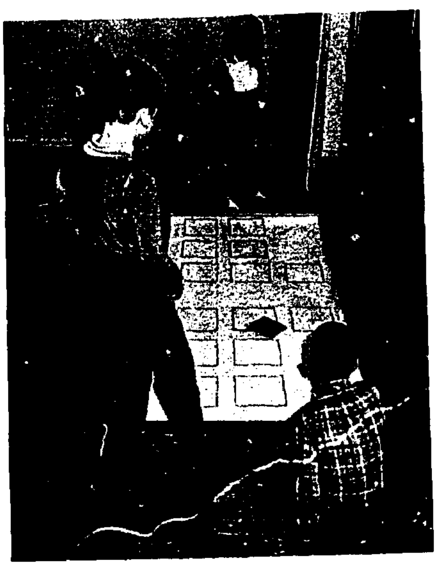


Plate 4. Beanbag Game

3. Button-Box Game (plate 5): Coat buttons were glued to the cover of a 6 x 8 x 1 inch box to represent a dual-input, 14-key keyboard. In the beginning, this game was used to teach the letter code; but as soon as a few letters were learned, it became more meaningful to spell out words. The subject was instructed to touch the right and left side key positions for the letters required to spell a word, and subsequently messages, without looking at the "keyboard." Children enjoyed com-

Plate 5. Button Box Game

peting with each other to be the first to announce the words being formed by the player's fingering positions on the button keyboard.

The Button Box game contained colored cardboard charts showing the left and right groups of seven keys. Each chart showed which character or function would be produced by each key in the right group for a given key actuation in the left group. Thus, there were seven charts, one for each "Master Control" key in the left group. A composite or summary chart was also provided, showing the seven numbered keys in the left group, each with a different color, and showing for each key in the right group, the characters and functions color coded to correspond with the "Master Control" keys in the left group.

4. Overhead Projector Visuals (plate 6): Transparencies were also prepared for classroom instruction. For example, the plate shows keys 1 through 7 on the right side representing the letters "P,S,H,D,C,L,M" when the number 2 key on the left side is

Plate 6. Overhead Projector Visuals

depressed. Fingers were placed over keying positions on the transparencies and the entire display was projected on a screen. A complete set of transparencies was developed and used with the scroll story of "Secret Agent."

5. Secret Agent 7 Scroll Story (plate 7): This story involved two characters, Secret Agent 7 and Secret Agent 49, and their efforts to uncover the "secrets" of communicating with the dual-input keyboard. As one

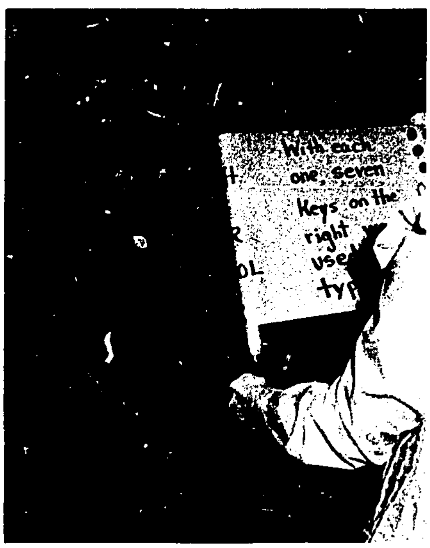


Plate 7. Secret Agent 7 Scroll Story

subject or the instructor read the story aloud, another subject typed words dictated from the story. This was especially successful with younger children (6-10 years).

6. Undercover Quiz Game (plate 8): This game (like the others, made from materials easily available in the home or classroom) consisted of a number of 4 x 6-inch index cards, with each card containing written characters or functions in positions corresponding to the seven keys in the right group of the interface. On the left side of each card, a blue circle was drawn in the "Master Control" key position associated with the characters and functions on the right side of the card. The game involved use of a master card with 14 window-flaps cut out in positions corresponding to key positions on the 14-key interface. To play the game, the child looked for the "Master Control" key hidden under one of the seven windows on the left side, and wrote on a score card the letters which should be "under cover" in the windows on the right side. After a child had five

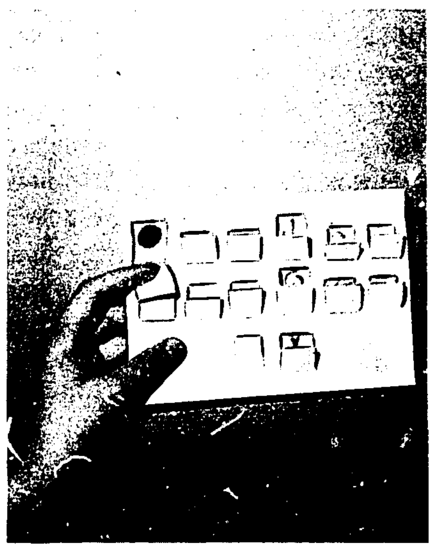


Plate 8. Undercover Quiz Game

turns with five cards, his scores were recorded and the next player took his turn. This game was observed to be more intriguing for the older children (10-19 years).

7. Letter-Tile Game (plate 9): Wooden blocks inscribed with characters and functions were used to play the Letter-Tile Game. Each of two players was allowed to select seven blocks from a mixed set thrown within reach of the subjects on a table top. The opponents raced to form a word from their acquired set of blocks. Then the players were required to place each letter-tile from their words in the appropriate finger position of the right hand to obtain that letter in typing on the keyboard. The players were then asked to write the number of the left-hand master control key on a chart next to the letter-tile. These answers were subsequently tabulated to obtain a score for each player.

Plate 9. Letter-Tile Game

8. Pop-Up Flash Cards (plate 10): A reviewing device was constructed consisting of ten 4 x 6 inch index cards, each of which had 14 window-flaps arranged in the positions of the keys on the interface. For each card, one of the window-flaps on the left side (representing "Master Control" keys) contained a blue circle to indicate key actuation. Characters or functions were written in red ink on each of the flaps on the right side of the card to correspond with the "Master Control" key indicated on the left side. The window-flaps were cut out along the two sides and the top, with the uncut bottom edge forming a "hinge" allowing each window to be folded forward and down against the surface of the card. When each window was released, it would "pop up" exposing the character, function or marking on its surface. The game was played by having a subject fold down the flaps on one side of the card, leaving the flaps on the other side of the card exposed. Another subject in the group would then try to relate what was inscribed on the folded flaps. For example, the flaps on the right side of the card could be turned down by one subject and a second subject would observe the indicated "Master Control" key on the left side, then relate the appropriate character or function for each key on the right side. As this subject gave each response, the first subject would release the corresponding window flap, allowing it to "pop up" and expose the correct response. Alternatively, the seven flaps on the left could be turned down, and a subject would indicate which control key corresponded to the seven characters or functions shown on the right side window flaps. A score was tabulated for each subject according to the number of correct responses made.

Plate 10. Pop-Up Flash Cards

9. Improvement of Finger–Key Relationships: Since all subjects in this group had good color vision, different colors were used to identify finger-keying positions. Four colored, circular felt pads were attached to the subject's fingernails (thumb and first three fingers) of each hand and were matched to the colored keys of the keyboard. this appeared to be useful for those subjects who were uncoordinated or experienced difficulty identifying their fingers.

In addition to these games, other motivation and learning aids were employed, including: (1) speed drills using rhythmic counting; (2) singing and playing melodies with piano accompaniment to coincide with rhythm drills; (3) dictation of sentences leaving out words to be typed; (4) mimeographed sheets for filling in characters and functions learned; (5) flash cards showing dual-input keying positions for various characters and functions; (6) fill-in charts for children to indicate the keying positions; and (7) reading charts for instruction in speech sounds, word formation, word endings, and vowel combinations.

Group instruction in this project consisted of eight sessions lasting ½ to 1 hour. They included the introduction to man-machine systems as described earlier, followed by practice and learning of the fingering positions by direct experience with the dual-input system and participation in the various games, projects, and exercises. In the process of learning the keying code, the children were provided with exercises containing words appropriate to their reading level.

RESULTS AND DISCUSSION

The investigators and observers studied each child's performance during the teaching sessions and recorded notes on attitude, progress, and effectiveness in written communications. Summaries of some of these reports and sample work sheets are provided in this Appendix. Observation of group performance on these man-machine systems leads to the following conclusions:

1. The dual-input code can be taught to subjects in a group environment with relatively few training sessions using only one "Cybertype" equipped with as many interfaces as required, usually not more than six. (The limit depends on the teacher's requirements.)

2. Bilateral-input interfaces can be used by individuals having motor disabilities resulting in poor coordination or dexterity. These disabilities may impede finger navigation and, hence, performance on large 49-key keyboards, but often allow operation of the dual-input, 14-key interface.

3. Acquisition of the character/function keying code provides experience in the formation of words and sentences.

The investigators believe this experience will enhance the development of skill in written communications for many children with or without motor and/or learning disorders.

4. Instructional materials can be economically constructed and quickly prepared from household items.

In addition, the following observations and recommendations were derived from teachers' reports: (1) a Socratic method of instruction in a relaxed atmosphere involving games and play was found to be successful in maintaining subject motivation and in teaching the dual-input code; (2) the initial use of visual aids in the form of charts and games facilitated learning of the code and resulted in excitement in later training sessions, when children discovered that they remembered well enough from previous practice sessions to type without use of visual aids or the teacher's prompting; (3) although instruction was tailored by the teachers to the capability level of each subject, most of the children, regardless of age or intelligence, stopped using charts or other visual aids after the third teaching session and took pride in communicating with their classmates and with their teachers; (4) language arts should be emphasized from the earliest instruction, with concentration on word and sentence formation and the utility of language in interpersonal communication; (5) to enhance verbal communicative ability, bilateral-input exercises should be related to children's personal experiences and reading comprehension level, rather than relying exclusively on rote letter drills; (6) since one objective of the CYBERCOM concept is to get the child to communicate, typing speed is not of prime importance and should not be stressed, especially when working with children in the earlier stages of learning; and (7) the principal investigator observed, not only in this, but in all other exposures, that school-age children often do not know the named identity of their fingers.

SUBAPPENDIX 1 TO APPENDIX F

I. Summaries of Performance Reports for Selected Subjects

[NOTE: The following summaries were selected from instructors' reports prepared for each of the eleven subjects in this study. The subjects were selected for description because the problems they presented and the teaching techniques used with them serve to illustrate the training experiences for other members of the group, not delineated here, who learned to use "Cybertype" quickly and without noteworthy difficulty in approximately 1 hour of training and practice.]

1. Subject No. 104 (Male, age 10; below average intelligence; myopic.) This subject's first response to the apparatus was negative. After initial instruction on a 14-key keyboard, in which

time he learned the fingering positions for the alphabet, this subject's attention was diverted to a television set at the other end of the room. He walked over, turned it on, and watched the program without interruption. After the instructors had finished working with another child, the first subject was asked if he wanted to come back and play with the rest of the children in the group. He agreed and was asked to show another child, who had not been exposed to the remote keyboard, how it worked. In spite of the boy's reluctance, the instructor placed the keyboard in his lap and persuaded him to demonstrate typing to the other child. This experience apparently reduced his reluctance to handle the keyboard. After watching other children using the keyboard and learning the code, he participated with greater interest and proceeded to type the entire alphabet, his name and age, and his sister's name and age by the end of the first one-hour training session. At the start of the second session, his reluctance had completely dissipated, and he approached his assignment enthusiastically. Keying Fill-In Charts and Code Charts were used to enhance his learning. Subsequently, this subject was taught the fingering positions for numbers and the "carriage-return" function and "upper shift/lower shift" functions. Dexterity and memory of the code improved during the second session, and his enthusiasm did not diminish, but rather was expanded through later training sessions. The principal investigator, after observing this subject with his teachers, attributes a major portion of the subject's favorable change in behavior to the enthusiasm of his teachers.

2. Subject No. 105 (Female, age 12; sixth grade; severe emotional and perceptual difficulties including inability to visually pursue moving objectives; enlarged fingers; torticollis, and other spinal deformities; poor coordination and dexterity; presently in remedial reading class at school.) This child was introduced to the equipment and shown how to make concurrent, bilateral responses with her fingers on the interface. Fill-In Charts were used to explain how different pairs of keys would produce different typed letters, symbols, and functions. The six most frequent letters, "E,T,A,O,N,I", and the "space" function were taught. The subject proceeded to practice and learn the additional letters necessary to type her name, an accomplishment which thrilled her. Fingering positions for numerals were introduced, but testing at the end of the session revealed poor memory of these fingerings. However, the subject was eager to continue, and took Fill-In Sheets home to practice on before the next training session. In subsequent sessions, it was found that she had great difficulty using correct fingering because of poor motor coordination. Recall for fingering positions did subsequently improve, and practice with words and sentences selected from a fifth-grade level vocabulary list produced marked improvement in comprehension. Instruction in the formation of words and sentences, and practice with word games, produced further improvement in verbal ability as demonstrated by the increased difficulty of words and sentences successfully typed with a 14-key keyboard.

3. Subject No. 106 (Male, age 10; normal intelligence.) This subject quickly learned the six most frequently used letters of the English alphabet, "E,T,A,O,N,I", and the typewriter "space" function. Thereafter, the teacher taught the remaining letters using a question and answer technique with the subject's hands placed on a mock keyboard. She used an experimental association story dealing with "Master Controls."

Question: "Which hand controls the master key?" Answer: "Left."

Question: "How many keys does the right hand use with each master control switch?" Answer: "Seven."

Question: "How many functions will be performed, or how many things learned altogether, with seven master controls?" Answer: "49."

Question: "Which finger does the system code begin with?" Answer: "Thumb."

Question: "Why?" Answer: "It's the nearest."

Question: "If you invented this machine would you start with the two thumbs making a space which separates words, and why?" Answer: "Spaces are important to reading."

Question: "Now, using the left thumb Master Control, how many letters can the machine type?" Answer: "Six."

Question: "What are they?" Answer: "E, T, A, O, N, I."

Question: "How come there aren't seven?" Answer: "Because the thumb was used for the space."

Question: "Which master control is next?" Answer: "The left index finger or finger number 2 on the chart."

Question: "Which right hand key is placed first with the left finger 2?" Answer: "The thumb."

Question: "What does it type?" Answer: "R."

During the "Master Control" game, practice sheets were provided and dots were filled in to answer the above questions.

The subject also received practice with other experimental instructional materials; e.g., the "Secret Agent 7" story, the Pop-Up Flash Cards, and the Button-Box Games. He remained interested and alert through all the training sessions and by the final session was able to type words from lists of words based on his reading level and sentence-completion tests with ease and few errors.

4. Subject No. 107 (Male, age 11; normal intelligence.) After introduction to the system and four training sessions, including games and Fill-In Tests, the subject was able to type simple words such as "cat," "ate," "onion," "ten," "red," "see," "hose," and "lane," without hesitation. The instructor tried to improve the subject's verbal ability by prompting responses to such questions as the following: (1) "Try to find this word in the story;" (2) "Look carefully at the shape of the word and tell me what letters it contains;" (3) "Think of words that sound like that word;" (4) "You know what vowels are, look at the vowels – are they long, short, or silent?"

Tape recorded instructions were used which provided rhythm exercises by typing letters to a melody. Following such practice, the subject was able to type such sentences as: "The children are at school." "Fred had a football." "It is a benefit affair." "Brenda read a forecast." By the last session he was able to type all letters of the alphabet quickly when dictated by the instructor, and, in fact, he composed a letter to his friend.

II. Sample Fill-In and Practice Sheets

The following (figures 26-28) are samples of various fill-in and practice sheets.

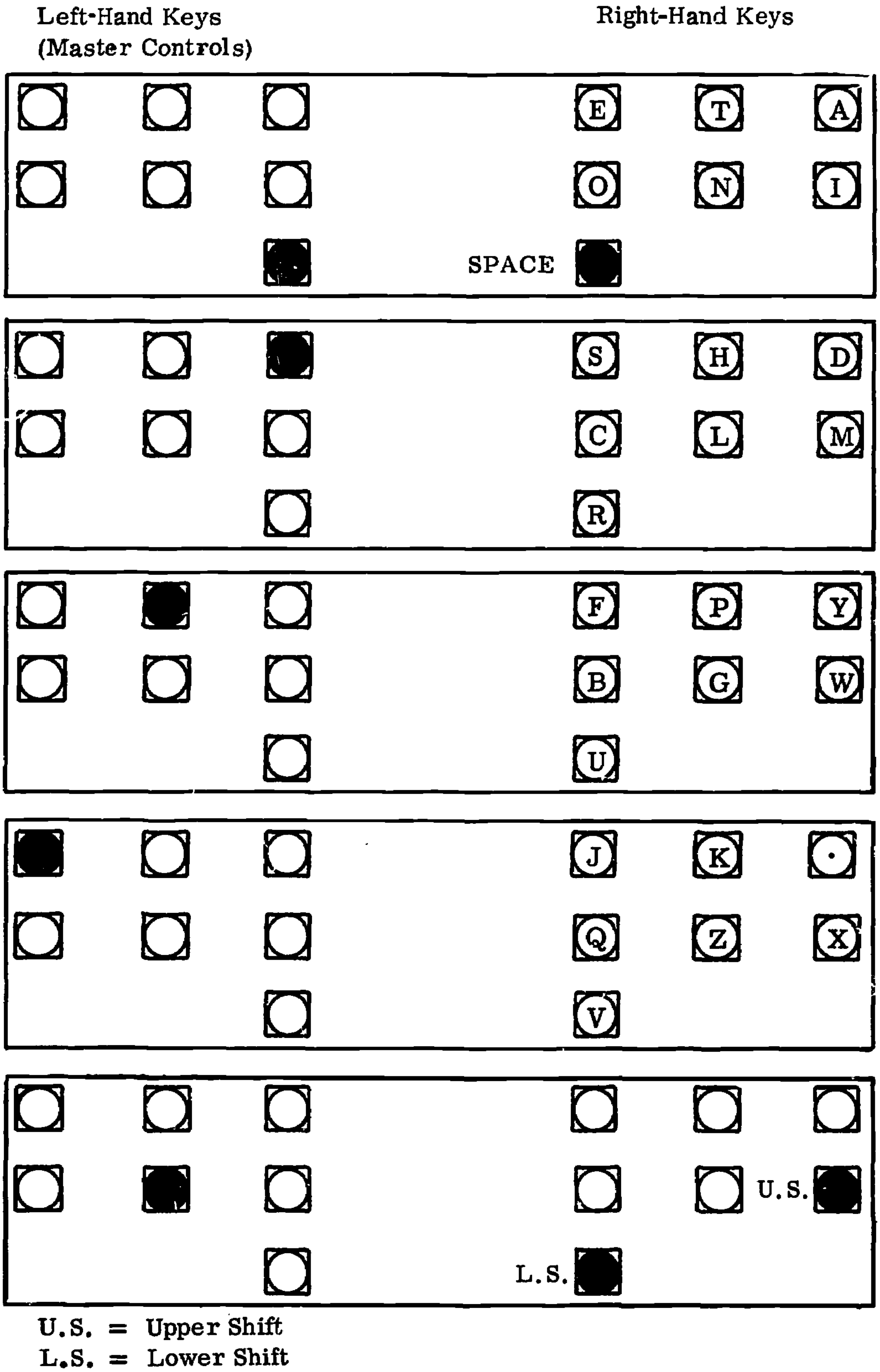


Figure 26. Practice Keying Chart for Letters and Functions (solid area indicates keys used)

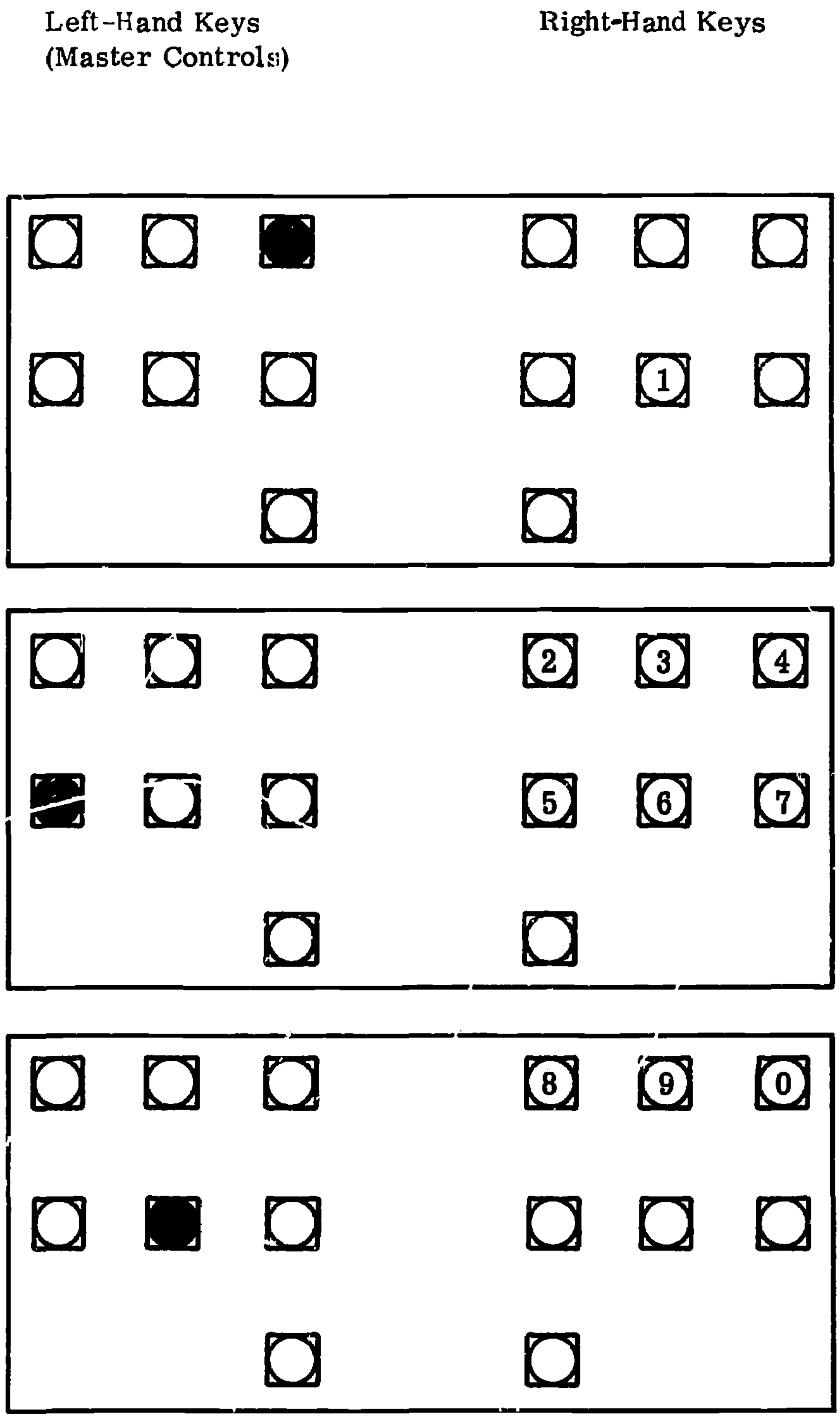


Figure 27. Practice Keying Chart for Numbers (solid area indicates keys used)

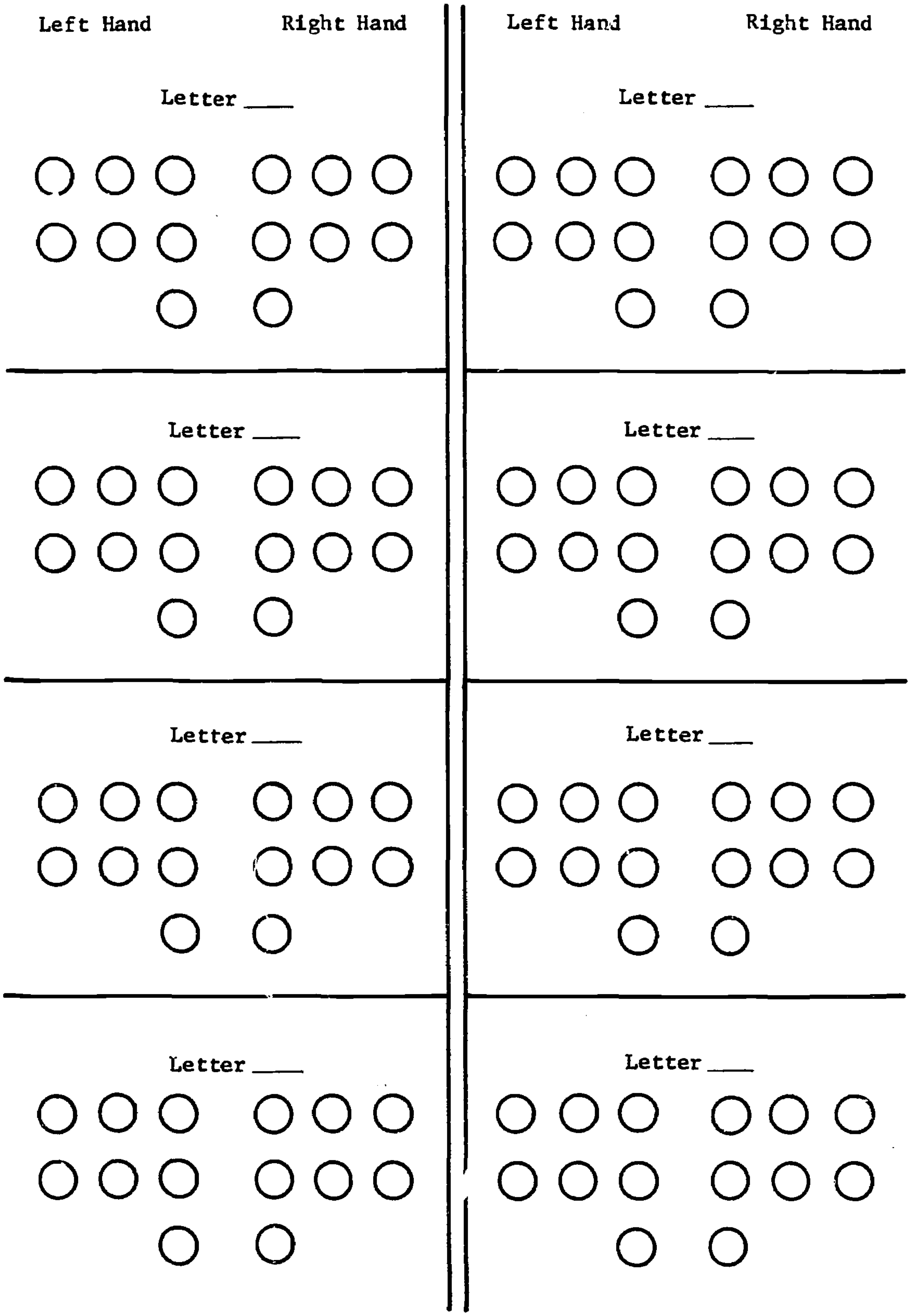


Figure 28. Sample "Fill-In" Exercise Sheet

Appendix G KEYBOARD FOR PARALYTIC SUBJECT

1. SUBJECT.

Subject No. 103 is a 30-year-old female quadriplegic with severe poliomyelitis and respiratory involvements. Principal body movements of interest to the investigators were controlled motions of the head and tongue and limited muscle function in the fifth digit of her right hand. Her perserverance, along with good training by previous tutors, resulted in her ability to operate a telephone switchboard using mouth controls and a standard 49-key electric typewriter using a "type stick" held in her mouth and controlled by her head movements. The subject had also been trained to locate, strike, and depress typewriter keys with an eraser-tipped pencil attached to her right hand and controlled via a Rancho Electric Arm.

This particular subject was selected for study since there are many children who are afflicted with similar disabilities. Hence, one objective was to ascertain the capabilities and constraints involved with this subject using a dual-input typewriter. Moreover, her present method of typing was not only time-consuming, but especially tedious for her as it is with children who use a head or mouth stick for typing. Consequently, another objective was to learn whether or not it would be easier and less tiresome for this subject to operate a dual-input keyboard.

2. DESCRIPTION OF EQUIPMENT.

A dual-input typewriter, the "Cybertype", was mounted on a table at a height which permitted the subject to position her electrically powered wheelchair adjacent to it and the "Cybertype" split-keyboard interface. The latter consists of a mouth keyboard with eight double-throw toggle switches which make up one section of the interface, and a three-position, finger-controlled state-selector switch which makes up the other portion of the dual-input interface. The subject activates a separate control switch on the right side of her head to swing the tongue-operated toggle switches directly in front of her mouth, ready for use. She operates the state-selector switch with her right fifth finger. Normally, the state-selector switch is at its rest position for state A, and operation of the tongue switch permits 16 characters and functions to be obtained on the typewriter. By deflecting the state-selector switch one step, state B is obtained and 16 new characters and functions are available via the tongue-operated interface. Likewise, by deflecting the switch further to its second step, state C is obtained, and 16 additional characters and functions are available, making a total of 48. When the finger-operated switch is released, it automatically returns to the rest position of state A. Thus, the subject uses her finger on the state-selector switch only to produce states B and C. The character/function keying code (see figure 29) was assigned so that state A provides the 16 most frequently used characters and functions, or about 90 percent of "standard" English in communicating.

3. SUBJECT'S TRAINING PROGRAM.

A practice log sheet has been prepared so that instructors can keep a record of the time spent on practicing words and sentences.

4. FUTURE PLANS.

The subject will be tested to determine not only typing speed but the convenience of using the dual-input system. A 16 mm movie showing the subject operating the interface will be made in order to observe more closely the operation of the system.

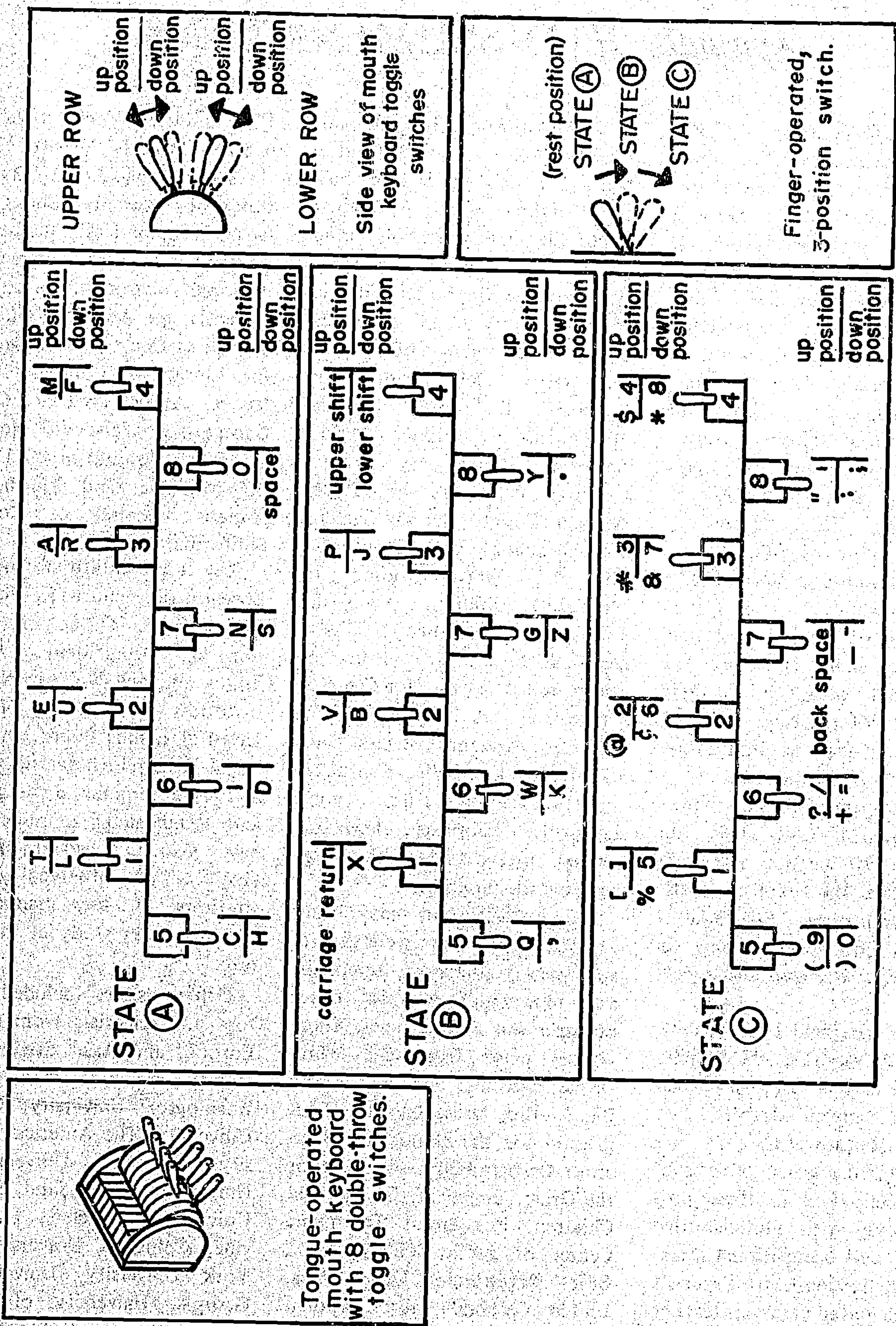


Figure 29. Transfer Code for 3x16, Dual-Input Interface

Appendix H | DISSEMINATION

One of the activities at C/R/I has been the dissemination of information related to this study. Hence, members of the research staff have acquainted visitors and members of other organizations to the programs in C/R/I's laboratories. Lectures by the principal investigator and staff members have also taken place at educational institutions here and abroad. Demonstration of educational systems under study have been made at professional conferences, e.g. CEC local and national meetings. A listing of these activities for the period of this report follows:

Members of the Indoor Sports Club (a national organization for the physically disabled) held their January 1969 meeting at C/R/I where demonstrations and films of the systems were exhibited.

The Welcome to Washington International Club held its January 1970 meeting at C/R/I. Women from the Union of South Africa, Indonesia, Switzerland, Peru, and Chile were among the visitors who attended this meeting.

From Springfield High School, Springfield, Virginia, 103 students interested in teaching and special education careers devoted two mornings of study at C/R/I.

Parents and teachers of the subjects participating in these programs along with administrative personnel and occupational therapists from the cooperating schools have participated in parent-teacher meetings at C/R/I.

Occupational, physical, and speech therapists and educators from Belle Willard School, Fairfax, Virginia; North Springfield Public Elementary School, Springfield, Virginia; Accotink Academy, Springfield, Virginia; Fairfax County Board of Education; Department of Special Education, Richmond City Schools, Richmond, Virginia; Montgomery County School System; Montgomery County Cerebral Palsy Center; Prince Georges County School System; Kendall School, Washington, D.C.; the D.T. Watson Home for Crippled Children, Leetsdale, Pennsylvania; Matheny School, Peapack, New Jersey; Home of the Merciful Saviour for Crippled Children, Philadelphia, Pennsylvania; Academy of Our Lady of Mercy, Louisville, Kentucky; and the Cerebral Palsy School, Louisville, Kentucky, have attended presentations at C/R/I covering the programs.

The Institute had many other visitors; among them were general and special educators, scientists, and representatives from other organizations and agencies. These visitors came from the White House; Perkins School for the Blind; the Massachusetts Commission for the Blind; the Alexander Graham Bell Association for the Deaf; Council for Exceptional Children; Residential Treatment Center of Junior Village, D.C.; Bell Telephone Laboratories; United Cerebral Palsy National Office; Veterans Administration D.C. and New York Offices; Education Projects Department of the World Bank; P.O.S.M. Laboratories of Aylesbury, Bucks, England; Technion-Israel Institute of Technology of Haifa, Israel; the National Advisory Committee on Dyslexia; the American Guidance Service of Circle Pines, Minnesota; the Library of Congress; Walter Reed Army Medical Center; Georgetown University Hospital; Children's Hospital of the District of Columbia; and Rancho Los Amigos Hospital of Downey, California.

Key representatives from the Bureau of Education for the Handicapped, Office of Education, U.S. Department of Health, Education, and Welfare; National Institutes of Health; National Labor Relations Board; Office of Naval Research; industrial organizations; governmental committees; and congressional representatives, have visited, received presentations, and observed demonstrations of the man-machine systems under study at the Institute.

Other visitors included educators and scientists from Canada, Europe, and Asia. Students and faculty members from George Washington University, Catholic University, The American University, Georgetown University, the University of Maryland, Stanford University, University of Louisville, Columbia University, New York University, University of Georgia, University of Illinois, State University College at Buffalo, Yeshiva University, Southampton University, the University of Toronto, and the Institute of Education of the University of London also visited C/R/I.

LECTURES AND DEMONSTRATIONS

Lectures and demonstrations were given by various members of the staff of C/R/I as follows:

1. Space Institute Conference, University of Tennessee, Tullahoma, Tennessee, June 19, 1968, at the invitation of Professor Charles Helvey. (This lecture series also included two other C/R/I members, the late Professor Warren S. McCulloch, then Chairman of the Board of Trustees of C/R/I, and Professor Heinz von Foerster, former Chairman of the Board of Trustees of C/R/I.)

2. IFAC (International Federation of Automatic Control), Symposium, September 27, 1968.

3. Institute of Education, University of London, London, England, October 4, 1968, at the invitation of Professor J. Tizzard.

4. Operations Research Seminar, Johns Hopkins University, Baltimore, Maryland, November 19, 1968, at the invitation of Professor Rufus Isaacs.

5. Distinguished Lecturer Series, Department of Special Education, University of Kentucky, Lexington, Kentucky, November 21, 1968, at the invitation of the late Professor William Tisdall.

6. Fairfax County Chapter of Phi Delta Kappa, Fairfax, Virginia, at the invitation of Dr. Edward J. Arndt, Director of Instruction, Area IV, Fairfax County, Virginia.

7. Second Louisville Conference on Rate and/or Frequency of Controlled Speech, Louisville, Kentucky, October 23, 1969, at the invitation of the Perceptual Alternatives Laboratory, University of Louisville.

8. Perceptual Alternatives Laboratory, University of Louisville, Louisville, Kentucky, January 8, 1970, at the invitation of Professor Emerson Foulke.

9. Washington Chapter of the American Society for Cybernetics, May 27, 1969, at the invitation of William B. Gevarter, Chapter Chairman. This meeting took place at the offices of C/R/I.

10. Belle Willard School, The Sharpe Health School, The Edison School (a joint meeting), October 10, 1968, at the invitation of Mrs. Aurelia Howland, Mrs. Ethel Neustadter, and Mr. William Wyson, the respective principals.

11. Department of Special Education Conference, The George Washington University, Washington, D.C., October 23, 1968, at the invitation of Mr. Robert Prouty.

12. In-Service Training Day, Special Education Teacher, Arlington County, Virginia, November 11, 1968, at the invitation of Douglas Prillaman, Director of Special Education.

13. Francis Scott Key Elementary School, Arlington, Virginia, July 2, 1969, at the invitation of Mr. Robert Seitzer, Summer School Principal.

14. Council for Exceptional Children Convention, Conference on Early Childhood Education, December 10-13, 1969, New Orleans, Louisiana.

PRESENTATIONS

1. Special Education Instructional Center, University of Texas at Austin, Austin, Texas, September 16-17, 1968, at the invitation of Dr. William Wolfe and Dr. Claude Marks, Associate Directors of the I.M.C.

2. Annual Convention, Pennsylvania Federation, Council for Exceptional Children, Harrisburg, Pennsylvania, October 5, 1968, at the invitation of Nelle Mazotti, former State Federation President.

3. Staff Seminar, D. T. Watson Home for Crippled Children, Leetsdale, Pennsylvania, December 10, 1968, at the invitation of Frances Kelly, Chief Psychologist.

CONFERENCES AND TRIPS

1. VIRGINIA CEC CONVENTION:

At the Virginia CEC Convention held in Virginia Beach on March 20-21, 1969, a large number of visitors stopped at C/R/I's booth to see the "Cybertype" demonstrated, the different interfaces explained, and the teaching methods described by members of C/R/I's teaching staff. Visitors included students, teachers, members of the special education departments of the various colleges and universities, principals and directors of rehabilitation centers, educational consultants, and a member of the Virginia Commission for the Visually Handicapped. They evidenced a strong interest in the "Cybertype" and in the photographic display of the Cyberbrailler$_{TM}$ and the Cyberglove$_{TM}$.

Many inquired about the availability of the mechanism and the possibility of including particular populations of subjects with whom they are working in the research projects being conducted at C/R/I.

A number of the visitors also requested copies of the Interim Report (Kafafian, 1968), and asked that they be sent copies of any material developed by C/R/I describing new developments and projects.

Graduate students attending the conference were quite interested in the display and inquired about the possibility that C/R/I staff members demonstrate the equipment to their departments.

2. INTERNATIONAL CEC CONVENTION, DENVER, COLORADO:

The President of C/R/I and three members of the teaching staff attended the International CEC Convention at Denver, April 8-11, 1969. The teaching staff attended the formal sessions and discussions and exchanged insights and ideas with other professionals in the field concerned with similar research.

Two members of the teaching staff were on hand at all times to handle the steady flow of visitors to C/R/I's display. The display consisted of a slide presentation showing a number of the children who are presently using the systems under study at C/R/I. They included six different styles of interfaces developed for the children, along with a visual lamp display, and an electric brailler which operates in parallel with a standard electric typewriter.

Several hundred visitors stopped to view the slides, see the equipment being demonstrated, and discuss the programs being developed by C/R/I. These visitors included students, professors, and the chairmen of special education departments of various universities and colleges across the nation, directors of state special education departments, consultants to state special education departments, directors and teachers of both private and public schools for the physically handicapped, therapists from children's hospitals and rehabilitation centers, directors of rehabilitation centers, and directors of county and statewide programs for the physically handicapped.

The visitors expressed interest about the mechanisms being developed by C/R/I and their impact upon the communication problems of the physically handicapped, as indicated by letters and other subsequent inquiries. More than one hundred of these visitors requested copies of the Interim Report (Kafafian, 1968). They were advised that copies of the Interim Report were available. Over 110 visitors also registered their names and addresses with C/R/I's teaching staff, and asked that any additional material describing the mechanisms and programs being developed by C/R/I be sent to them.

Both instructors and students in special education programs made inquiries about the possibility of obtaining copies of the slides being shown, and some narrative material for use in class presentations. They were told that the Institute would send the necessary material to them on a loan basis and that they should write directly to the Institute to make the necessary arrangements.

The NBC film "The Interface" was shown at one of the special sessions.

3. ENGLAND AND SCOTLAND:

At the request of Lady Hamilton, Chairman of the Disabled Living Activities Group of the Central Council for the Disabled, who visited Cybernetics Research Institute along with Miss Jayne B. Spain, Vice-Chairman of the President's Committee on Employment of the Handicapped, a technical exchange of information was made between scientists and researchers of C/R/I and personnel concerned with aids for the handicapped in England. A presentation was made for the King Edward's Hospital Fund for London at the Hospital Centre on July 17, 1969 both in the morning and the afternoon with about 100 people attending the demonstrations.

Dr. Alan G. Mencher, United States Scientific Attache, American Embassy, London, said in a letter to the Institute, "I wanted you to know how very important I consider the work of the Cybernetics Research Institute and how pleased we are at the reception it has received in this country [Great Britain]."

4. OTHER VISITS:

Members of the staff of C/R/I made the following visits:

First International Conference on Theory and Application of Differential Games, September 29–October 1, 1969, at the University of Massachusetts, Amherst, Massachusetts; and the International Conference on the Blind in Computer Programming, on October 9-11, 1969, in Cleveland, Ohio.

Anne Sullivan Macy Service Center for the Deaf-Blind of the Industrial Home for the Blind, Brooklyn, New York; and the Howe Press of the Perkins School for the Blind, Watertown, Massachusetts, for technical exchanges on current programs.

Trips were also made to the Page School, Arlington County, Virginia, and to the Partridge School, Gainesville, Virginia; the schools were examined as possible research sites in future studies.

5. TV AND RADIO BROADCASTS

TV networks have covered the Office of Education project here at C/R/I. Two TV programs were given prime time exposure, one in Washington, D.C., and one in Louisville, Kentucky. The first was a 16mm color-sound film describing the project, prepared by NBC for Jean Smith's documentary program "Probe," and shown after the Huntley-Brinkley Report on November 25, 1968.

In September and October of 1968, the Voice of America carried two programs sponsored by the United States Information Agency covering the work in this program on man-machine systems for the handicapped.

Appendix J PHONEME STUDY FOR PUNCTOGRAPHIC CODES

It has been estimated that there are about 3,000 languages spoken on our planet, many of which do not have a writing system; therefore, communication through numerous languages in a written form is not possible.* However, for those languages which do have established writing systems, sets of signs or symbols known as "graphemes" are employed and have assigned usages. These graphemes represent either a morphemic or phonemic reference. For example, the English word "tax" represents a set of three Latin graphemes of various subtypes of phonemic reference, all within the English written system. The phonemic reference of "t" is /t/ and may have slight variations, but these are essentially of no consequence. However, the reference of "a" in this instance is /æ/; it is really misrepresented by the grapheme "a". Similarly, the reference of "x" is /ks/, in reality a sequence of two phonemes. This and similar examples demonstrate intricacies which prevail between English writing systems and English phonology.

The English symbol "&" (ampersand), on the other hand, represents a reference to the morpheme "and", or when translated into the phonemic reference, /ænd/. Note that the symbol "&" does not graphically represent a sequence of phonemes, since only one graphic symbol is discerned. If the symbology did represent the three phonemes /æ/,/n/, and /d/, then spellings such as "h&" for "hand", "s&" for "sand", "&rew" for "Andrew" might be appropriate. Hence, this particular grapheme clearly has only a morphemic reference.

Graphemes with morphemic reference which represent an idea are called ideograms. There are writing systems which use ideograms, one of which is Chinese, where most of the graphemes have morphemic references. However, in most of the normal writing systems, graphemes have references within the phonologic system of the given spoken language.

Individual phonemes have individual graphemes, or individual graphemes may represent a sequence of phonemes. The first system is referred to as "alphabetic writing" such as in English, and the latter as "syllabic writing," of which Japanese is a good example.

English has a phonemic system in which subsystems are distinguished. The phonological analysis of the vowels presents difficulties in English. Most Americans and Britishers have the very same total of vowel phonemes in their phonology, although their description varies from dialect to dialect.

In studying the characteristics of any spoken language, linguists initially determine its phonemes. To do this, they compare and examine samples of the spoken language in question to ascertain words which are distinct in expression and in content without reference to context. Two minimally different samples which denote differences of content and expression are commonly called a minimal pair. By establishing the differences of minimal pairs, it is determined whether given phonemes in the given pair contrast in meaning and expression, e.g., bill – pill; chill – jill; till – dill; pet – bet; wet – yet; met – net.

In English, there are 9 simple vowels and the following 24 consonant phonemes.†

/b/ as in bill	/t/ as in till
/d/ as in dill	/v/ as in ville
/f/ as in fill	/w/ as in will
/g/ as in gill	/y/ as in yet
/h/ as in hill	/z/ as in zeal
/k/ as in kill	/θ/ as in thigh
/l/ as in lill	/ð/ as in thy
/m/ as in mill	/š/ as in shall
/n/ as in nil	/ž/ as in rouge
/p/ as in pill	/č/ as in chill
/r/ as in rill	/ǰ/ as in jill
/s/ as in sill	/ŋ/ as in sing

In order to demonstrate the distinction between each of the aforementioned phonemes, numerous minimal pairs are available with the exception of a few consonant phonemes, such as

*Joshua Whatmough, Language: A Modern Synthesis, (New York, Mentor Books, 1960).

†George L. Trager and Henry Lee Smith, Jr., An Outline of English Structures, 3d Printing – American Council of Learned Societies, Washington, D.C., 1957.

/θ/ and /ð/, or /š/ and /ž/. In the case of /θ/ and /ð/, only five minimal pairs are commonly known: thigh – thy: ether – either; mouth (noun) – mouth (verb); wreath – wreathe; thistle - this'll. The phoneme /ž/ in English occurs rarely e.g., dilution – delusion; glacier – glazier. Similar difficulties arise in the study of other languages. Hence, it is sometimes necessary to use other methods than simply the finding of minimal pairs.

One of these methods is articulatory phonetics. It is based on the assumption that characteristics of speech sounds are the result of the manner by which the very speech sounds themselves are formed. These characteristics are commonly described and classified in accordance with the position and action of human speech organs. In acoustic phonetics, investigators analyze speech sound through the study of linguistically significant features of speech from an acoustic viewpoint. Thus, the consonants may be grouped as follows:

Resonants:
- nasal - /m, n, ŋ/,
- lateral - /l/, and
- median* - /r, y, w/,

Fricatives:
- voiceless - f, θ, s, š/,
- voiced - /v, ð, z, ž/.

Stops:
- voiceless - /p, t, k/,
- voiced - /b, d, g/.

Affricates:
- voiceless - /č/ and
- voiced - /ǰ/.

*All English vowels are median resonants.

TABLE XIV
LANGUAGES EXAMINED AND APPROXIMATE NUMBER OF USERS

A. Indo-European	
1. Germanic	
(a) English	400,000,000
(b) Dutch	15,000,000
(c) German	90,000,000
(d) Danish	5,000,000
(e) Norwegian	3,500,000
(f) Swedish	7,500,000
(g) Yiddish	5,000,000
2. Romance	
(a) Classical Latin	———
(b) Italian	55,000,000
(c) Spanish	120,000,000
(d) Portugese (incl. Brazil)	80,000,000
(e) Rumanian	20,000,000
(f) French	60,000,000
3. Slavonic	
(a) Serbo-Croatian	20,000,000
(b) Polish	35,000,000
(c) Russian	200,000,000
(d) Other	10,000,000
4. Indo-Iranian (Persian, Pachtu Afghan)	45,000,000
5. Armenian	5,000,000
B. Finno-Ugrian	
1. Hungarian	10,000,000
2. Finnish	4,500,000
C. Turkic	
1. Osmanli	30,000,000
2. Azeri	5,500,000
D. Semitic	
1. Egyptian/Arabic	30,000,000
2. Amharic	20,000,000
3. Hebrew	3,000,000
E. Sino-Tibetan	
1. Mandarin (Chinese)	500,000,000
2. Japanese	100,000,000
F. Indonesian	90,000,000
G. Swahili	10,000,000
TOTAL	1,979,000,000

POINT OF ARTICU-LATION	MANNER OF ARTICULATION: STOPS VL	STOPS VD	AFFRICATES VL	AFFRICATES VD	FRICATIVES (SPIRANTS) VL	FRICATIVES (SPIRANTS) VD	TRILLS	LATERALS	NASALS	SEMI-VOWELS
BI-LABIAL	p p‘	b b‘			ɸ̱	ʋ			m	w
LABIO-DENTAL					f	v				
INTER-DENTAL					θ	ð				
DENTAL	t t‘	d d‘								
PRE-ALVEOLAR			c ȼ	ʒ			r̃	l	n	
ALVEOLAR					s	z	r			
*POST-ALVEOLAR			ç č	ǰ	š	ž		λ	ñ	y
PALATAL	k^y	g^y								
VELAR	k k‘	g g‘			x	ɣ		ł	ŋ	
UVULAR	Q					ʁ				
PHARYNGEAL						ʔ				
LARYNGEAL	ʔ				h	ɦ				

VL = VOICELESS
VD = VOICED
* = PRE-PALATAL

Figure 30. Chart of Aggregated Consonant Phonemes

All the consonants are characterized by closure or narrowing at some point in the mouth and are classified by this point of articulation. In each case there are two parts which are called articulators, and they are brought together when we speak or utter words.

In the English language, stress and intonation are phonemic. However, a detailed discussion of their value is inappropriate here since that would be beyond the scope of this phase of the study or its application to the communication problems for the handicapped to which this part of the study is directed. In ascertaining the phonemic content most suitable for a simplified punctiform system for the blind, stress and intonation should not be considered at this time.

Using the same methods, in addition to English, the investigators have examined 29 other languages spoken by approximately two billion people (see Table XIII).

Figures 30 and 31 show aggregated consonant and vowel phonemes contained in these languages.

	POINT OF ARTICULATION			
	FRONT		CENTRAL	BACK
	UR	R	UR	R
HIGH	i	ü	ɨ	u
MID-CLOSED	e	ö	ə	o
MID-OPEN	ɛ	ɔ̈		ɔ
LOW	æ		ɑ	a

R = ROUNDED
UR = UNROUNDED

MODIFIERS
: = LENGTHENED
•• = LABIALIZED
~ = NASALIZED

Figure 31. Chart of Aggregated Vowel Phonemes

Appendix J A STUDY OF THE RELATIONSHIP BETWEEN VISUAL DEFECTS AND SPEECH DEFICITS*

The problems of visually handicapped individuals are many and varied, stemming from the lack of disruption of visual sensory input. According to Broadbent in Berry's Language Disorders of Children (1969), "Speech is the most obvious case of stimuli being dealt with in sequence. . . It is normal for the whole sequence to be delivered before any response is required." It follows that, if the chain of stimuli is broken, communicative difficulties may arise.

Carroll (1961) has stated, "Every one of us—whether he realizes it or not—is to some degree a lip reader." If this ability is removed, or perhaps not developed at all, listening ability, and possibly speech, may be affected.

The purpose of the study reported herein was to investigate the area of communication for the visually handicapped, specifically the area of articulation problems that might be contingent upon visual defects. The questions here are whether these problems do exist, whether there is any correlation between visual defects and speech deficits, whether speech deficits are attributable to a visual inability to detect mouth movements corresponding to speech sounds, and whether these deficits can be categorized according to lip, mouth, and tongue placement.

Crowley (1965) has conducted a study comparing the listening ability of blind and sighted subjects. One conclusion he reached was that the listening ability scores of the sighted subjects were significantly higher than the scores of the blind subjects. Hartlage (1963) also made a comparative study and found that sighted subjects showed slightly better listening ability than blind subjects, although at a nonsignificant level. The above references, among others, suggest that the listening ability of blind individuals might be inferior to that of sighted persons.

Little has been written concerning the speech of visually handicapped individuals. In Carroll's book on blindness (1961), he also states, "In fact, the blind person speaking is, in a sense, 'deaf' to his own voice, since he is deaf to the reaction of others to it."†

A study by Donald M. Brieland (1950) corroborates the above. Eighty-four congenitally blind students, ages 12 to 18, were matched with 84 sighted high school students. The groups were judged for several different characteristics, including degree of lip movement in speaking, with high inter-judge reliability. The results showed that the sighted group was judged as speaking with more lip movements than the blind group, with the intergroup difference significant at the 2 percent level.

L. E. Minor (1964) conducted a study investigating the incidence of speech defects in the visually impaired population. Two hundred blind and partially sighted students from kindergarten through sixth grade participated in a controlled experiment. Minor found an incidence of speech defects equal to 33.8 percent, about four to five times higher than the incidence in public schools.

*This study was conducted for C/R/I at the University of Illinois under the direction of Professor Heinz von Foerster.

†For a balanced perspective, the reader is reminded that successful use of the telephone by sighted people who have never seen each other raises serious questions about inferences which may be drawn from these observations; the very same pertains to written communication. [Principal Investigator]

TABLE XV

Summary of Subject Characteristics

Subject	Acquired or Congenital	Home State	Attended Public School	Attended Special Classes	Attended School for Blind	Hearing Normal	Speech Problems in Immediate Family
1	A	N.Y.	X		X	X	
2	A	Ill.			X	X	
3	A	Ill.	X	X		X	
4	C	Ill.	X		X	X	
5	C	Conn.	X	X		X	
6	A	Ill.	X			X	X
7	A	Ill.	X			X	
8	A	Mich.	X	X		X	

METHOD:

Since few students with serious visual impairment were enrolled in the University of Illinois (Urbana) 1969 summer session, the subject sample for the study reported herein consisted of seven university students (six graduate students and one undergraduate). One high school student also participated (see Table XV). Etiologies varied, but none of the subjects had had prolonged hospitalization during the critical period for speech development.

Equipment used in the study included a short case history form, a Beltone Model 10-A Audiometer, and the Templin-Darley Test of Articulation, Sentence Form. This test was modified and used as a screening device presented in one of three forms: braille, oversized print, or oral repetition, depending upon which form best suited the individual subjects. Information obtained from the case histories included the subjects' home states (because various states' school laws have different provisions regarding the education of blind children), types of schools attended (since schools for the blind often incorporate speech courses specifically directed at eliminating 'blind speech'), and family history of speech problems (because a speech problem might be attributable to poor speech models).

The testing session consisted of recording the case history, checking hearing in speech frequencies (500-2,000), and administering the screening test in one of its three forms. Testing was conducted in locations most convenient to the subjects, away from distracting noises.

RESULTS AND DISCUSSION:

Six subjects made no errors on the screening test. The remaining two subjects erred on three distinct sounds in various positions. Subject No. 4 evidenced mild distortion of /s, z, š /, which could be attributable to new dental braces (upper and lower). Errors made by Subject No. 5 were lateral emission of /l/ in the initial and medial positions, and addition of /g/ to /ŋ/ in medial and final positions. Though these errors probably could not be corrected by visual reference cues, tactile-kinesthetic feedback might be effective in error reduction. In essence, then, no errors were made which would show correlation between visual defects and speech deficits (see Table XVI).

Two main questions have arisen: (1) Is there any valid speech screening or diagnostic test available for use with visually

TABLE XVI

Summary of Subject Performance

Subject	Test Administration	Test Results	Extraneous Factors
1	repeated sentences	no errors	
2	Braille	no errors	
3	oversized print	no errors	
4	Braille	3 errors (see text)	new dental braces, upper and lower
5	Braille	4 errors (see text)	
6	oversized print	no errors	
7	repeated sentences	no errors	
8	oversized print	no errors	

handicapped individuals? (In the above study, the testers substituted the sense of touch for the sense of sight in order to obtain a braille form for the Templin-Darley Test of Articulation, although the test has not been proven valid when administered in this braille form.) (2) Are there specific speech anomalies of the blind and partially sighted which could be eliminated by speech courses aimed at this problem? These questions deserve further study.

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Appendix K INDIVIDUAL AND GROUP INSTRUCTIONAL PROGRAM

C/R/I is currently conducting an individual and group instructional research program at the D.T. Watson Home for Crippled Children, in Leetsdale, Pennsylvania. Eight severely handicapped children are being taught to communicate through writing with the use of bilateral-input keyboard systems. These children either cannot produce cursive handwriting or can do so only with extreme difficulty. Their attempts to operate any style of typewriter have not been successful.

Each child has been provided with a "Cybertype" keyboard interface configured to match his remaining motor capabilities. The 14-key finger-operated interface has been provided for five of the children who have sufficient motor coordination to operate the keys with at least one finger or knuckle on each hand (Subjects 122, 125, 126, 128, 129).

The remaining three children are not capable of operating keys with their fingers, and special interfaces have been constructed at C/R/I's laboratories for them. One child (Subject No. 123) is a diplegic with upper limb involvement, who has good control of feet and legs. This child uses her feet to operate a "pedal" interface consisting of 14 large keys appropriately spaced (see plate 2a, Volume I, Part Two). The child sits in a chair which supports her legs so that her feet "float" closely above the 14 key tops. Two keys are then activated concurrently by simple toe depressions, one from each foot.

Another child, (Subject No. 124) is a quadriplegic who can provide enough motor coordination in arms and hands to strike the large keys of the pedal interface (placed on a table) with the heels or sides of her hands. This subject has never been able to express herself in writing throughout her 16 years at the Home. She has considerable intellectual potential as evidenced by her poem "Those Sixties." Five of her classmates who are also subjects in this study shared with her the joy of having her poem reproduced, each typing an assigned verse on "Cybertype." Helen, the author (Subject No. 124) typed the title and the first three stanzas, Diane (Subject No. 128) typed stanzas 4 and 5, Andrea (Subject No. 129) typed stanza 6, Tony (Subject No. 127) typed stanza 7, Veronica (Subject No. 125) typed stanza 8, and Donnie (Subject No. 122) typed the last two stanzas. Her classmates were particularly pleased to be a part of the "show." The poem, as actually typed on "Cybertype," is reproduced in figure 32.

A third child (Subject No. 127) is able to operate a "fist interface," consisting of 14 keys which are larger than the keys of the finger-operated interface but smaller than the keys of the pedal interface (see plate 3b, Volume I, Part Two). This youngster is also typing successfully by operating pairs of keys with his two hands.

Most of the children are instructed in groups by Mrs. Anna Mae Gallagher, a senior member of C/R/I's special education staff, who is in residence at the school during this program. Four of her subjects are instructed together as a group, consisting of three children (Subjects 122, 125, and 126) operating the standard 14-key interfaces, and one child (Subject No. 127) using the fist interface. Two of the children (Subjects 128 and 129), using the standard 14-key interface, are taught together as a pair. The remaining two children, Subject No. 123 using the pedal interface with her feet, and Subject No. 124 using the pedal interface with her hands, are seen individually.

Each child has received 1 hour of instruction each day, 4 days per week. The "Cyber-Circus Story," developed by Mrs. Gallagher (Kafafian, 1968), is used as a learning aid. The association of circus acts and participants as related to the keying combinations for the various letters, symbols, and typing functions provides unique and exciting instructional

THOSE SIXTIES

by

Helen Kern

1

Those Sixties! Oh! those Sixties
They echo through our thoughts
Those ten long years of constant change
That brought forget-me-nots.

2

Those years when a dog named "Snoopy"
Was the mascot of our age,
And those longhaired "Beatles"
Were the teenage rage.

3

A time when transplants
Finally got their start,
And the tune on Barnard's lips
Was, "You gotta have heart."

4

A time when the President
Was shot down in his youth;
It seemed to be a flashback
To Lincoln and Booth.

5

Three men from Cape Kennedy
Won the great race.
Two were the first to touch down
On Tranquility Base.

6

A time when the Kennedys
Tragically lost another.
Bobby will appear in the history books
Along side his brother.

7

The negroes were shocked
With the murder of Martin Luther King.
It's hard to imagine the chaos
One man's death could bring.

8

A time when the hippies
Said, "Love, we need more,"
And they burned their draft cards
Protesting the Vietnamese War.

9

President Nixon and the Underdog Mets
Left in our minds no doubt
That in 1969
They wouldn't strike out.

10

A time when Broadway
Plays were really the hairiest.
Yes, this was truly the dawning
Of the Age of Aquarius.

Figure 32. "Those Sixties," Poem by Helen Kern, Typed by the Author and Five Classmates on the "Cybertype." (numerals added)

materials which the children really enjoy.

Instruction began on January 12, 1970, and the children learned the keying positions for all letters within 2 weeks. Keying positions for numerals, symbols, and typing functions were also learned very quickly.

Sample work sheets from the sixth work of instruction, shown in figures 33–40, demonstrate that the children have developed considerable skill in using their interface systems for communicating. These results are particularly encouraging in view of the fact that previously these children had been virtually incapable of communicating through writing in any form, and in some cases their verbal communication comes about with difficulty.

On February 19, 1970, about 5 weeks from the commencement of the program, one of the physicians on the staff of the D.T. Watson Home observed the children in this program and made evaluative comments and recommendations. Excerpts from his evaluations are given below.

> Subject No. 122. "Donnie is primarily an athetoid patient and in the four weeks that he has been working on the "Cybernetics Board," [14-key "Cybertype" keyboard] he has developed a very marked improvement in control and is now able to type without making too many mistakes. . . . It is extremely important that the "Cybernetics Board" be firmly attached to the table, because this boy does hang on to the board to control his athetoid movements. . . . I also think that it is important that this boy be close enough to the table so that he does not have to lean forward and thus have his body out of balance, which could very well increase the athetoid movements and fatigue. I think that Donnie is doing well enough with the "Cybernetics Board" that in another 6 to 8 weeks, perhaps we can try him on a regular typewriter and see how well things are going at that time."

> Subject No. 123. "Carolyn is using her feet in typing but has been keeping her shoes on and has not developed much speed and coordination in her typing because she has to continually look at the words she wants and then look down at her feet and see what buttons she wants to push. She is using the [pedal interface] with the big knobs and she types fairly well with this board. I am recommending that we have Carolyn remove her shoes and socks and type in her bare feet. . . I think that with some training in her bare feet, this girl will learn to type much faster and will not have to continually look down at her feet to see where she is placing them. . . . A "Cybernetics Typewriter" ["Cybertype"] for this girl is almost a must. She has no fine control of the upper extremities and is not able to do any kind of writing. Her speech is fairly good, but she does have difficulties in coordinating tongue, throat, and mouth muscles in her speech program and would tire rather quickly if she had to talk for long periods of time."

> Subject No. 124. "From the physical therapeutic standpoint, according to Mrs. Gallagher, Helen when she started out, would take almost an hour to type one sentence, and now she is able to type a full letter in approximately a half hour. Also, the control of the arms is improved. With the right arm she has fairly good control and uses the palm of the hand on the large knobs of the [pedal interface]. On the left side, she is using the loaded cuff or the side of the hand, the ulnar side, to press the buttons down."

> Subject No. 125. "Veronica (recently) had hand splints made and checked out. . . . Rather than discontinuing Veronica, I would like to recommend that we try [her] on the Cybernetics Program [C/R/I] with the hand splints on to see if after a few sessions she might not get just as good control this way as she has without the splints. . . . According to Mrs. Gallagher, Veronica has done exceptionally well in her typing this way, and she feels that it would be a shame not to have her continue in the program."

Donnie Alleen

February 17, 1970

Please ask dad for a cake.

Vanilla is my favorite flavor.

Think and work, Jake.

Work and think, John.

Every one loves to win.

W[We work to succeedd.

We listen and then we learn.

Winners are workers.

Observations

Anna Mae Gallagher.

I wish I had a picture of Donnie when he realized that he typed seven sentences and had no shivers (double letters). I am giving lessons on finger control and it is paying off with their work. This is one of Donnie's best papers.

Figure 33. Typing Sample – Subject No. 122

Carolyn M. Brownee   Febru,ary 16, 19700

She lost her shoe.

Are the shells here?

Ellen's shells are here..

A lassie ran to Roni.

I see a tosn tire.

He has i an increase.

Dad is seen at the dam.

TThe doll cost a dime.

Daniel is a radio man.

Dad is a democrat.

Mother has a red shoawl.

Mother served hot rolls.

Paul eats green grapes.

Father bought eggs for Pam.

yellow flowers

Observations

Anna Mae Gallagher

This was one of Carolyn's good days. She loves to typewrite and shows it when in class. With twelve perfect sentences, I think she did well. She has several small errors on the entire paper. Carolyn has an hour class (individual), thus she can accomplish more than the other children.

Figure 34. Typing Sample – Subject No. 123

D. T. Watson Home
Leetsdale, Pennsylvania
February 19 , 1970

Mr. William E. Harrison
2746 Eighth Street
ERie, Pennsylvania

Dear Sar

My father was called to Chicago yesterday. He asked me to let you know that he cannot meet you on Wednesday of next week as planned.

Sincerely yours

Miss Helen Kern

Observations

Anna Mae Gallagher

Helen was determined to complete a letter today. It was too much of a struggle for her but she would not give up. Just as she was finishing her letter, Dr. Rex Newton came in to evaulate Helen's physical and educational results by using the Cybernetics cybertype. I was so glad Helen had an opportunity to complete her letter. She could not sign it, thus, I left it unsigned.

Figure 35. Typing Sample – Subject No. 124

Veronica Labish February 16, 1970

James came quickly.

The blue jay is not qquiet.

Gerald made a square.

Jahn and Jane play croquet.

Paul please pass the grapes.

Franis has a big pig to sell.

Observations

Anna Mae Gallagher

Veronica is one of my best students. It is unusual for her ote make an error. To see her deformed hands in action, one would wonder how she could have such beautiful papers.

Figure 36. Typing Sample -- Subject No. 125

Katie 67Lozow February 177, 1970

Please ask dad for a cake.

Vannilla is my ffavorite flavor.

Think aa and work, JJake.

Work and think,, John.

Every one loves to win..

Observations

Anna Mae Gallagher

Three sentences without doubling words is success for Katie. She is trying very hard and I think in time, all will be well for her. She is a very nervous child and has extremely jittery fingers.

Figure 37. Typing Sample – Subject No. 126

Tony Miralles February 17, 1970

Please ask dad for a cake.

Vanilla is my favorite flavor.

Think and work, Jake.

Work and think, John.

EO Every one loves to win.

We work to succeed.

We listen and then we learn.

Winners are workers.

Observations

Anna Mae Gallagher

Tony has a grand paper. His one error was the fault of his flailing fists. He tries very hard and is a darling boy. When he has a good paper, he smiles all over his face. "Tomorrow, I'll have no errors," is usually what he says after reading over his paper.

Figure 38. Typing Sample — Subject No. 127

Diane E.. Provan February 17, 1970

Think and work, Jake.

Work and think, John.

Every one lovess to win.

Please ask dad for a cake.

Vanilla is my favorite flavor.

Did youfind the exit door?

Dad's tuxedo is here, Roy.

He had a sneezing spell.

She rode her bike home.

Kathryn saw grazing cattle. I did too.

January 22, 1970 July 4, 1776

March 17, 1970 June 31, 1970

84 27 19 36 50 258 146 370 904

. , ? 's n't " "( ) ° _ _

ISN"T AREN"T WASN"T BOY"S BOYS" GIRL"S GIRLS" isn

isn't aren't wasn't boy's bb boys' girl's girls'

Observations

Anna Mae Gallagher

Diane had class alone today as Andrea's chair needed more repair. Diane has a perfect paper and learned many of the punctuation marks. She retains what is taught and never seems to forget. She types slowly owing to her condition but she is accurate.

Figure 39. Typing Sample – Subject No. 128

Andrea Yeager February 16, 1970

James came quickly.

The blue jay is not quiet.

Gerald made a square.

John and Jane play croquet.

He requested a jump act.

Mother served hot rolls.

FRANK EATS GREEN GRAPES.

Observations

Anna Mae Gallagher

Andrea came in her new chair today. She was so delighted and wanted me to notice the large tires on her chair. She was singing all the time she was typing. With all this, Andrea made no errors. I am pleased and full of wonder at this youngster's progress.

Figure 40. Typing Sample – Subject No. 129

Subject No. 126. "Katie has been on the "Cybernetics Typewriter" ["Cybertype"] now for a month. She has learned hand control from this, in that when she first started, she did not release the fingers and consequently would get a repetition of one letter several times so that the typing was not meaningful.

She has now developed a technique of pushing down and a very accentuated type of release which has helped her in typing, and she is no longer making the repetition of letters. I have noticed in the program that Katie is keeping her head in flexion so that she can see the board of the wheelchair table, and I think it would be most important to put the "Cybernetics Board" [14-key keyboard] up on an inclined plane of perhaps 50° to 55° so that [the subject] will hold her head up while she is doing her typing."

Subject No. 127. "This 12-year old boy has been working on the (program) for about a month, and during that time he has shown very marked improvement in his ability to control his hands. He is using the intermediate board with the buttons approximately 7/8 of an inch in diameter and about 3-½ inches apart, and in using this board he is able to control his hands quite well now. . .I certainly think that for Tony this is a very definite means of communication because his writing is extremely difficult. He is not able to keep the letters within the lines on the paper, and he prints rather than writes."

Subject No. 128. "Diane is 9 years old and is in the third grade. . . .it is amazing to watch this girl type with absolutely no help from Mrs. Gallagher. . In watching her write, she still is printing and she is able to keep the letters within the lines on the paper, but it is extremely slow and she certainly would have considerable difficulties in writing any length of a report or letter, whereas with the "Cybernetics Typing" [Dual-Input] she could go right along without too much difficulty. I am in hopes that as time goes along, this girl will develop enough finger dexterity that we can consider a regular typewriter, but I feel this is months or maybe several years away yet."

Subject No. 129. "Andrea is 8 years old and has severe osteogenesis imperfecta. . . She found that by putting a thimble on the left thumb she could control the distal phalanx of the thumb enough to get pressure [to] push down on the keys. On the right hand she uses the thumb at times and at times uses the middle finger to press the keys down. . .I am amazed at how well this girl has learned to master the "Cybernetics Board" [14-key]. She needs no help in her typing, and she has come a long way in the past month. . . . In her new chair, she has good posture, and the only recommendation that I would have at this time would be to lighten the spring load on the "Cybernetics Key Board". . . . I had Andrea write, and she writes left-handed. She prints and her letters are extremely large; and it takes her a considerable time, so I feel for Andrea that the Cybernetics typing ["Cybertyping"] is almost a must for her to be able to communicate, except vocally."