

## DOCUMENT RESUME

ED 326 014

EC 232 618

AUTHOR Weisgerber, Robert A.  
 TITLE Research on the Use of Technology in the Education of the Learning Disabled: Project CREATE.  
 INSTITUTION American Institutes for Research in the Behavioral Sciences, Palo Alto, Calif.  
 SPONS AGENCY Special Education Programs (ED/OSERS), Washington, DC.  
 REPORT NO AIR-31400-12/87-FR  
 PUB DATE 31 Dec 87  
 CONTRACT G008302861  
 NOTE 93p.; For related documents, see ED 277 166-171.  
 PUB TYPE Reports - Descriptive (141) --

EDRS PRICE MF01/PC04 Plus Postage.  
 DESCRIPTORS \*Cognitive Processes; \*Computer Assisted Instruction; Computer Software; Elementary Secondary Education; Human Factors Engineering; \*Learning Disabilities; \*Man Machine Systems; Microcomputers; \*Perceptual Development; Program Development; \*Reading Instruction; Technology; Word Recognition  
 IDENTIFIERS Project CREATE

## ABSTRACT

Project CREATE was a 4-year federally funded research program which sought to determine ways in which computer technology could improve the education of learning-disabled students. Early work on the project centered on the development of a theoretical and conceptual foundation; a hierarchical conceptual model was constructed that related school performance in reading to underlying cognitive processing skills, perceptual enabling skills, and neuromuscular vision skills. Two California school districts were involved in the project: the Fremont Union High School District and the Cupertino Union School District. A software selection and evaluation tool (included in Appendix B) was developed, several adaptive software handbooks were produced, and two software programs were created (TurboScan and Wordsworth). Elementary students who received the TurboScan software treatment improved in their ability to rapidly discriminate critical features associated with character and word recognition, and demonstrated better reading skills. Secondary students who received the Wordsworth software treatment for cognitive processing development improved in their ability to recognize literal facts and details in narrative text and, to some extent, to make inferences. Student-machine interface conditions that acted as barriers to effective study were identified, and a facilitating interface was designed. An appendix contains scope and sequence information. (Author/JDD)

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## Project CREATE

Robert A. Weisgerber

31 December 1987

Submitted to the Office of Special Education Programs  
U.S. Department of Education  
Grant # G008302861, Project 023JH50004

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PO. Box 1113  
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(415) 493-3550

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## Table of Contents

Table of Contents	i
List of Figures and Tables	ii
Abstract	iv
Acknowledgements	vi
Overview of the CREATE Project	1
Theoretical and Conceptual Foundations	4
Occasional Papers	7
Dissemination	7
Enhancing the Educational Value of Existing Software	10
Software Selection	11
Integrating Computer Software in <sup>a</sup> the Curriculum	11
Publication of the Workbooks	13
Disseminating Information About Computer Use	14
Experimentation with Specially Developed Software	16
Description of <u>TurboScan</u> in Its Final Form	18
Description of <u>Wordsworth</u> in Its Final Form	20
Results of the 3rd Year Experiment	21
Study 1: Assessment of Perceptual Enabling Skills and Improved Reading	21
Study 2: Evaluation of the Instructional Impact of <u>TurboScan</u> Features	26
Study 3: Using <u>TurboScan</u> to Remediate Severe Learning Difficulties	35
Optimizing the Student/Machine Interface in <u>Wordsworth</u>	44
Results of the 4th Year Experiment	48
Research Design: Cognitive Processing and Reading Comprehension	43
First Analysis: Main Effect with Paired Control and Treatment Groups	56
Second Analysis: Main Effect with Students as Their Own Controls	58
Summary	58
Implications for Future Research	62
Appendix A	66
Appendix B	74

## List of Figures and Tables

Figure 1. A Conceptual Heirarchy of Skills Contributing to Effective Reading	6
Figure 2. Gains on the Gray Oral and RRVD Tests: Elementary Data	30
Figure 3. Relationship of Study Time on Story 1 to Attained Total Story Scores	53
Figure 4. Relationship of Total Story Scores to Scaled Posttest Scores	54
Figure 5. Relationship of Assigned Grade Levels to Grade Equivalent Scores	55
Table 1. Correlations of Background Variables and RRVD Tests: Elementary School Sample	23
Table 2. Analysis of Treatment and Control Differences Elementary Data	24
Table 3. Analysis of Treatment and Control Differences: Secondary Data	25
Table 4. Assignment of Subjects to Conditions	27
Table 5. Pre- and Posttest Means on Gray Oral and RRVD Tests: Elementary Data	29
Table 6. Pre- and Posttest Means on Eye Trac Measures: Elementary Data	32
Table 7. Comparisons Among <u>TurboScan</u> Treatment Groups	33
Table 8. Pre- and Posttest Means on Gray Oral and RRVD Tests: Secondary Data	34
Table 9. <u>TurboScan</u> Skill Categories Used in Study 3	36
Table 10. Number of Screens Completed by Study 3 Students	38
Table 11. Study 3: t Tests on Gray Oral Passages	39
Table 12. Study 3: t Tests on the RRVD Measures	40
Table 13. Means by Skill Category for <u>TurboScan</u> Process Variables	42
Table 14. Grade Levels of Participants & Severity of Learning Disability	48
Table 15a. Study Time for Students Exposed to <u>Wordsworth</u> Software	51
Table 15b. Accuracy of Study on Each Story for Students Exposed To the <u>Wordsworth</u> Software	52
Table 16. Pretest Comparisons of Treatment and Control Groups Using Raw Scores on the "Literal" Matching Criterion	57
Table 17. Posttest Comparison of Treament and Control groups Using Scaled Scores on the Comprehension Subtest	57
Table 18. Comparison of Special Day and Resource Students Using Raw "Literal" Scores as Matching Criterion	59
Table 19. Comparison of Special Day and Resource Students Using Scaled Scores on the Comprehension Subtest	59

Table 20. Gains in Comprehension by Individual Students in the "Control" Group After Exposure to <u>Wordsworth</u> Treatment	60
Table 21. Gains in Comprehension by Individual Students in the "Treatment" Group, Including Special Day Students	60
Table 22. Gains in Comprehension for All Students after Study of <u>Wordsworth</u>	61

## Abstract

The CREATE Project was a multi-year study of ways in which computer technology might be used to better serve the learning disabled. Early work centered on the development of a theoretical and conceptual foundation for subsequent investigation based on a comprehensive review of the literature on learning, cognition, perception, software design, selection and utilization, and computer experimentation in education. A number of occasional papers were issued to summarize the results of these investigations.

A hierarchical conceptual model was constructed that related school performance in reading to underlying cognitive processing skills, perceptual enabling skills, and neuromuscular vision skills. Research was conducted in CREATE to explore the potential of the computer for improving reading through special purpose software tools intended to improve students' cognitive processing and perceptual enabling skills. (Research was conducted outside the project in a related study on neuromuscular skills.) Two cooperating school districts (one elementary and one secondary) participated in the CREATE studies as did other volunteer schools around the country.

A new software selection and evaluation tool was developed, field tested in volunteer schools, and revised in line with suggestions received. This form focuses the attention of school staff on the educational applications of software consistent with the model described above.

Several adaptive software handbooks were developed, and two published commercially, to demonstrate the ways in which computer study (using specific commercial software) can be better integrated into the curriculum in order to benefit the handicapped.

Two new software programs were developed for the experimental research conducted in CREATE. With these tools we were able to show that significant gains can be made by learning disabled students in relatively short periods of time on the underlying skills associated with reading.

Students who received the TurboScan software treatment (for perceptual enabling skill development) in the cooperating schools improved in their ability to rapidly discriminate critical features associated with character and word recognition. Students at the elementary level demonstrated better in their reading skills as well. There was no clear evidence favoring specific design features being present or absent in the specially developed TurboScan software. These features included immediate knowledge of progress, corrective feedback, relative difficulty of exit criterion, and learner-controlled rate of presentation.

Secondary students who received the Wordsworth software treatment (for cognitive processing development) improved in their ability to recognize literal facts and details in narrative text and, to some extent, make inferences, contributing to better comprehension. An important aspect of the Wordsworth research program involved the identification of student - machine interface conditions that acted as barriers to effective study and the redesign of the interface to facilitate computer study by the learning disabled.



## Acknowledgements

The CREATE project was the joint product of planning and execution by Dr. David Rubin, who served as Project Director for the first three years, and Dr. Robert Weisgerber, who served as Principal Investigator for all four years. Various AIR staff made important inputs to the project.

Singled out for particular recognition are David Rubin, for his programming expertise in the TurboScan software; George Shaw and Mark Duchaineau, for their programming of the Wordsworth software; Patty Blake, for her leadership in preparing adaptive software workbooks; David Brandt, who helped in the gathering of school data and in the analysis of TurboScan research; Pat Lund and Susan Debysingh-Reutz, who identified or developed appropriate measures; and David Grisham, who provided expertise and equipment for assessing eye movement patterns. Throughout the project, all project staff appreciated the continuous help they received from Virginia David, who ably took care of secretarial and administrative matters.

Outstanding cooperation was received from the collaborating schools. At the Fremont Union High School District, we were fortunate to have the full backing of Dr. Dorothy Emerson, the Coordinator of Special Education, and two of her key people, Mary Gean Hubbell and Robert Snowden, as well as teachers and staff in several of the high schools in the district.

At the Cupertino Union School District, we benefited from the cooperation of Dr. Jim Paul, Coordinator of Special Education, and heavily relied on assistance from Alice Rosner, an outstanding lead teacher, as well as numerous other teachers in a number of the elementary schools in the district.

At the Office of Special Education Programs we found our interactions with Nancy Safer and the late Jim Johnson to be quite helpful in zeroing in on crucial issues. They also played a valued role in arranging for forums in which our work could be shared with them and other researchers in three sister projects that were concurrently investigating the use of technology in the education of the handicapped.

R.A.W.

## Overview of the CREATE Project

## Overview of the CREATE Project

The Office of Special Education Programs (OSEP) in the Department of Education awarded four research grants in October of 1983 to undertake systematic research on the ways in which technology, particularly computer technology, could be used to better serve in the education of handicapped students.

In the competition, the American Institutes for Research (AIR) was selected to undertake a program of research outlined in the proposal, a four-year, multipurpose investigation. Perhaps the study could best be described as proactive. That is, rather than merely assessing the extent to which computers were currently being used in the schools and trying to ascertain the benefits and problems that might be attributable to their use, AIR attempted to explore the unrealized potential of computer technology through a series of investigations that would build upon a conceptual framework of theory and research to "stretch the limits" of the technology beyond current practice.

In carrying out this research program, AIR worked closely with two school districts whose administrators and teachers had established themselves as leaders in using computers in the schools and whose special education staffs were known to be innovative. They provided valuable perspectives during the planning of the different investigations, helped in developing some of the innovative computer materials that were prepared, and provided "laboratory" settings in which pilot testing and experimentation could take place. The school districts were the Fremont Union High School District and the Cupertino Union School District, both in California, respectively representing grades 9-12 and K-8.

The domains of interest in the original proposal, to be modified as a result of initial year investigations, were

1. Building learners' enabling skills, processing skills, and performance skills.
2. Stimulus-properties and user-friendly techniques to incorporate in commercial and teacher-authored materials
3. Methods for evaluating, selecting, and using existing materials for suitability to handicapped learners
4. Logistics of hardware, software, and training of staff and student leadership

5. Innovative subject matter applications in mainstream, resource room, home, and community-based contexts

6. Networks, interactive systems, and the inter-school pooling of resources, information, and instructional content.

One of the characteristics of multiple year grants is that they afford the researchers an opportunity annually to shift the emphasis toward particularly promising aspects of the originally targeted purposes. Such was the case in this study. Because the study was one of four that were concurrently funded by OSEP, a review of their proposals made it clear that issues relating to classroom logistics and utilization of technology (#4, 5, and 6 above) would be amply covered by those projects, making it desirable for AIR to pay proportionately more attention to issues #1, 2, and 3 which were not as thoroughly covered.

Midway through the course of the project, staff became more focused on two research questions that influenced our experimentation in the third and fourth years. Put simply, they were:

1. Can microcomputers/particular software be used to teach/improve the learning performance of learning disabled students with particular characteristics?
2. What features are critical in software for learning disabled students with particular characteristics?

## Theoretical and Conceptual Foundations

## Theoretical and Conceptual Foundations

The overall theoretical framework that was developed during the first year of the CREATE study suggested that a number of learning disabled students, whose reading performance in academic subject matter was not commensurate with their general ability, might lack certain cognitive processing skills which facilitate comprehension. Likewise, a number of poor readers might lack lower order perceptual enabling skills, such as the "automatic" recognition of words based on their length, shape and initial letter(s), that are a precondition to efficient cognitive processing. The general research question posed was whether computer technology could be used to address these skills and thus enhance poor readers' ability to function at a higher level.

Accordingly, experiments were designed and special purpose software developed to focus first on research relating to perceptual enabling skills (using a newly developed software research tool, TurboScan) and later on research relating to cognitive processing (a second newly developed software research tool, Wordsworth).

Figure 1 shows the conceptualized hierarchy of skills at the perceptual-enabling and cognitive-processing levels. In examining Figure 1, it should be pointed out that

- Neuromuscular vision skills were investigated outside project CREATE in a concurrent study. This project, led by Dr. David Grisham, an AIR researcher who held a joint appointment at the School of Optometry, University of California, Berkeley, found that computer technology could be used to facilitate vision training in binocular fusion and near/far accommodation.
- Most, but not all, of the scope and sequence topics outlined in the perceptual enabling skills level were covered in the TurboScan software. (See Appendix A for the Scope and Sequence chart.)
- A relatively small proportion of the full range of cognitive processing skills were addressed in the Wordsworth software. Specifically, we focussed on the lowest level of comprehension skills – identifying facts and details in narrative text. (See Appendix A.)
- No attempt was made to study the academic performance of students' reading in the subject areas (e.g., English and mathematics) inasmuch as the sister research projects elsewhere were studying patterns of use and academic outcomes of classroom use of computers.

**A Conceptual Hierarchy of Skills  
Contributing to Effective Reading**

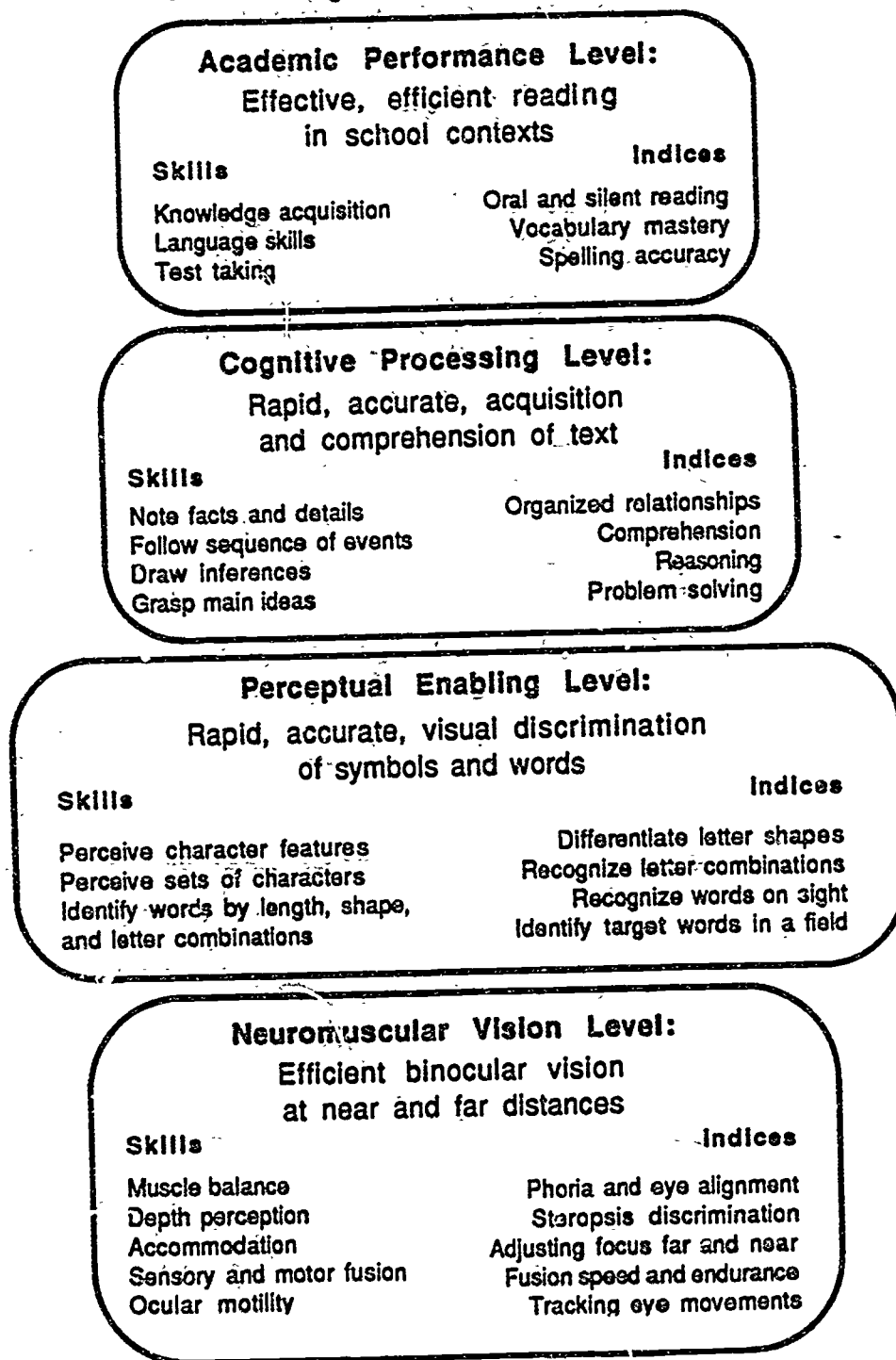


Figure 1. A conceptual hierarchy of skills contributing to effective reading

## Occasional Papers

Early in the CREATE project a number of reports were prepared to summarize the "state of the art" (in 1984) with respect to the application of computer technology to learning. The first two papers cited below were central to the formulation of later CREATE experiments. The occasional papers included

- Weisgerber, R. A., (1984) Implications of Research and Theory for the Use of Computers with the Learning Disabled
- Rubin, D., Blake, P., and Aten-Iossi, B. (1984) The Learning Disabled and Computer-Based Education: Program Design Strategies
- Bakke, T., (1984) Existing and Emerging Technologies in Education: A Descriptive Overview
- Weisgerber, R. A. and Blake, P.L., (1984) The Evaluation and Selection of Instructional Software for Use with the Learning Disabled
- Bakke, T., (1984) Optimal Approaches to Microcomputer Implementation in the Schools
- Rossi, R., Rubin, D., and Bakke, T., (1984) Promoting Use of Technology in the Schools: An Organizational Analysis of California's Teacher Education and Computer Centers

One additional paper will be released concurrently with this final report. It will address "breakthroughs" that have been observed and reported (largely anecdotally) when disabled persons have been given the opportunity to use computers. An example of a breakthrough is the case of a dyslexic young man in Oregon whose expressive abilities were severely limited but who, through use of the computer, now has become a university teacher in visual design. Anecdotes about changed life experiences have served as beacons pointing out new directions for researchers, practitioners, and the disabled.

## Dissemination

The first and second of these papers have been widely circulated to requesting educational and research institutions. The fourth paper was shared with schools that had volunteered to participate in field testing of the evaluation and selection form and other interested schools. The third, fifth, and sixth



papers were narrower in scope and were circulated principally to requesting schools from within California.

Copies of all occasional papers were submitted to the Office of Special Education Programs and to the three other projects concurrently funded to investigate the application of technology to the education of the handicapped: University of California (Santa Barbara), the University of Maryland, and Vanderbilt University.

Several of the occasional papers were specifically adapted for journal publication or referenced in journals. These included:

The Learning Disabled and Computer Based Education: Program Design Strategies, published by the International Council for Computers in Education in their SIG Bulletin, October/November, / December, 1985.

Implication of Research and Theory for the Use of Computers with the Learning Disabled referenced by The Computing Teacher, May, 1986.

Articles that described or cited various aspects of AIR's research in the CREATE project included:

Weisgerber, R. and Rubin, D. Designing and Using Software for the Learning Disabled. In Journal of Reading, Writing and Learning Disabilities, Vol. 1, No. 2, Winter, 1985, pp. 133-138.

Rubin, D. and Weisgerber, R. The Center for Research and Evaluation in the Application of Technology to Education. In T.H. E. Journal. February, 1985, pp. 83-87.

Rudy, R. Effective reading goal of school's computer studies. Newspaper story in the Times-Tribune, published in Palo Alto, Sunday, June 22, 1986.

Rosenfeld, N. New Vistas for Disabled: Computers Lead the Way. In II Computing, For Apple Users, August/September 1986.

\_\_\_\_\_. New Computer Study Funded. ACLD Newsbriefs, March/April 1984, pp. 1, 13.

\_\_\_\_\_. Adapting Technology to the Needs of Handicapped Learners. Entre Nous, May 1984, pp. 1-2.

\_\_\_\_\_. Project CREATE. REACH Bulletin, Issue 1: March, 1984; Issue 2: October, 1984; Issue 3: November, 1985; Issue 4: November, 1986.

Additionally, the project was referenced on computer bulletin boards (e.g., Counterpoint), resulting in numerous inquiries to the project.

## Enhancing the Educational Value of Existing Software

## Enhancing the Selection and Use of Available Software and Disseminating Information about Computer Use

### Software Selection

The process by which educational software is selected by school districts varies widely. One product of our research in 1985 was a new technique for evaluating and selecting programs designed to

- (a) focus the attention of the educator-reviewer on issues related to educational values in the software while providing for clerical input on information that is simply descriptive of the product,
- (b) introduce a distinction between software selected for academic purposes (performance skills) and software selected to meet specific deficits of disabled youth (enabling skills involving perception; processing skills involving cognition)
- (c) provide a way of rating and weighting the merits of the software according to instructional design elements (instructional strategy, learner control, and feedback/reinforcement) and the quality of individual components (documentation, supplementary materials, and program operation and presentation).

The Software Evaluation and Selection Form included in Appendix B of this report resulted from a thorough search and analysis of published selection forms available at that time and an iterative process of development and evaluation with school personnel in volunteer "field test" school districts around the country.

It is worthy of note that the evaluation and selection procedure as shown in Appendix B would lend itself very well to a computerized data base retrieval system that could enable teachers in a district to access relevant software according to its educational purpose rather than by title or other general terms. While such a task could not be accomplished within the framework of CREATE research, this remains an objective worthy of support by OSEP.

### Integrating Computer Software into the Curriculum

Frequently, criticism has been directed toward popular computer software as being interesting but not well correlated with the core educational curriculum. Typical of the interesting but seemingly unrelated software are some of the more challenging programs that require cognitive "problem solving" skills. Accordingly, some software that has been very popular in

terms of unit sales has not been integrated into the curriculum but rather tends to be used as a separate "activity," and treated as a reward. When computers are used in an unrelated way, the student can hardly be expected to transfer knowledge gained through computer study (if any) to the basic educational goals in the core curricula.

Research has shown that the most common use of the computer in the schools is for drill and practice. Drill and practice can be a relatively dull application of technology when it simply means the workbook-like presentation of math problems, vocabulary, spelling words and so forth. Consequently, it is not surprising that another criticism leveled at some software is that it is unimaginative and repetitive. On the other hand, some popular commercial software, such as Reader Rabbit, has motivational characteristics but some teachers may not know how to tie it in with the curriculum as effectively as they might.

A fundamental axiom of good instructional planning in a computer-using classroom is that computer study and classroom study should be tied together in appropriate, mutually reinforcing ways. To demonstrate the feasibility of this premise, we selected five popular (in the schools) educational software products, and designed and prepared adaptive teacher guides showing how the software could complement regular class activities. The Factory, Reader Rabbit, Kid Writer, Word Spinner, and Story Machine were the commercial software products selected to demonstrate that better integration of the software would better facilitate the efforts of regular education teachers in supporting their disabled students in the basic subject areas.

The selection of the software and the design of the handbooks were the joint responsibility of the American Institutes for Research project staff and special education teachers in the two cooperating "laboratory" school districts in California, Fremont and Cupertino, respectively representing the secondary and elementary grades. Educator and researcher teams were formed to develop adaptive handbooks for each software program.

The strategy followed for the development of the adaptive handbooks was to

- Identify the "educationally relevant" content and/or principles that were in the software.
- Segment the software content into logical increments or "units" to be presented in the workbooks, gradually increasing these units in complexity and difficulty.
- Prepare a set of three lessons for each unit of study that would

- (1) take place in the regular classroom, setting up the computer experience that would follow,
- (2) be executed in a particular sequence on the computer in the lab or other setting in which computer use was scheduled,
- (3) provide follow-up in the regular classroom and "test" the transfer of the computer-gained knowledge to subject matter being taught there.

Teacher participation was important in the design, development and classroom testing of these adaptive workbooks and many hours were spent by them outside of school hours in developing the draft materials. Draft materials were developed and tested in the schools for The Factory, Reader Rabbit, Kid Writer, Word Spinner, and Story Machine. The AIR report to OSEP entitled CREATE: Software Handbook (September 1983- October 1984) included a complete set of the five adapted workbooks.

#### Publication of the Workbooks

The workbooks for two of the software titles mentioned above (The Factory and Reader Rabbit) were carried through the complete cycle of preparation, testing in the schools, and revision. They were subsequently published by the firms who sell the software, Sunburst and The Learning Company. As expected, the commercial availability of these two workbooks, which were specifically designed to bridge the gap between the classroom and computer study, has extended the usefulness of the software and has been welcomed by the hundreds of school districts that have purchased the workbooks.

Evidence of the way in which these workbooks have been received was offered in the publication Closing the Gap, April-May 1986, which regularly informs the educational field about advances in computer use in the schools.

Learning Disabilities teaching materials are now available for Sunburst's The Factory and will soon be available for The Learning Company's Reader Rabbit and Word Spinner. These materials were developed by the American Institutes for Research, under a grant from the Office of Special Education.

I've seen The Factory workbook. It contains eight excellent modules, each containing pre-computer, computer, and post-computer/assessment activities. Many reproducible worksheets are included. These are the kinds of materials LD teachers have needed for a long time.

Miriam Furst, Contributing Editor

## Disseminating information about computer use

Throughout the CREATE Project, professional staff made presentations at various conventions, conferences and meetings. These presentations had several purposes: (a) to inform the field about the grant and the CREATE project, (b) to inform the field about the strategies for the use of computer technology that we were designing and testing, and (c) to offer suggestions to the field regarding future directions for software design that would benefit the handicapped and related research that needs to be conducted.

The following is a list of the appearances and presentations made.

R. Weisgerber and D. Rubin. CEC/CASE National Conference and Training Workshops on Technology in Special Education. Reno, January, 1984.

D. Rubin and R. Weisgerber. The CREATE Project: New Directions for New Technologies. California State Federation/CEC 34th Annual conference, Oakland, November, 1984.

D. Rubin and R. Weisgerber. Computers and Reading/Learning Difficulties. Fourth Annual Western States Conference, San Francisco, January, 1985.

D. Rubin and R. Weisgerber. Research in Learning Disabilities: New Computer Approaches to the Treatment of Learning Disabilities. ACLD International Conference, San Francisco, February, 1985.

D. Rubin. CREATE: Computer Learning Strategies for the Learning Disabled. Council for Exceptional Children, 63rd Annual Convention, Anaheim, April, 1985.

R. Weisgerber and D. Rubin. Meeting of OSEP Technology Research grantees, Washington, D.C. March, 1986.

D. Rubin. Project CREATE. World Congress on Education and Technology, Vancouver, June 1986.

D. Rubin. Project CREATE. Center for Special Education Technology, June, 1986.

R. Weisgerber. Project CREATE. Special Project on Interagency Information Dissemination, Council for Exceptional Children, July, 1986.

D. Rubin. Computer Software to Remediate Reading Deficiencies. SERN Region 5 Secondary Conference, San Jose, October, 1986.

R. Weisgerber and D. Brandt. New Findings and Directions in Using Computers with the Learning Disabled. Council for Exceptional Children 65th Annual Convention, Chicago, April, 1987.

R. Weisgerber. Design of Visual Skills Software. Special Education Software Center; Third Annual Conference, Washington, D.C., May, 1987.

R. Weisgerber. Future Directions in Microcomputer Research (Panel), Invitational Research Symposium, Washington, D.C., May 1987.



## Experimentation with Specially Developed Software

## An Overview of CREATE Experimentation

The various experimental studies that were undertaken with the cooperation of the laboratory schools were essentially exploratory in nature. In a very real sense, they were limited "one shot" trials to assess the possible impact of special purpose software on disabled students who had one common denominator— that they had been classified by the schools as learning disabled. Because reading is a serious problem for many (but not all) learning disabled children we focused on reading related experimentation. Thus in the broadest sense we were posing the general hypothesis that

The use of special purpose computer software can improve the reading skills of learning disabled children.

At the specific level, we were concerned with trying to demonstrate that special purpose computer software could be helpful in developing the underlying skills that must be in place if better reading skills are to be applied to the variety of reading tasks in school.

Following the conceptual model outlined in an earlier section of this report, we hypothesized a set of relationships that ideally should be solidly in place in order for reading to be efficient and effective. That is, we argued that if academic performance skills such as reading, vocabulary, and spelling are not demonstrated at a level consistent with maturity and general ability, the gap may be due (in part) to a fundamental deficiency in one or more of (a) cognitive processing skills, (b) perceptual enabling skills, or (c) neuromuscular vision skills.

We believed that if appropriate, carefully designed software could be targeted at these underlying levels that it might be an appropriate way to demonstrate how computer technology could be used in a new and different way to aid learning disabled students. With this perspective, we could phrase the specific hypotheses and associated assumptions as

1. The use of special purpose software that addresses cognitive processing skills can facilitate the reading of learning disabled children

Assumption: The underlying perceptual enabling skills and neuromuscular vision skills are in place.

2. The use of special purpose software that addresses perceptual enabling skills can have an indirect, positive effect on the reading of learning disabled children

Assumption: The underlying neuromuscular vision skills are in place.

3. The use of special purpose software that addresses neuromuscular vision skills can have an indirect, positive effect reading of learning disabled children

An important issue related to the development of these software prototypes involved the experimental determination of what features of instructional design ought to be embodied in effective software for the learning disabled. The particular features that were examined were: the use of on-screen display of criterion performance, the ability for the learner to set the rate of presentation, the relative difficulty of exit criteria, and the provision of corrective feedback.

Funding constraints and time limitations prevented a comprehensive test of the *entire* conceptual framework within a rigorous, concurrent experimental design. Research on neuromuscular vision skills was conducted outside the CREATE study in a separate AIR project. The initial experiment that was undertaken was at the enabling skills level, and the software research tool was called TurboScan. The second experiment was done with a software research tool called Wordsworth.

Considerable attention was given to practical design problems having to do with learning disabled students' ability to use the computer interface flexibly and in as transparent a manner as possible. Clearly, the evaluation of computerized instructional design must take into account whether the students are forced to attend cognitively to the medium (hardware and software) more than to the message it purports to convey. Accordingly, these issues are described in some detail later in this section. A brief description of each of the two software research tools follows.

#### Description of TurboScan in its final form

In its final research form, TurboScan consists of a program disk (side), a data disk (side) for scoring of students/classes, and a separate editing disk for creating new instructional screens. It is designed for use on the Commodore 64 computer with color monitor.

The main elements in the screen display are

- a reserved upper area of the screen which shows
  - a selectable sprite (either robot, duck or none)
  - a set of empty squares symbolizing the number of targets to be found
  - a horizontal "thermometer" cumulatively displaying right responses (green segments) and wrong responses (red segments) and a criterion "star" to be reached at a

character(s), choice of sprites, and control of rate. Use of the editor is straightforward and requires no special computer knowledge.

### Description of Wordsworth in its final form

The Wordsworth program consists of a set of disks containing program information on one side, with one "story" per disk, and individual student performance data on the other side. The program is designed for use with an Apple IIE computer and color monitor.

The main elements in the computer display are

- a reserved upper area of the screen for presentation of directions and questions
- a reserved lower area reserved for the presentation of text
- a narrow, horizontal band which separates the previous two areas and is used to present cumulative scoring results
- a "phantom" area which appears as an overwrite to the text for presenting memos and hints
- two on-screen buttons for program control-- "Hint" and "Done"
- a bottom line reserved for reminders about additional "pages" that are available for view or review

The instructional task is simply to read the text (as one would read pages and passages in in books) and respond to the directions/questions given. Questions are of two types: mark specific words or sentences that answer the question or choose the correct answer from among multiple choice alternatives.

As will be described in greater detail later in this report, the student is to "solve" a mystery and earn "reward" points by answering the questions correctly. If an error is made, the individual gets a second chance, but at a lower level of reward. After two wrong responses the correct answer is provided.

The computer record-keeping system allows detailed tracking and printout of each student in terms of every key pressed and screen display generated, and right/ wrong scoring as well as a log of elapsed time.

## Results of the 3rd Year Experiment

### Study 1: Assessment of Perceptual Enabling Skills and Improved Reading

Study 1 was conducted to evaluate the effectiveness of a first implementation of TurboScan in developing Reading-Related Visual Discrimination skills (RRVD) within a heterogeneous population of "learning disabled" children. TurboScan, the remedial reading software we designed for this project, reflects research-based principles drawn from two literature reviews and is described elsewhere in this report. TurboScan is intended to develop low-level visual discrimination skills characteristic of good readers and underdeveloped in poor readers.

#### Research design

Study 1 was designed as a two-group treatment-control study, with subjects drawn from eight classes of learning disabled students at the Cupertino Union School District (elementary level) and five resource rooms at the Fremont Union High School District (secondary level), a total of 231 students (141 elementary and 90 high school).

Participating students were pretested with a battery of instruments to establish a baseline for each learner. Included were tests of general ability, reading ability, reading-related visual discrimination, reading motivation, and motivation to use computers. Using the pretest and background skill information, the entire sample was sorted into strata using a nesting approach, with students first matched on teacher, then on RRVD level, then general ability level, and finally by sex. Subjects were then randomly assigned to either treatment or control groups. Tests of group means showed no significant differences between the treatment and control groups.

Students in the treatment group used the TurboScan software program 15 minutes daily for six weeks. At the end of the treatment period, both treatment and control groups were given posttests to measure the following skills: eye movements (as measured by the Eye Trac apparatus), oral reading speed (as measured by reading passages of the Gray Oral) and reading related visual discrimination skills (as measured by RRVD tests of the visual discriminationskills taught by TurboScan). The RRVD battery included:

- *Matching shapes.* A match-to-sample exercise.
- *Finding reversals.* Circle reversed letters and numbers.
- *Matching short words I.* Match-to-sample two and three letter words.

- *Matching letters.* Match-to-sample small and capital letters.
- *Matching short words II.* Match-to-sample two to five letter words.
- *Matching letters within words.* Match-to-sample within word.
- *Matching letter combination.* Match-to-sample letter combination within a word.
- *Finding words of given length.* Match-to-sample by word length.
- *Matching long words.* Match-to-sample four to seven letter words.
- *Finding the word that is different.* Identify non-matching word.
- *Make words using letter combination.* Spell word by inserting letter combination in blanks.

## Results

An analysis of covariance was used to estimate the size and significance of the treatment effect and was conducted in two steps. (1) A set of background variables to be used as covariates was identified, and (2) an analysis of covariance was conducted on each set of criterion measures of interest.

For the elementary school data, Table 1 shows the correlations between the candidate background measures and the posttest RRVD skills measures. It was clear that age and reading ability are correlated with all eleven RRVD tests; none of the other background variables are related.

The two background variables, age and reading ability, were included in the analysis of covariance. A multivariate test evaluating the entire battery jointly was significant at the .05 level. Table 2 summarizes the results for the individual variables.

The same analytic procedures were carried out for the secondary school sample. A multivariate test evaluating the entire battery jointly was not significant. Table 3 summarizes the results for the individual variables.

## Summary

The primary objective of Study 1 was to determine whether the use of TurboScan produces measurable gains in visual discrimination and reading skills. This objective was met to a limited degree. Although the analyses of

Table 1. Correlations of background variables and RRVD tests:  
elementary school sample.

RRVD Test	Age	Slossen	Woodcock	Motivation to read	Motivation for computer
Shapes	.26	.04	.40	-.07	-.13
Reversals	.26	-.05	.25	.03	-.04
Short words I	.23	-.10	.39	-.01	-.05
Letter I	.31	.01	.39	.10	-.03
Short words II	.29	-.05	.54	.04	-.02
Letters II	.38	.01	.38	.01	-.09
Letter combinations	.34	-.03	.40	-.06	-.08
Word length	.39	.14	.49	.07	.00
Long words	.28	-.12	.44	.03	-.02
Identify different items	.32	-.01	.46	-.04	-.03
Make words	.35	.06	.39	.02	-.05



Table 3. Analysis of treatment and control differences: Secondary data

Dependent Variable	Group Means and S.D.'s				Tests of Adjusted Mean Differences		Analysis of Within-group Relations		
	Treatment		Comparison		F	p level	R <sup>2</sup>	F	p level
	Mean	S.D.	Mean	S.D.					
Matching Shapes	6.28	.89	6.23	1.06	.01	—	.18	3.60	.01
Finding Reversals	11.29	2.85	11.11	2.43	.02	—	.16	3.22	.02
Matching Short Words I	5.81	.56	5.80	.58	.02	—	.12	2.28	.07
Matching Letters	9.10	.92	9.17	1.10	.48	—	.09	1.72	.16
Matching Short Words II	6.81	.46	6.63	.60	3.11	.08	.21	4.35	.01
Matching Letters in Nonsense Syllables	22.71	3.38	22.03	4.36	.18	—	.17	3.43	.02
Matching Letter Pairs	13.53	2.00	13.23	1.68	.35	—	.13	2.52	.05
Finding Words of Given Length	13.37	3.15	13.09	3.31	.01	—	.17	3.47	.02
Matching Medium-Length Words	6.34	.88	6.29	1.02	.01	—	.14	2.70	.04
Finding Word that is Different	8.50	1.35	8.31	2.03	.04	—	.17	3.39	.02
Make Words with Letter Pairs	10.26	3.65	9.77	3.07	.17	—	.34	8.78	.01
Gray Oral Total	77.53	33.75	75.29	21.73	.01	—	.50	17.04	.01

Note: Each R<sup>2</sup> is the proportion of variance in the dependent variable that is explained by the linear regression of the dependent variable on age, WRAT, Slossen, and Gates. These analyses are based on 38 cases in the treatment group and 35 cases in the comparison group.



the data did produce a significant effect in favor of the treatment, the size of the effect was smaller than expected, primarily due to problems in instrumentation, we believe. Because the RRVD pretests showed a pronounced ceiling effect, it was necessary to use shorter time limits on the posttest. This led to a posttest-only design and a weaker analytic technique. We were encouraged that a significant effect was found for the elementary school sample.

We also learned that the measurement of eye movements in this population is more problematic than originally thought. Consistency among the raters of the Eye Trac printout was not as high as we expected and we therefore standardized the Eye Trac scoring procedures so that similar problems would not occur in Study 2. We also gained some ideas about how to improve TurboScan, particularly in making the task more motivating and challenging to the student.

#### Study 2: Evaluation of the Instructional Impact of TurboScan Features

Study 2 was a further investigation of the effectiveness of TurboScan in remediating reading skill deficiencies. A new research objective was added, the research design was modified, and significant changes in instrumentation were made. Five treatments similar to those of Study 1 were evaluated, using the control students from Study 1 as the treatment group. No control groups were used. Refinements in the RRVD skills batteries and standardization of procedures in the administration of Eye Trac and Gray Oral instruments resulted in more consistent and sensitive measures of RRVD skills, eye movements during reading, and reading speed.

#### Research design

Subjects were heterogeneous with respect to reading ability and scores on intelligence tests. At the elementary level, groups of subjects with the same teacher were assigned to specific treatments. Use of the TurboScan software program for 10 to 15 minutes each day for six weeks with five different program variants. Assignments and conditions are shown in Table 4.

At the secondary level, the subjects (N=33) received the conditions 2.4 and 2.5 described above (N=13 for 2.4 ; N=20 for 2.5).

The five different treatment conditions were created by modifying the software in selective ways to address questions about generalizable program features that were considered to have a potentially significant impact on the effectiveness of the treatment.

Table 4. Assignment of subjects to conditions

(Elementary level)			
Study no.	Conditions	Teacher	N
2.1	No bar graph showing accuracy	1, 2	18
2.2	No feedback on errors of omission	3, 4	24
2.3	Learners can set their own speed	5	17
2.4	Relatively easy exit criterion	6	12
2.5	Relatively hard exit criterion	7	11
(Secondary level)			
2.4	Relatively easy exit criterion	8	13
2.5	Relatively hard exit criterion	9	20

(1) *Does the use of a visual indicator giving continuous information on accuracy of learner responses and on overall performance serve to shape subject response patterns in a beneficial way?* A bar graph or "thermometer" was included in the upper part of the screen to provide immediate visual evidence of performance relative to the criterion. It provided cumulative information on the proportion of right and wrong answers.

(2) *Does knowledge of specific omissions, coupled with additional opportunities to find those targets, increase the effectiveness of the software?* A feature was added to highlight missed targets in red following the completion of scoring for each screen.

(3) *Does learner control over the rate of presentation improve the effectiveness of the treatment?* Subjects were able to set and change the speed at which the scanning window would move, rather than having the automatic adjustment used in Study 1 and for other conditions in Study 2.

(4) and (5) *Does the difficulty of the exit criterion affect the performance of subjects and the rate at which they are able to learn RRVD skills?* The exit criterion was made easier in one version and more difficult in the other.

Gains were evaluated using a pretest-posttest design, with Study 1 posttest measures for the control group used as the pretest measure for this study, and three sets of dependent measures for the post-test: eye movements (as measured by the Eye Trac apparatus), reading-related visual discrimination skills (as measured by RRVD tests of the visual discrimination skills taught by TurboScan), and oral-reading speed (as measured by reading passages of the Gray Oral).

## Results

For the elementary school students, Table 5 summarizes the results for the Gray Oral and the RRVD measures. All measures are statistically significant at the  $p < .01$  level or greater. On the average, elementary school students gained on both the visual discrimination and reading tests.

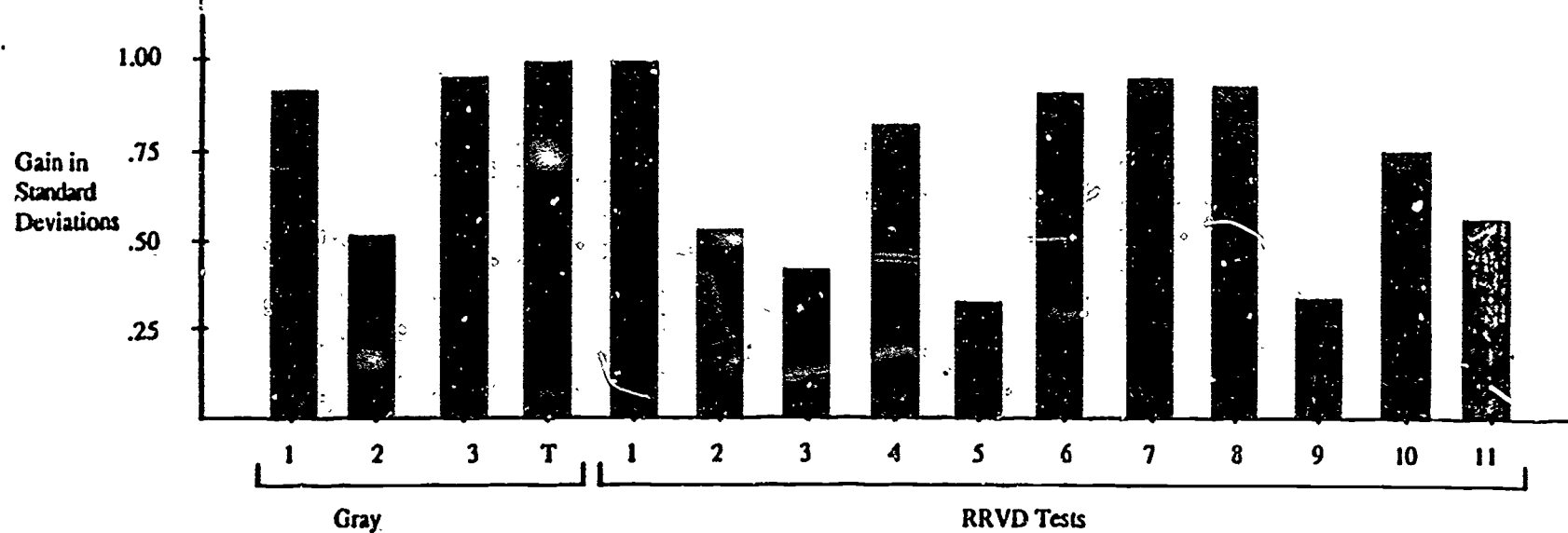
Because the Gray Oral and RRVD tests are on different scales of measurement, it is not easy to judge the magnitude of the effects from inspection of the means. To make this easier, we divided each average gain score by its standard deviation. This statistic is reported in the last column of Table 5 and graphed in Figure 2.

Table 5. Pre- and posttest means on Gray Oral and RRVD tests:  
elementary data

Variable	Number of Cases	Means		t-test	Effect Size
		Pretest	Posttest		
<b>Gray Oral</b>					
Paragraph 1	76	.97	.86	7.68**	.88
Paragraph 2	75	1.29	1.24	4.58**	.53
Paragraph 3	72	1.44	1.34	7.49**	.89
Total	72	1.75	1.66	8.50**	.99
<b>RRVD Tests</b>					
Matching Shapes	76	5.34	6.38	8.52**	.98
Finding Reversals	76	8.39	9.60	4.68**	.54
Matching Short Words I	77	4.92	5.40	3.62**	.41
Matching Letters	77	7.14	8.05	7.48**	.85
Matching Short Words II	77	6.02	6.29	2.73**	.31
Matching Letters	77	18.11	21.01	7.94**	.90
Matching Letter Pairs	77	9.60	11.62	8.41**	.96
Finding by Length	77	9.87	12.43	8.00**	.91
Matching Long Words	77	5.14	5.54	2.83**	.32
Finding Different Words	77	6.06	7.36	6.47**	.74
Making Words	76	6.13	7.67	4.95**	.57

Note: The means for the Gray Oral tests were computed from the logarithm of the time to read each paragraph.

\*\*p<.01

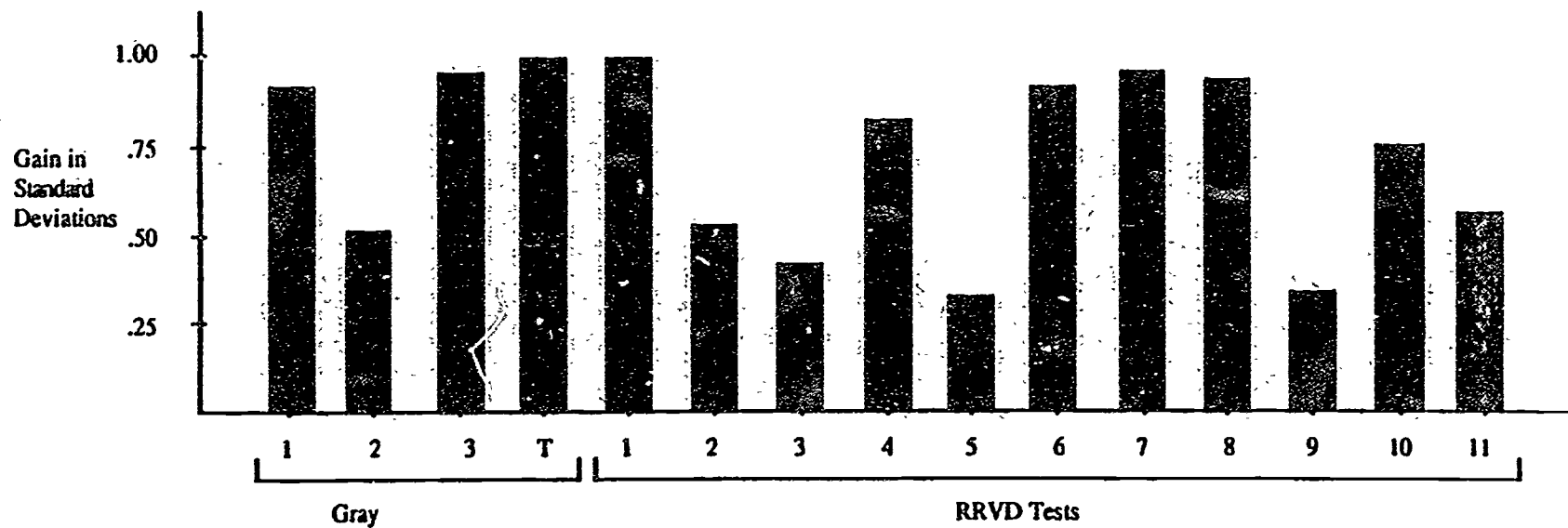
**Key****Gray Oral Passages:**

- 1: Pre-Primer
- 2: Primer
- 3: First Grade
- T: Total of the above

**RRVD Skills:**

- 1: Matching Shapes
- 2: Finding Reversals
- 3: Matching Short Words I
- 4: Matching Letters
- 5: Matching Short Words II
- 6: Matching Imbedded Letters
- 7: Matching Imbedded Letter Pairs
- 8: Finding Words of Given Length
- 9: Matching Medium-Length Words
- 10: Finding Non-Matching Words
- 11: Making Words Using Letter Pairs

Figure 2. Gains on the Gray Oral and RRVD tests: Elementary data

**Key****Gray Oral Passages:**

- 1: Pre-Primer
- 2: Primer
- 3: First Grade
- T: Total of the above

**RRVD Skills:**

- 1: Matching Shapes
- 2: Finding Reversals
- 3: Matching Short Words I
- 4: Matching Letters
- 5: Matching Short Words II
- 6: Matching Imbedded Letters
- 7: Matching Imbedded Letter Pairs
- 8: Finding Words of Given Length
- 9: Matching Medium-Length Words
- 10: Finding Non-Matching Words
- 11: Making Words Using Letter Pairs

Table 6 summarizes the results for the Eye Trac Data on the subset of the elementary school sample for which we were able to obtain valid pretest-posttest data (some students could not be calibrated on the Eye Trac device).

The results indicate that TurboScan had an impact on eye movement patterns. However, we have no data for the group of students whose eye movements are known to be the most erratic, so extrapolation of these results to populations with different characteristics is not encouraged.

The effects of variations in the features of TurboScan were measured by comparing differences among gain scores. Table 7 reports on the significance of differences among gain scores, with t-test entries in the first five columns to indicate whether the gain associated with a particular condition is significantly different from the *average* of the gains of the remaining conditions.

Table 7 does not show any strong trends. None of the RRVD tests indicate differential gain. One of the three Gray Oral tests, the first-grade passage--does show differences in gain that "approach" significance. We conclude that no strong evidence favors one particular variation over another.

For secondary school students, Table 8 summarizes the Gray Oral and RRVD results. Gains for the secondary school students were statistically significant for all three Gray Oral passages and for nine of the eleven RRVD tests. The two RRVD tests not showing significant gains both require students to match target words. Because the remaining such RRVD test does show significance, it is not clear why these two tests do not show significant gains.

Valid gain scores on the Eye Trac were obtained for only twelve secondary school students. No improvements in fixations or regressions were found. These levels correspond exactly to the posttest status of the elementary school students that were assessed using the Eye Trac and may represent some sort of ceiling.

Comparisons of the means on the RRVD and the Gray Oral for the "Easy Exit" and "Hard Exit" conditions did not reveal any consistent patterns, so we do not draw any conclusions from the results.

## Summary

Study 2 established that TurboScan is an effective remediation tool. Significant gains were found on all three sets of outcome measures. Evidence was gained that the effect of doing TurboScan exercises on the computer does transfer to both visual discrimination paper-and-pencil tests and oral reading speed. Differential effects of TurboScan by varying certain features of the software were not demonstrated.

Table 6. Pre- and posttest means on Eye Trac Measures: Elementary data

Variable	Number of Cases	Means		t-test	Effect Size
		Pretest	Posttest		
Fixations/100 words	32	170.00	150.63	3.42**	.60
Regressions/100 words	32	46.90	35.06	2.78**	.48
Per Cent Regressions	32	.27	.23	2.08*	.37

Note: The tests of significance were carried out on the logarithms of the counts.

\*\*p<.01

\*p<.05



Table 7. Comparisons among TurboScan treatment groups

Dependent Variable	No Therm	Easy Exit	Hard Exit	No Red	Change Speed	F-Statistic	
Gray Oral 1	-.48	.51	1.65	-2.97	.47	2.79	(.06)
Gray Oral 2	.39	1.48	-1.46	.82	-1.16	1.27	(.29)
Gray Oral 3	.76	3.28	-1.42	-.96	-2.39	3.78	(.01)
Matching Shapes	1.29	-1.11	.27	1.00	-1.16	1.09	(.36)
Finding Reversals	.53	.32	1.19	-.91	-1.56	.99	(.42)
Short Words I	-.89	2.39	-1.14	-.73	.13	1.59	(.19)
Matching Letters I	-.39	1.63	-1.01	.89	-1.13	1.17	(.33)
Short Words II	.13	-1.13	-.89	.36	1.93	1.17	(.33)
Matching Letters II	1.18	1.75	-.93	-1.77	-.45	1.76	(.15)
Letter Pairs	.50	-.62	.36	-1.05	.77	.52	(.72)
Word Length	-.76	-1.13	1.33	.17	.28	.72	(.58)
Matching Words III	.37	2.00	-.96	-.39	-1.19	1.28	(.26)
Different Word	1.56	-.28	-.57	-.94	.37	.82	(.52)
Make Words	-.60	.39	1.59	-1.55	-.36	1.05	(.39)

Notes: Entries are t-tests that test each subgroup against the average of the remaining groups. A t-test that is greater than 2.00 is significant at the .05 level.

Table 8. Pre- and posttest means on Gray Oral and RRVD test: Secondary data

Variable	Number of Cases	Means		t-test	Effect Size
		Pretest	Posttest		
<b>Gray Oral</b>					
Paragraph 3	32	1.27	1.23	4.12**	.73
Paragraph 4	32	1.40	1.37	3.46**	.61
Paragraph 5	32	1.48	1.44	3.37**	.60
Total	32	1.87	1.83	4.56**	.80
<b>RRVD Tests</b>					
Matching Shapes	33	6.18	6.87	3.83**	.67
Finding Reversals	33	11.18	12.36	2.74**	.48
Matching Short Words I	33	5.70	5.94	2.27*	.59
Matching Letters	33	9.24	9.36	.68	.12
Matching Short Words II	33	6.51	6.94	3.97**	.69
Matching Letters	33	22.36	24.03	3.44**	.60
Matching Letter Pairs	33	13.42	14.42	2.81**	.49
Finding by Length	33	13.24	15.09	4.33**	.75
Matching Long Words	33	6.36	6.45	.53	.09
Finding Different Words	33	8.24	8.94	2.77**	.48
Making Words	33	9.97	12.58	5.51**	.96

Note: The means for the Gray Oral tests were computed from the logarithm of the time to read each paragraph.

\* $p < .05$

\*\* $p < .01$

### Study 3: Using TurboScan to Remediate Severe Learning Disabilities

Study 3 was designed to investigate the efficacy of TurboScan in the remediation of fairly severe learning disabilities. The major goals were to understand how members of this population interact with particular kinds of material that can be taught by TurboScan.

#### Research design

A case study methodology was used because the kind of information sought required a detailed analysis of the relationship between student background characteristics and performance and because very few students were available to AIR who met the criterion for inclusion in the study.

Study 3 differed from Studies 1 and 2 in four ways.

- (1) The target population consisted of the weakest students who are generally placed in remedial reading programs.
- (2) The most complete version of the TurboScan program was used (including features added in Study 2).
- (3) Entirely new screens were written, limiting the textual content to a pre-selected vocabulary and presenting it in a newly-defined instructional sequence.
- (4) Students met for one hour a day, five days a week, for one month. The session took place during the summer break; students were not attending regular school at the time.

Outcome data gathered in Studies 1 and 2 were used to identify students with serious reading difficulties. Students who could not read a first grade level paragraph sample on the Eye Trac device with at least 50% comprehension were nominated; nineteen students met the criterion; eight were volunteered. Three other students, siblings who were weak readers but stronger than those who met the criterion, were added subsequently.

The sessions were conducted by a resource specialist from the cooperating school district; an AIR staff member served as an aide. Testing took approximately two days at the beginning and end of the session, and each student received between 8 and 12 hours of actual exposure to TurboScan. The skill categories covered in the treatment and the number of screens contained in the curriculum are shown in Table 9.

Table 9. TurboScan-skill categories used in Study 3

Category	Number of screens
Initial letter	20
Initial letter combination	10
Word length	10
Word length and initial letter	10
Word length and initial letter combination	10
Shapes (2 and 3 letter words)	10
Shapes (4 letter words)	10
Shapes (5 letter words)	6
Shapes (2 target shapes per screen, with word length constant)	12
Shapes (2 target shapes per screen)	30
Shapes and initial letter	10
Comprehension (Find word according to category)	30
Find and say target word	100

The following outcome measures were used.

- Six RRVD Tests were administered: match short words, match long words, find words that start with a 2-letter combination, find words of given length, find the word that is different, and make words with letter combinations.
- The pre-primer, primer, first- and second-grade passages from Form B of the Gray Oral test were administered. Students were tested individually on the RRVD tests and the Gray Oral.
- The Eye Trac measure was attempted, but we soon realized that the test was unsuitable for this group due to our inability to get reliable data on eye movement.
- Variables that described students' performance on each screen were automatically recorded by the TurboScan program. On the basis primarily of the pre-primer passage on the Gray Oral, students were grouped into three subgroups: readers, intermediate readers and non-readers.

## Results

Given the individual differences in reading that were evident in the three subgroups, it is not surprising that the students were able to complete a different number of screens in the TurboScan program during the course of the summer class. The order of screens was predetermined because of assumptions about task difficulty, so it is of some interest to report, in Table 10, how far each student got.

Tables 11 and 12 below contain the results of the group level analyses for the Gray Oral and RRVD tests. Although the number of observations is small, gains on the first three Gray Oral passages and three of the six RRVD tests were statistically significant. Despite the wide range of ability levels within the group, results showed clear and convincing evidence of gain.

Data on several *process measures* were provided by the TurboScan program. The program will maintain records of students' progress and describe how well individual students do on particular kinds of exercises. Four variables were recorded: (1) total time spent on each screen (derived by adding across any multiple passes or screen "tries," (2) number of tries needed to reach the criterion, (3) number of targets and number of them found on the try that met the exit criterion and (4) number of incorrect targets marked on the try that met the exit criterion. Because of problems with missing data during computer recording, results are approximations and may be somewhat affected by attendance problems. We combined two original variables,

Table 10. Number of screens completed by Study 3 students

Student	Last category studied	No. of screens studied
<i>Readers</i>		
Lori	Find and say	230
Mark	Find and say	220
Jenny	Find and say	210
<i>Intermediate readers</i>		
Karyn	Find and say	220
Marie	Find and say	230
Jason	Find and say	180
Ellen	Comprehension	170
Bob	Shapes (2 per screen)	95
David	Shapes and initial letter	138
<i>Non-readers</i>		
Bill	Comprehension	146
Stan	Find and say	155
Joshua	Shapes (2 per screen)	103

Table 11. Study 3: t tests on Gray Oral passages

Passage		Pretest	Posttest	t-test
Level 1 Pre-primer	Median Time (Seconds)	26.00	17.67	5.07**
	Mean Log of Time	1.48	1.33	
	S.D.	.44	.48	
	N=12			
Level 2 Primer	Median Time (Seconds)	48.00	32.10	4.70*
	Mean Log of Time	1.71	1.55	
	S.D.	.39	.35	
	N=10			
Level 3 First Grade	Median Time (Seconds)	81.00	53.00	5.27**
	Mean Log of Time	1.83	1.65	
	S.D.	.35	.32	
	N=9			
Level 4 Second Grade	Median Time (Seconds)	77.00	62.00	1.97
	Mean Log of Time	1.82	1.75	
	S.D.	.35	.28	
	N=8			

\*p < .005

\*\*p < .001

Table 12. Study 3: t tests on the RRVD measures

RRVD Test		Pretest	Posttest	t-test
Match Short Words	Mean	11.5	13.7	2.40*
	Median	12.5	12.5	
	S.D.	4.7	6.2	
Match Long Words	Mean	9.7	11.3	2.66*
	Median	8.5	8.5	
	S.D.	5.6	6.2	
Match by Initial Letter Pair	Mean	10.1	11.2	2.76*
	Median	9.5	10.5	
	S.D.	3.6	4.6	
Find the Word that is Different	Mean	8.7	7.8	-1.20
	Median	8.0	8.0	
	S.D.	3.0	3.0	
Find Words of Given Length	Mean	20.6	20.7	.12
	Median	20.5	20.5	
	S.D.	4.3	4.6	
Make Words Using a Letter Pair	Mean	3.4	4.2	1.29
	Median	2.0	3.5	
	S.D.	2.6	3.4	

Note: N = 12

\* p < .05



number of targets and the number of targets found, into a single measure, percentage correct, and we computed means for each variable, by skill category, as shown in Table 13 below.

Overall, the pattern of results is consistent with intuition. Within nearly every skill category, the expected rank ordering of the subgroups is consistent with the actual ordering. The performance of all three subgroups improved as they proceeded through the three kinds of "length" screens; the ten screens that teach the "shapes of two- and three-letter words" proved to be the most difficult screens in the entire curriculum.

The three readers and two in the intermediate subgroup did well on the comprehension screens; non-readers and poor readers developed a compensatory strategy that enabled them to do the screens without knowing how to read any of the words.

For "Find and Say," the better readers performance clearly improved. For the worst students, those screens were ineffective. For the top five students, the goal of completion of the "Find and Say" screens—was reached.

### Summary

Our outcome data show that practice in TurboScan transfers to similar paper-and-pencil tests (RRVD tests) and improves oral reading speed. Although the sample was small, pre- to posttest gains were highly significant. We believe that the general efficacy of TurboScan cannot be seriously challenged. The Gray Oral data indicate that, excluding the non-readers, gains in reading speed are fairly uniform, while the RRVD data suggest that gains on skills taught by TurboScan are positively related to initial ability. Our data also suggest that the Gray Oral can be a useful screening device.

The low ability, non-readers pose two unique instructional problems: (1) Non-readers need intensive instruction in decoding skills and we cannot identify an existing computer program that can provide this instruction. Although non-readers might benefit in some ways from work on TurboScan, acquiring basic decoding skills is a higher priority for their classroom study. (2) Non-readers in our sample have been able to build up maladaptive compensatory strategies to cope with schoolwork that they cannot do. These strategies are a kind of outer "shell" that any effective instructional program of remediation must penetrate. In its present form TurboScan cannot provide this type of remediation.

Both non-readers and the intermediate subgroups had considerable difficulty with the advanced word length and word shape screens, a problem that seems to be associated with left-handedness and large WISC Verbal-Performance differences. This suggests the need for a specialized curriculum that

Table 13. Means by skill category for TurboScan process variables

Process Variable Group	TurboScan™ Skill Category											
	Initial Let.	Initial Let. Comb.	Length	Length/ Init Let.	Length/ Init Let Comb.	Shapes (2 & 3)	Shapes (4)	Shapes (5)	Shape Combin.	Shape/ Init Let.	Compre-hension	Find & Say
<b>Time per Screen</b>												
Non-Readers	45.48	43.03	61.09		41.33	66.56	56.25	44.78	48.38	93.75	33.25	46.41
Intermediate	34.68	31.73	50.26	38.83	31.22	65.69	38.77	34.67	32.47	34.40	32.95	26.19
Readers	25.37	29.5	27.61	23.10	19.60	35.67	33.24	27.25	29.46	32.04	26.52	16.48
<b>Number of Attempts</b>												
Non-Readers	2.03	2.33	4.17		3.44	3.89	4.92	1.61	2.61	4.94	5.62	3.18
Intermediate	1.48	1.47	3.37	1.45	2.08	4.47	3.30	1.67	2.10	2.60	2.37	1.70
Readers	1.78	1.75	2.18	1.77	1.90	2.67	2.75	1.75	1.80	2.18	1.98	1.87
<b>Per Cent Correct</b>												
Non-Readers	.88	.94	.94		.94	.88	.92	.97	.95	.91	.94	.99
Intermediate	.96	.97	.98	.98	.96	.94	.98	.94	.94	.95	.93	.98
Readers	.95	.97	.96	.94	.94	.85	.91	.97	.95	.94	.92	.97
<b>Number of Wrong Keypresses</b>												
Non-Readers	1.07	2.87	2.03		1.78	1.78	1.54	.72	1.13	1.72	2.75	.29
Intermediate	.91	1.74	1.98	1.58	1.43	1.28	1.60	1.21	1.31	1.47	1.72	.41
Readers	1.45	1.40	1.78	1.53	1.80	2.00	1.43	.75	1.12	1.78	1.28	.43

42

emphasizes length and shape skills to a greater degree than was used in the experimental curriculum.

TurboScan offers an automated way of teaching visual discrimination skills to children. Based on this research, it now seems possible to predict gain reliably in terms of visual discrimination ability. There is evidence to suggest that a number of students are better able to read orally following TurboScan study. It is also possible to describe subgroups of learning disabled children who need intensive work on particular skills that TurboScan teaches. Finally, it is also possible to identify a subgroup of nonreaders for whom a more intensive program of remediation is indicated than can be provided by TurboScan.

## Optimizing the Student/Machine Interface

The general instructional strategy was to cause students to attend carefully to facts and details in the presentation of several detective "cases." Three detective stories were used as a primary means for developing students' attention to facts and details within narrative text. By graduating the difficulty of the questions within and across the detective cases it was expected that students would improve their ability to recognize facts and details that are frequently imbedded in other information.

The students' attention to detail was required to prepare for questions interspersed through the story. By presenting the information as clues in the context of a problem to be "solved," this attention to detail seemed justifiable to the students (very probably more so than would be expected to occur during the silent reading of standard passages in school texts).

In each case the student played the part of a junior detective and "solved" the case. Each student was presented blocks or "pages" of information about the case and then asked to identify specific facts or details. Depending on the question, identification was accomplished either by selecting the best answer from among four multiple-choice options or by marking the sentence within the text that actually presented the fact referred to in the question.

During the presentation of the cases, each increment of information (termed a lesson) was scored by the computer whenever the student indicated he or she was satisfied by the answer that had been selected and highlighted. Scoring was activated by pressing the spacebar. Students could change their minds and freely select different answers prior to pressing the spacebar. Five "dollars" were awarded for correct answers on the first try, three "dollars" were awarded for correct answers on the second try, and no "dollars" were awarded if the question was answered wrong twice (the correct answer was automatically displayed in this situation).

### Critical Design Issues Involving the Student/Machine Interface

In the early stages of planning for the CREATE research, project staff felt that it was important to make the interface between the student and experimental programs as "transparent" as possible. In the prior year's research with Turboscan software, designed to develop students' perceptual enabling skills, the "press any key" interface greatly simplified students' responses, which had to be quick and accurate. This strategy could not be tried in Wordsworth.

In the Wordsworth software, which was designed to develop cognitive processing skills, the goal was to make the software as transparent as possible

but also to give the student a great amount of flexibility and control over the content being presented. To accomplish this, we initially planned for

- Separate display "windows" for
  - (a) textual information,
  - (b) directions, questions and reinforcement statements,
  - (c) "feedback" corrective memos and hints
- Scroll capability on each of the windows so that additional text could be accessed forward and backward in a manner similar to some word processors. Access was accomplished by registering the cursor over upward and downward pointing blinking arrows (buttons) located in the margin of each window and then depressing a control button on the joystick.
- On-screen "buttons" for management of program functions. Six were envisioned, including
  - (a) Hint- to request a hint
  - (b) Done- to indicate that the day's study is finished
  - (c) Next- to activate scoring and advance to the next lesson
  - (d) Undo- to "erase" a mistaken answer
  - (e) Mark- to identify target words or sentences in text
  - (f) Move- to extract a target word or sentence from one location and insert it at another location
- Cursor control via a joystick, allowing direct movement (horizontal, vertical, diagonal) to particular locations on the screen. Alternatively, the cursor could be controlled from the keyboard. The cursor itself was in the shape of a pointing hand.
- Student-controlled highlighting of text to prepare for the transfer of words, phrases and sentences from one location to another or for the cutting and inserting of text (the cut and insert capabilities were never implemented in the detective stories dealing with facts and details but were incorporated in the program so they could be used with subsequent research studies dealing with sequencing and main ideas.)

#### Preliminary Pilot Trials of the Interface

As a check on the usability of the screen design and the joystick input device, the program was tried out with younger students (5th and 6th grade) and with a few adults. It was immediately apparent that the initial configuration

(described above) was not a workable interface. The following features were targeted and changed based on observation of students' problems:

- Cursor control. The joystick proved to be an inefficient and unreliable method for controlling the cursor under conditions where specific lines of text had to be parked or specific buttons activated on the screen. (Three models of joysticks were tried -- all were so erratic and uncontrollable that they frustrated the students and distracted from the lesson.)

Accordingly, the joystick was replaced with a mouse. The use of keyboard entry was sharply reduced; only the spacebar, return, B (back), N (next) keys continued to be used.

- Screen. Four of the six control buttons were eliminated, retaining only HINT and DONE. The windows (for directions and questions, for text, and for corrective feedback) were increased in size, allowing more information to be seen at a time.

In the revised version, special instructions were caused to appear at the middle of the screen or at the bottom of the screen under specific conditions. For example, if there were additional pages of text, a bottom line would appear informing the student of the Next or Back page-turning options.

- Text marking. The use of diagonal marking action was originally expected to allow direct movement from the beginning to the end (or vice versa) of phrases or sentences in the same manner as the with the Macintosh. This non-linear movement confused the students.

Next, a simpler means of marking was tried in which the highlighted text would automatically wrap to the next line. This was conceptually more straightforward, but still required a degree of motor skill that got in the way of the cognitive process of reading the text and comprehending it. In addition, students were experiencing difficulty in isolating specific words or phrases because programming required that only the relevant text be marked in an answer.

For these reasons, the text marking procedure was further liberalized to automatically highlight entire sentences when any part of the sentence had been pointed to and marked by depressing the mouse button.



- Text Handling. The scrolling feature proved to be less than satisfactory in the trial with younger students. It was difficult for students to orient the cursor on the up/down arrow and hold it steady during the time the scrolling was taking place. The optimal rate of scrolling varied considerably across students, so that the actual setting of the rate represented a delay for some students but was too fast for others. In addition, the students would sometimes quit scrolling before the end of the block of text in which the correct answer was imbedded, with the consequence that they would try to select an answer based on incomplete information.

Because of this, the procedure for viewing additional text was changed from scrolling to a student-controlled page-turning action, activated by pressing the N(ext) or B(ack) keys. This presented new information in increments of up to eight lines of text. A check was built into the program to ensure that all pages had been read before the question could be answered.

It was apparent that this experience with interface design and redesign was an important and unanticipated event with considerable import for any developers of software aimed at the learning disabled.

## Results of the 4th Year Experiment

### Research Design: Cognitive Processing and Reading Comprehension

The experimental design called for a comparison of matched randomly assigned treatment and control groups. Pre and posttests were administered to both groups. The control group then began computer study after the posttest was completed. They then took a third test. This design allowed examination of treatment effects with matched groups (subsequently referred to as the First Analysis) and also with each student serving as their own control (subsequently referred to as the Second Analysis).

All students were administered the Comprehension subtest of the Stanford Achievement Test, Intermediate level 2, Form E, (1982 edition) prior to the initiation of the training. Students were then matched according to their score on the literal subscore of the comprehension subtest and randomly assigned to the treatment or control condition. Posttests consisted of Form F on the same test.

### Student Characteristics

Twenty six students began the fourth year Wordsworth study. One student who was assigned to the control group dropped out due to illness and other family problems. Table 14 shows the grade assignments of the participants and the relative severity of their learning disability.

Table 14. Grade Levels of Participants and Severity of Learning Disability

Study #1	Grade				Severity	
	9	10	11	12	moderate	mild
Treatment (N=13)	4	3	1	5	5	8
Control (N=12)	3	2	4	3	1	11

Participating students had been previously identified by the school district as learning disabled (not necessarily reading disabled) and were either in a resource program (mildly handicapped) or in a special day class (moderately handicapped). Six of the 25 were moderately handicapped. It should be noted that the procedure for assigning students to the treatment and control groups was random (after matching according to the score for the literal factor in the reading comprehension pretest). However, using the random procedure,



five of the six moderately handicapped students were assigned to the treatment group:

### Treatment Environment

Three Apple II E computers were placed in two classrooms and one counseling center, at the Cupertino High School, Fremont Union High School District, California. Each computer was equipped with a color monitor, disk drive and mouse.

Students were scheduled to use the computers on a rotation basis over the course of a six-period day. Supervision of the computer training was by two or three AIR staff, who only intervened on those infrequent occasions when the program malfunctioned or if any student failed to enter their name correctly at the start.

Typically, students worked diligently on-task during their computer study even though classes were continuously in session in the two classrooms and there was a fair amount of activity (phone calls, counseling, et. ) in the counseling room.

### Description of the Experimental Treatment

The treatment consisted of the following:

- Initial practice using a disk that had no relevant text or content but required that each student learn
  - (a) the screen format
  - (b) where the story would appear (lower part of screen)
  - (c) where questions and directions would appear (upper part of screen)
  - (d) where feedback would appear (in a temporary memo window overwriting the story text)
  - (e) where the scoring and cumulative progress status would appear (presented as colored squares forming a line across the middle of the screen, together with a detective fee "earned" to that point)
  - (f) how to use the "HINT" button to obtain additional information as needed (the HINT button was also automatically activated after a time-delay)
  - (g) how to use the "DONE" button, signifying the end of study for a particular day (automatically marking the restart position for subsequent study periods)
  - (h) how and when to use the n and b keys to advance to the Next page or Back to the prior text page (used in

passages where text material extended beyond the space available in the text window)

- (i) how and when to use the return key and spacebar to initiate the program and advance it from lesson to lesson
- (j) how to turn on the computer, handle the disks, and use the disk drive

- Detective Story #1--The Case of the Missing Brother

- The story deals with the disappearance and finding of a younger brother while visiting Disneyland. There is a "reward" of \$100 (20 questions).
- The story begins with "easy" questions (Mark my brother's name.) and moves toward precise, literal questions (When did Jim first know that he was lost?).

- Detective Story #2--The Case of the Sea Queen

- The story deals with the disappearance and finding of a "ghost ship," the Sea Queen. The story offers a reward of \$120 (24 questions).
- The story includes items in which the fact and the question are transformed, (He watched the....; What did he see?) and awareness of implicit facts (How many people were in the car?).

- Detective Story #3--The Case of the Missing Bicycle

- The story deals with the disappearance and finding of a missing bicycle. It offers a reward of \$115 (23 questions).
- The story includes items requiring strict attention to the timing of events (John's bike was last seen at: 11: 20, 11: 30, 11: 45, 11: 46) and moves toward inference based on clues (John's bike was probably at: the fire department, the police station, the library, his home)

The Wordsworth program allowed each student to interrupt study at the end of each class period and resume study at the same point in the story on the next day. This feature made it possible for slower students to complete the

stories without retracing their steps through the lesson material. Allowing for absences, most students completed the training (practice) lesson and the three stories in less than four class periods.

The computer program automatically kept track of student performance on each item for each detective story and logged elapsed time as well. At the conclusion of the experimental study printouts were made of each student's responses. These print-outs detailed every action taken (e.g., key presses) and every item displayed (e.g., text highlighted) for all three stories.

## Results

Not surprisingly, most of the students were glad to try the computer program. As mentioned previously, considerable attention had been paid to the way in which the students would interact with the Wordsworth software and the interface was simplified based on pilot testing. Accordingly, students did not find it frustrating to use the modified screen display nor the mouse and simplified keyboard interface.

They quickly learned and observed the rules for operating Wordsworth as presented in the specially developed training program. The observed performance of the students on the main treatment (the three different stories) is summarized below in Table 15a.

Table 15a. Study time for students exposed to the Wordsworth software.

<u>Study Time</u> (minutes)	<u>Story 1</u>	<u>2</u>	<u>3</u>
Low time	15	15	11
High time	43	53	43
Median	26	22	20
Mean	26.3	27.1	22
N (combined groups)	25	23*	24**

\* Time data on two cases not saved on disk

\*\* Time data on one case not saved on disk

It was clear that each of the stories required less than a half hour of study time for most students. About 75 minutes overall was the mean time for exposure to the treatment. This is an important consideration because it means the combined amount of exposure to training is quite small given the desired outcome of improving students' comprehension ability.

It was noted that students were attentive to the screen. The deliberateness of their reading and searching for correct answers indicated a desire on their part to get high scores (earn high reward money on the computer screen) during their computer study. This was reflected in the attained scores as shown in Table 15b.

Table 15b. Accuracy of study on each story for students exposed to the Wordsworth software.

<u>Accuracy</u>	<u>Story 1</u>	<u>2</u>	<u>3</u>
Maximum score possible	100	120	115
Low score	72	61	73
High Score	100	118	115
Median	95	109	107
Mean	92.5	105.5	105.9

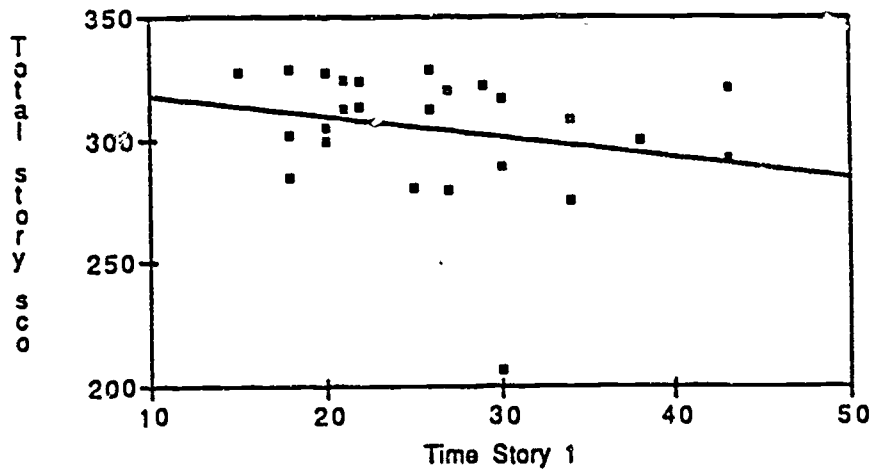
The relationship was examined between the speed of completing the stories and the total score attained in the first story. Figure 3 shows a regression plot and associated statistics for all students exposed to the treatment. Although it was not significant, there was a slight tendency for the students who took less time to have higher total story scores.

Students were asked to evaluate the three stories after they completed all three. Most of them preferred the second story, which concerned the finding of a "ghost ship." When asked why, they gave varied responses which generally suggested that it had a higher interest level. We speculate that the mysteries solved in stories one and three (a lost brother and a lost bicycle) may have been perceived by these secondary students as "a little young."

Simple regression was used to examine the relationship between the total score earned in the three stories and the performance on the reading comprehension test after computer study. Figure 4 shows a strong positive relationship ( $p < .02$ ) which indicates that the same students do well on Wordsworth activities and on the standardized comprehension subtest.

Students participating in the study were drawn from grades 9, 10, 11, and 12. The question was considered as to whether, following Wordsworth study, the students were comprehending at, above, or below grade level as measured by the Stanford Achievement Test, comprehension subtest. At the time of the posttest all but three of the students were still exhibiting a level of reading comprehension *below* their school-assigned grade levels (though somewhat *higher* than they had on the pretest). (See Figure 5.) The three who did score

Figure 3. Relationship of study time on story 1 to attained total story scores



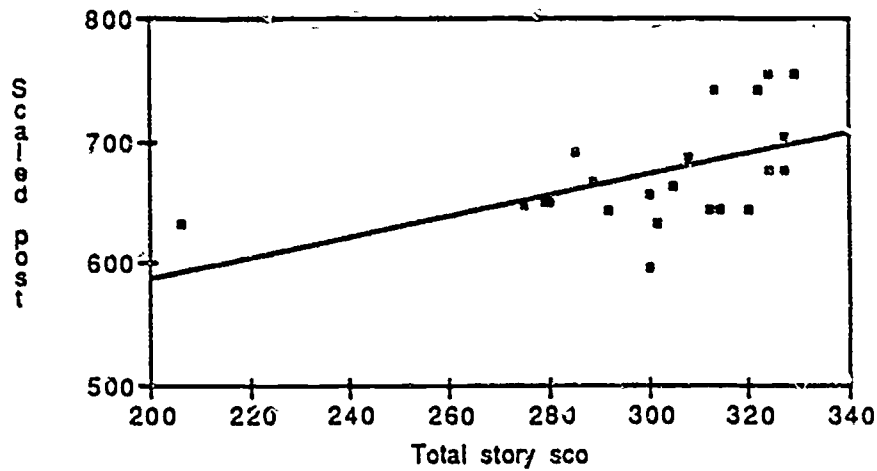
Dependent Variable: Total story sco

Variable Name	Coefficient	Std. Err. Estimate	t Statistic	Prob > t
Constant	325.586	19.112	17.035	0.000
Time Story 1	-0.821	0.699	-1.175	0.252

Source	Sum of Squares	Deq. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	951.979	1	951.979	1.380	0.143
Error	15868.021	23	689.914		
Total	16820.000	24			

Coefficient of Determination (R<sup>2</sup>) 0.057  
 Adjusted Coefficient (R<sup>2</sup>) 0.016  
 Coefficient of Correlation (R) 0.238  
 Standard Error of Estimate 26.266  
 Durbin-Watson Statistic 1.550

Figure 4. Relationship of total story scores to scaled posttest scores



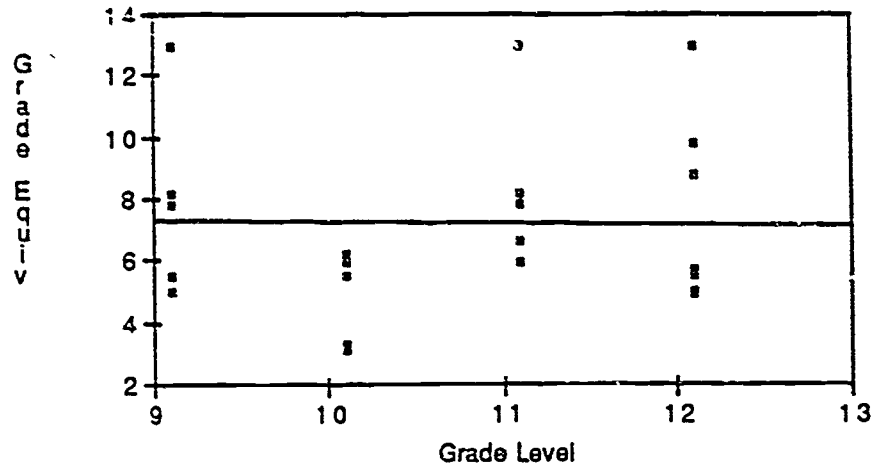
Dependent Variable: Scaled post

Variable Name	Coefficient	Std. Err. Estimate	t Statistic	Prob >  t
Constant	418.047	94.583	4.423	0.000
Total story sco	0.632	0.311	2.736	0.012

Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob > F
Model	11842.025	1	11842.025	7.488	0.012
Error	33210.584	21	1581.456		
Total	45052.609	22			

Coefficient of Determination (R<sup>2</sup>) 0.263  
 Adjusted Coefficient (R<sup>2</sup>) 0.228  
 Coefficient of Correlation (R) 0.513  
 Standard Error of Estimate 39.768  
 Durbin-Watson Statistic 1.308

Figure 5. Relationship of assigned grade levels to grade equivalent scores



Dependent Variable: Grade Equiv

Variable Name	Coefficient	Std. Err. Estimate	t Statistic	Prob > t
Constant	7.814	5.452	1.433	0.165
Grade Level	-0.051	0.508	-0.101	0.921

Source	Sum of Squares	Deg. of Freedom	Mean Squares	F-Ratio	Prob>F
Model	0.095	1	0.095	0.010	0.921
Error	214.820	23	9.340		
Total	214.914	24			

Coefficient of Determination (R<sup>2</sup>) 0.000  
 Adjusted Coefficient (R<sup>2</sup>) -0.043  
 Coefficient of Correlation (R) 0.021  
 Standard Error of Estimate 3.056  
 Durbin-Watson Statistic 1.656



at grade equivalents higher than their school-assigned grades, tested at the high school level, shown as grade 13 in the figure.

#### First analysis: Main Effect with Paired Control and Treatment Groups.

Students were paired (matched according to the raw scores for the literal factor on the comprehension subtest) and randomly assigned to treatment and control groups. As shown in Table 16, based on raw scores for the matching criterion, the treatment and control groups were very much alike ( $p < .84$ ) at the time of the pretest. When comparisons were made between the treatment and control groups at the time of the posttest, again using the raw scores on the literal factor, no significant differences were found ( $p < .34$ ). This would seem to indicate that no main effect was obtained for the Wordsworth treatment insofar as the matching criterion was concerned.

The Stanford 7 Plus Norms Book provides scaled scores only for the comprehension subtest (allowing direct comparison across alternate test forms) and does not separately report on the literal factor. The literal factor comprises 30 of the comprehension items, while the factor measured by the remaining 30 items taps inferential skills in reading. When the scaled comprehension scores were analyzed it was found that the pretest scores were still very similar for the two groups ( $p < .90$ ). As shown in Table 17 the posttest scores were still not significantly different ( $p < .15$ ) though they were in favor of the treatment group.

At least three alternative explanations exist for the *seeming* lack of significant main effect. First, the relatively short exposure to Wordsworth (with an average study time of less than 75 minutes) may have not been enough to bring about the desired change.

Second, there may have been some "learning" on the part of control students who were present in the classrooms while the treatment group was studying the computer materials. This does not seem likely since the positioning of the computers was such that direct viewing by an observer was only possible if he or she stood directly behind the student at the keyboard. Whenever this was observed by the staff it was terminated, but it cannot be stated with assurance that it did not take place when staff were not present.

Third, the groups might not have been as well matched as indicated by the pretest scores. This would raise questions about the appropriateness of the group comparisons. Recall, for example, that in spite of random assignment five of the six "special day" students were in the treatment group. Their ability to benefit from the Wordsworth experience may not have been as high as the learning disabled students who were classified as resource students.



Table 16. Pretest comparison of treatment and control groups using raw scores on the "literal" matching criterion

Paired Samples...

Variable:	C Literal Pre	T1 Literal Pre
Mean:	21.000	20.667
Std. Deviation:	3.766	3.869
Paired Observations: 12		
t-statistic:	0.217	
Degrees of Freedom:	11	
Significance:	0.832	

Table 17. Posttest comparison of treatment and control groups using scaled scores on the comprehension subtest

Paired Samples...

Variable:	C Scaled post	T Scaled post
Mean:	650.385	665.077
Std. Deviation:	26.588	42.970
Paired Observations: 13		
t-statistic:	-1.563	
Degrees of Freedom:	12	
Significance:	0.144	

When the scaled scores for the special day and resource students are compared a picture emerges that shows significantly different populations. The special day students tended to be older (mean age = 17 years and 7 months) than their counterparts in the mainstreamed, resource program (mean age = 16 years and 9 months). As shown in Table 18 and Table 19, the special day class students were lower on the literal raw scores ( $p < .04$ ) and on the scaled comprehension scores ( $p < .01$ ). In other words, the cards were inadvertently "stacked" against a treatment effect in the group comparison.

#### Second analysis: Main Effect with Students as Their Own Controls.

After the posttests were administered to both the treatment and control groups, the control group students were themselves exposed to the Wordsworth materials. Thus they became a second treatment set and another posttest was administered to them following their treatment.

When the scaled scores for the control group were compared prior to administering the Wordsworth treatment to the control group, no significant difference was found ( $p < .23$ ). This was expected because we are merely comparing two pre-treatment administrations of the comprehension criterion test. However, as shown in Table 20, when the scaled scores are compared after the control group had received Wordsworth training, significant differences were noted ( $p < .01$ ).

As shown in Table 21, when comparisons were made between the pre- and posttest scaled scores for individuals receiving the first treatment only (the original treatment group, which included five of the six special day students) there was an upward shift in performance on reading comprehension, but not a significant difference ( $p < .15$ ).

Finally, a comparison was made of the pre and post comprehension scores for the combined groups after each group had been exposed to Wordsworth materials. (See Table 22.) In this comparison a substantial difference was also noted ( $p < .01$ ).

These data show that a definite increase in comprehension skills was noted for individuals exposed to the Wordsworth treatment, though the treatment does not seem to be as effective for lower ability students such as one might expect to find in the special day class category.

#### Summary

There was evidence that the Wordsworth software did help to raise the comprehension skills of the learning disabled students in secondary level

Table 18. Comparison of Special Day and Resource students using raw "literal" scores used as matching criterion

Independent Samples...

Variable:	Literal SD	Literal main pr
Mean:	19.333	21.800
Std. Deviation:	3.077	3.458
Observations:	6	20

t-statistic: -2.202  
 Degrees of Freedom: 24  
 Significance: 0.038

Table 19. Comparison of Special Day and Resource Students using scaled scores on the comprehension subtest

Independent Samples...

Variable:	Comp SD	Comp main
Mean:	32.000	44.750
Std. Deviation:	5.933	8.724
Observations:	6	24

t-statistic: -3.368  
 Degrees of Freedom: 28  
 Significance: 0.002

Table 20. Gains in comprehension by individual students in the "control" group after exposure to the Wordsworth treatment

Paired Samples...

Variable:	C Scaled post 2	C Scaled post 1
Mean:	689.900	665.400
Std. Deviation:	46.443	41.578
Paired Observations:	10	

t-statistic: 3.346  
 Degrees of Freedom: 9  
 Significance: 0.009

Table 21. Gains in comprehension by individual students in the "treatment" group, including special day students

Paired Samples...

Variable:	T Scaled post	T Scaled pre
Mean:	664.846	650.385
Std. Deviation:	43.066	26.588
Paired Observations:	13	

t-statistic: 1.541  
 Degrees of Freedom: 12  
 Significance: 0.149

Table 22. Gains in comprehension for all students after study of Wordsworth

Paired Samples...

Variable:	Comb Scaled pos	Comb Scaled pre
Mean:	675.870	652.435
Std. Deviation:	45.253	25.536
Paired Observations:	23	
t-statistic:	3.442	
Degrees of Freedom:	22	
Significance:	0.002	

resource programs. However, there is less reason to expect that the software would be of as much help to the more severely learning disabled who are in special day classes.

## Implications for Future Research

## Implications for Future Research

Each phase of study in this multi-year project led to important findings that inform the use of technology for special education students.

In the early stages of the project our review of the literature led us to hypothesize a hierarchical model in which lower order skills were considered as preconditions for higher order functioning. Our reasoning was that efficient reading performance for instructional or leisure purposes was dependent on efficient underlying cognitive skills. In accordance with the research literature on automaticity in reading, it was further reasoned that efficient cognitive processing was possible only if the perceptual enabling skills were "automatic" and did not require an inordinate cognitive-capacity demand. Similarly, the assumption was made that this "effortless," automatic perception would be difficult to attain if the image presented to the eyes was improperly fused or if fatigue resulted from inefficient binocular accommodation.

Research within the CREATE project and a separate, but allied, vision skills project was designed to shed light on these relationships and to explore the potential for using computer technology to assist learning (reading) disabled youngsters in bridging these hierarchical skill levels.

### Implications concerning reading related visual, perceptual and cognitive processing skills

Our findings suggest that substantial progress can be made in developing students higher order reading skills by addressing their lower order needs in cognitive processing skills, perceptual enabling skills, and (as shown in a related project) neuromuscular vision skills through *carefully designed, special purpose* computer software.

The use of this type of special purpose software is seldom seen in the schools and generally is not being developed by software firms. This represents, in our judgement, a *major gap* in the tools that teachers should have to work with as they attempt to help reading disabled youngsters.

The experimental phases of the CREATE study focused on determining whether this kind of software (TurboScan and Wordsworth) could have an impact and what features were important to have in software that is aimed at the learning disabled. The limited data from this study shows the potential for *significant impact on elementary level students in the perceptual enabling skills*

*less*, but students without any decoding skills may not be benefited until these are developed by the teacher. Similarly, a strong impact on secondary level students was shown at the cognitive processing level, though again not as much for students who are more severely reading disabled.

In terms of software features, we were unable to experimentally identify any specific features that are essential to success of the software. We suspect that a critical mass of "good" instructional design features is important but we can only suggest the appropriate principles of instructional design that have been known for some years in education and which guided our own development of the research tools. These principles involve clear directions, an engaging screen display that is free of irrelevant distractions, provision for feedback or knowledge of results to the student, and challenging, relevant content set at an appropriate level of difficulty for the learner.

#### Implications concerning software/hardware design

In terms of *student/machine interface design*, we are able to demonstrate convincingly that "less is better." That is, in terms of software display the less the learner has to know and remember to "operate" the software the better. In addition, the motor skills and manipulative acts required to enter responses or control the stimulus on the screen must be kept simple. The task set before the designer of configurations of hardware/software for the disabled is to ensure that the required student/machine interaction does not become a source of frustration or distraction.

For example, in our TurboScan study we learned that "press any key" entry is successful, even when timed responses must be made. In our Wordsworth study we learned that *mouse input is easier than joystick input or keyboard input when care must be taken to direct the cursor* in order to activate specific areas on the screen.

Finally, although it was not specifically included in our experimentation, our research leads us to believe that *the computer may be the ideal tool for assessing students' existing skill levels in reading and diagnosing deficit areas in underlying skills*. We refer here to the hierarchical skills presented in the CREATE model presented in an early chapter of this report. We believe that the development of such diagnostic computer tools should be one research and development area that receives priority funding by OSEP.

#### Implications for the evaluation, selection and integration of software

Currently, the pattern of software use in the schools seems to emphasize software that has been "proven" either by frequent school purchase or because



of word of mouth testimony. Subscribed "reviews" of new software by software review firms or in articles in magazines and newsletters also leads to some purchases as does "the reputation" of specific software development firms. Our study did not lead us to believe that much evaluation and selection is approached objectively and formally by the schools. This may be understandable in terms of the relative cost of the software in contrast to the time it takes to do a careful evaluation. However, this argument begs the question of what schools are all about -- the presentation of learning opportunities that are *appropriate* for the different students in the schools.

We believe that efficient evaluation and selection procedures are possible and should be put in place in each school district. They should *help teachers identify the special purpose software that handicapped students really need* rather than only adopt existing software that deals with academic performance skills, and which is primarily targeted at the mainstream populations of students. The prototype evaluation and selection form developed in CREATE (shown in Appendix B) can serve as a start in that direction.

When standard software is going to be used with the learning disabled (and with other students as well) it makes sense to *integrate the computer experience with the regular classroom program* rather than treat it as a separate, unrelated "reward." Toward this end, *more adaptive workbooks should be developed* along the lines of the Factory and Reader Rabbit Workbooks that were jointly developed and field tested with educators during the CREATE project.

## Appendix A

## SCOPE AND SEQUENCE

### Enabling Skill A (Disk A: screens 1-56)

To identify the attributes of symbols and characters that differentiate them from each other, and to make rapid discriminations between shapes that are similar.


Level 1. Recognize and differentiate forms based on gross characteristics.

Concepts: Distinguish straight, curved; open, closed; large, small; diagonal, vertical, horizontal.

Example: I C; o c; O o; / l -

Level 2. Recognize and differentiate forms based on directionality and laterality.

Concepts: Distinguish top, bottom; left, right; up, down.

Example: 

Level 3. Discriminate features based on component analysis.

Concepts: Less than, more than; part of, all of; same, opposite.

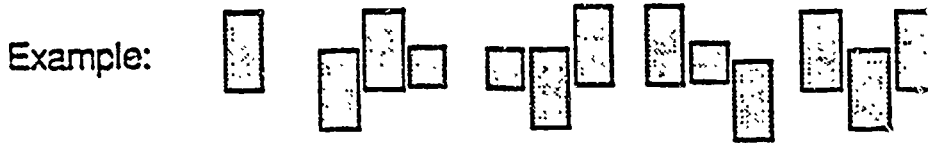
Example: n, m; F E; R P; p b

Enabling Skill B (Disk B: screens 1-63)

To distinguish particular symbols or characters, and patterns of symbols or characters, when presented in a background field of distractors.

Level 1. Perceive the form and position of a symbol or character in order to compare it to a specific target.

Concept: Relative shape and position on a horizontal line.



Level 2. Perceive the form and position of a character in order to compare it to a target character in a particular orientation.

Concept: Maintain relative orientation of significant feature.

Example: b bpb ddp pdb dbp

Level 3. Perceive a set of characters as a unit within the field.

Concept: Maintain form constancy regardless of field position.

Example: ch change reach cheap catch

Enabling Skill C (Disk C1: screens 1-70; Disk C2: screens 1-20)

To distinguish selected features of words that contribute to sight recognition (initial, character, word shape, and word length).

Level 1: Recognize initial and ending letter combinations.

Concept: Quickly classify words by their beginnings.

Example: Beginning wh--Where were those when I wanted them?

Level 2: Recognize the ascender and descender patterns of particular words.

Concept: Quickly classify words by the presence or absence of ascenders and descenders in character sets.

Example: Ending ght

I was right to hold tight

Level 3: Distinguish the relative lengths of words.

Concept: Differentiate words based on perceived length.

Example: Find three letter words

\_\_\_ You and I went to the store.

Enabling Skill D ( Disk D1: screens 1-44; Disk D2: screens 1-31)

To recognize particular combinations of characters as being meaningful.

Level 1: Distinguish sets of characters that constitute a target word when presented within a field of words.

Concept: Identify specific words by sight.

Example: Find through

Go through the door and then through the hallway.  
Be sure to call when you are through.

Level 2: Distinguish acceptable and unacceptable letter patterns within a field.

Concept: Proofread for errors.

Example: He siad that was OK, dut she said it was not.




Level 3: Apply visual memory to silent and oral reading.

Concept: Combine word beginnings and endings appropriately.

Example: Find and say the words that start with ex.

\_\_periment \_\_peg \_\_plain \_\_tra

## Skill Categories Used in TurboScan Study 3

Skill Category	Instruction line	Sample from Screen
Initial Letter	"Find each word that starts with b."	go he do by if of oh it be had but how did big day old
Initial letter combination	"Find each word that starts with st."	stop turn tree ship stay clay trees still short shows stand
Length	"Find words as long as the dashes"	--- sun so song sea sing cut city cat call care
Length and initial letter	"Find words like this."	s__ so she safe said saw salt sad school seeds
Length and initial letter combination	"Find words like this."	st___ stand stay strong story stop study string step
Shape	"Find words with this shape."	 to at be go am by on he my oh of do
Shape and initial letters	"Find words like this."	b  barn bark bear bird f  fish fine fast form
Comprehension	"Find all the animals."	door big horse table pig dog was chickens chair
Find and Say	"Find and say she."	She said that is one can. Is this what she said? She said that

## SCOPE AND SEQUENCE

### Cognitive Skills

To read with comprehension.

#### Level 1. Attend to facts and details in narrative text.

**Concept:** Identify specific information in response to a question.

**Example:** Joe went shopping at the supermarket. He had six dollars in his pocket. He wanted to buy some milk, bacon, a toothbrush, crackers and gum. He would only buy the gum if he had at least 45 cents left after he bought the other things. The milk was \$1.69, so he bought one bottle. The bacon was \$2.15. He saw a sale sign in the toothbrush section and got one for only 59 cents. There were lots of crackers to choose from, and he chose some cheese crackers for \$1.19. The total came to \$5.62.

How many items did Joe buy at the store?

#### Level 2. Maintain a logical order in a sequence of events in narrative text.

**Concept:** Identify relationships between a series of activities.

**Example:** The peace conference was very successful. A week before the peace conference government officials had met to discuss matters that most concerned the leaders of their countries. A list of topics was prepared and sent to all the leaders who would be attending. When the conference began each leader already knew what the other leaders would be discussing, so there were no surprises. After each leader spoke there was time for responses by the other leaders. The last thing they did was to sign the agreement that was reached.

How did the leaders know what would be discussed at the conference?



Level 3. Draw inferences based on the content and context of information.

**Concept:** Apply reasoning to form conclusions based on facts supplied.

**Example:** Tears came to Mary Ann's eyes. The house looked smaller than she remembered it. She had been away so long she had forgotten how the place looked. As she glanced around she remembered little things. There was the porch her mother and dad used to sit on in the evening. There was the back yard where she played with the puppies. The swing that hung from the apple tree was gone now, but she could remember how much fun it was to be pushed by her older brother. Mary Ann wasn't crying because she was sad, but because coming back was so important to her.

What place did Mary Ann come back to?

Level 4. Identify the main idea in narrative text.

**Concept:** Combine narrative information to form higher level abstractions.

**Example:** Young people today are able to do more things, go more places, and have more fun than they did when I was growing up. Part of the reason is that so many of them have cars to get around in. But I read the other day that they also have the most accidents with cars. If they knew how one accident could change their lives forever, I wonder if it would make them more careful. I hope so, because one quick mistake is all it takes to hurt someone they love or even themselves.

What is the main idea in this paragraph?

Appendix B

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CREATE : The Center for Research and Evaluation in the Application of Technology to Education

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# Software Evaluation and Selection Form

Field Test: October 1985



AMERICAN INSTITUTES FOR RESEARCH  
IN THE BEHAVIORAL SCIENCES  
P.O. Box 1113: 1791 Arastradero Rd.,  
Palo Alto, CA 94302

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# Software Evaluation and Selection Form

## The Purpose of this Form

Educators everywhere are intrigued by the prospect of using computer technology in educationally sound ways to improve the teaching and learning process. A key to doing so, however, is ensuring that the software that is selected and used is of high quality and serves a specific purpose that is consistent with the instructional mission of the schools. This document will help in locating, selecting, and describing the software that schools may want to acquire and use. Moreover, it is designed to accommodate the instructional needs of special education students by differentiating between academic performance skills, cognitive processing skills, and the perceptual enabling skills essential to the development of understanding and appropriate behaviors by students. There are four sections to the form. Directions for completing them follow.

## I. Program-Source Data

**Who should complete this section:** This information can be filled out by clerical staff, classroom aides, or volunteers before the program is reviewed by faculty.

**How to complete this section:** Fill in the information as supplied with the software package. This information is usually found in the first few pages of the documentation.

## II. Program Evaluation

**Who should complete this section:** This section might be filled out by a designated reviewer representing the district or several districts. Typically, this would be a resource specialist.

**How to complete this section:** Circle a rating score of 0-4 for each item. If information or materials are not included but are applicable, circle a rating score of 0. If information or materials are not applicable, circle the X. To obtain an average rating score for each section, divide the sum of the rating scores by the total number of items rated 0-4. For example:

Supplementary Materials:	Not Applicable	Not Included	Rating Scale			
			0	1	2	3
Provides teacher worksheets	X	0	1	(2)	3	4
Provides instructor record sheets	X	0	1	2	(3)	4
Provides learner record sheets	X	(0)	1	2	3	4
Provides test materials	X	0	1	(2)	3	4
Provides technical activities	X	(0)	1	2	3	4

Sum of rating scores:  $\frac{7}{5} =$  Overall Average: 1.4

Add number of items that were rated 0-4: 5

## III. Appropriate Applications

**Who should complete this section:** Both regular and special education teachers should complete this section.

**How to complete this section:** Check off each skill that is either directly or indirectly taught by the program.

## IV. Summary of Evaluation and Selection Data

This is a simple transfer of key information for ready access.

# I. Program-Source Data

Completed by: \_\_\_\_\_  
Organization: \_\_\_\_\_

## A. Product and Source Description:

1. Program Name:	_____
2. Distributor Name:	_____
3. Address:	_____ _____
4. Telephone:	_____
5. Single Program _____ or Part of a Series _____	
6. Cost:	_____
7. Terms for Updated Versions:	_____
8. Back-up Policy: How many copies included?	_____
	Costs per copy _____
	Terms for multiple copies _____
	Hard disk version available? _____

## B. Hardware Requirements

1. Program runs on these microcomputers:	_____	_____	_____
	_____	_____	_____
2. Memory required:	_____		
3. Equipment requirements:	_____		
	_____		
4. Optional Devices:	_____		

C. Educational Objective:

1. Instructional Purpose:

Regular Instruction \_\_\_\_\_

Remediation \_\_\_\_\_

Enrichment \_\_\_\_\_

2. Suggested Grade/Ability levels: \_\_\_\_\_

\_\_\_\_\_

3. Presentation mode:

<input type="checkbox"/> Drill and practice	<input type="checkbox"/> Classroom management
<input type="checkbox"/> Educational game	<input type="checkbox"/> Information retrieval
<input type="checkbox"/> Problem Solving	<input type="checkbox"/> Authoring System
<input type="checkbox"/> Simulation	<input type="checkbox"/> Game (for fun only)
<input type="checkbox"/> Tutorial	<input type="checkbox"/> Testing

4. Specially relevant to special education students: \_\_\_\_\_

\_\_\_\_\_

D. Summary of Program Content:

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

# II. Program Evaluation

Completed by: \_\_\_\_\_  
 Organization: \_\_\_\_\_

## A. Instructional Design Features:

Instructional Strategy:	Not Applicable	Not Included	Rating Scale			
			Poor	Excellent		
Learner is informed of objective	X	0	1	2	3	4
Branches to adjust to learner's ability level	X	0	1	2	3	4
Gives hints to encourage correct answer	X	0	1	2	3	4
Instructor can adapt/modify program	X	0	1	2	3	4
Employs a sound theoretical base	X	0	1	2	3	4

Sum of rating scores:  ÷  = Overall Average:

Number of items that were rated 0-4:

Learner Control:	Not Applicable	Not Included	Rating Scale			
			Poor	Excellent		
Can control frame speed/movement	X	0	1	2	3	4
Can select activity	X	0	1	2	3	4
Can repeat any activity	X	0	1	2	3	4
Can get clues on-line	X	0	1	2	3	4
Can get help on-line, at all times	X	0	1	2	3	4
Can exit at anytime	X	0	1	2	3	4

Sum of rating scores:  ÷  = Overall Average:

Number of items that were rated 0-4:

Feedback/Reinforcement:	Not Applicable	Not Included	Rating Scale			
			Poor	Excellent		
Positive reinforcement is immediate	X	0	1	2	3	4
Incorrect responses are explained	X	0	1	2	3	4
Remedial loops are built in	X	0	1	2	3	4
Rewarded for correct responses	X	0	1	2	3	4
Daily assessment of performance	X	0	1	2	3	4
Continuous assessment of performance	X	0	1	2	3	4

Sum of rating scores:  ÷  = Overall Average:

Number of items that were rated 0-4:

## B. Quality of Individual Components:

Documentation:	Not Applicable	Not Included	Rating Scale			
			Poor	Excellent		
Useful teacher's guide information	X	0	1	2	3	4
Clear information for learners	X	0	1	2	3	4
Clear operating instructions	X	0	1	2	3	4
Clear instructional objectives	X	0	1	2	3	4
Clear instructions on how to modify program features/content	X	0	1	2	3	4
List of prerequisite skills	X	0	1	2	3	4

Sum of rating scores:

Number of items that were rated 0-4:

= Overall Average:

Supplementary Materials:	Not Applicable	Not Included	Rating Scale			
			Poor	Excellent		
Provides learner worksheets	X	0	1	2	3	4
Provides instructor record sheets	X	0	1	2	3	4
Provides learner record sheets	X	0	1	2	3	4
Provides test materials	X	0	1	2	3	4
Provides follow-up activities	X	0	1	2	3	4

Sum of rating scores:

Add number of items that were rated 0-4:

= Overall Average:

Program Operation and Presentation:	Not Applicable	Not Included	Rating Scale			
			Poor	Excellent		
Grammar/punctuation correct	X	0	1	2	3	4
Safeguarded against "crashes"	X	0	1	2	3	4
Text on the screen is readable	X	0	1	2	3	4
Graphics have instructional intent	X	0	1	2	3	4
Color can be controlled	X	0	1	2	3	4
Sound can be toggled on and off	X	0	1	2	3	4
Menu driven	X	0	1	2	3	4
Help available on-line	X	0	1	2	3	4

Sum of rating scores:

Number of items that were rated 0-4:

= Overall Average:



### III. Appropriate Applications

Completed by: \_\_\_\_\_

Organization: \_\_\_\_\_

#### A. Developing Enabling Skills Involving Perception

<p>1. <b>Discrimination</b></p> <p><input type="checkbox"/> features</p> <p><input type="checkbox"/> patterns</p>	<p>6. <b>Tracking</b></p> <p><input type="checkbox"/> left to right</p> <p><input type="checkbox"/> top to bottom</p>
<p>2. <b>Attention</b></p> <p><input type="checkbox"/> concentration</p> <p><input type="checkbox"/> alertness</p> <p><input type="checkbox"/> span</p>	<p>7. <b>Part-whole Relationships</b></p> <p><input type="checkbox"/> verbal</p> <p><input type="checkbox"/> graphic</p>
<p>3. <b>Classification</b></p> <p><input type="checkbox"/> grouping</p> <p><input type="checkbox"/> comparing</p>	<p>8. <b>Spatial Orientation</b></p> <p><input type="checkbox"/> laterality</p> <p><input type="checkbox"/> figure-ground</p>
<p>4. <b>Cue Identification</b></p> <p><input type="checkbox"/> searching</p> <p><input type="checkbox"/> differentiation</p>	<p>9. <b>Decoding of Letter Shapes</b></p> <p><input type="checkbox"/> typed or printed</p> <p><input type="checkbox"/> reversals/inversions</p>
<p>5. <b>Coordination and Integration</b></p> <p><input type="checkbox"/> visual/motor</p> <p><input type="checkbox"/> auditory/motor</p> <p><input type="checkbox"/> visual/auditory</p>	<p>10. <b>Decoding of Words</b></p> <p><input type="checkbox"/> letter combinations</p> <p><input type="checkbox"/> word length</p> <p><input type="checkbox"/> shapes (ascenders and descenders)</p>

#### B. Developing Processing Skills Involving Cognition:

<p>1. <b>Analytic Techniques</b></p> <p><input type="checkbox"/> in reading</p> <p><input type="checkbox"/> in math</p> <p><input type="checkbox"/> in science</p> <p><input type="checkbox"/> social studies</p>	<p>3. <b>Recall of Information</b></p> <p><input type="checkbox"/> chunking &amp; grouping</p> <p><input type="checkbox"/> mnemonic techniques</p> <p><input type="checkbox"/> rehearsal</p>
<p>2. <b>Understanding and Meaning</b></p> <p><input type="checkbox"/> vocabulary and definitions</p> <p><input type="checkbox"/> use of context</p> <p><input type="checkbox"/> comprehension</p>	<p>4. <b>General Purpose Thinking</b></p> <p><input type="checkbox"/> reasoning</p> <p><input type="checkbox"/> problem solving</p> <p><input type="checkbox"/> study strategies</p>

## C. Developing Performance Skills Involving Subject Matter

### 1. Reading

- speed
- whole word recognition
- phonics and blends
- comprehension
- other \_\_\_\_\_

### 2. Writing and Communication

- spelling
- punctuation
- capitalization
- word usage
- parts of speech
- organization of ideas
- syntax
- proofreading
- other \_\_\_\_\_

### 3. Math

- acquisition of facts
- number relations
- math operations
- problem solving
- logic
- graphing
- other \_\_\_\_\_

### 4. Science

- acquisition of facts
- observing and measuring
- interpretation of data
- formulating generalizations
- problem solving
- other \_\_\_\_\_

### 5. Social Studies

- acquisition of facts
- interpretation of data
- identification of concepts & issues
- evaluation of evidence
- formulating generalizations
- other \_\_\_\_\_

### 6. Vocational/Business

- career awareness
- work readiness
- technical skills
- other \_\_\_\_\_

### 7. Foreign Languages

- vocabulary
- rules and patterns
- comprehension
- other \_\_\_\_\_

### 8. Arts

- perception of visual properties
- analysis and interpretation
- expressive techniques
- creativity of design and form
- other \_\_\_\_\_

### 9. Computer Literacy

- programming
- graphics
- keyboarding skills
- other \_\_\_\_\_

### 10. Personal and Social Skills

- \_\_\_\_\_

### 11. Other Subject Matter

- \_\_\_\_\_

# IV. Summary of Evaluation and Selection Data

## Program-Source Data

A. Program Name: \_\_\_\_\_

B. Microcomputer(s) and Memory Required: \_\_\_\_\_  
 \_\_\_\_\_

C. Educational Objective: \_\_\_\_\_  
 \_\_\_\_\_

D. Summary of Program Content: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Program Evaluation

Instructional Design Features:	Rating	Score	Average
Instructional Strategy	<input type="checkbox"/>		
Learner Control	<input type="checkbox"/>		
Feedback/Reinforcement	<input type="checkbox"/>		
.....			
Quality of Individual Components:	Rating	Score	Average
Documentation	<input type="checkbox"/>		
Supplementary Materials	<input type="checkbox"/>		
Program Operation and Presentation	<input type="checkbox"/>		
.....			
Sum of rating score averages:	<input type="checkbox"/>		
	<input type="checkbox"/>		
	6	= Overall Program Average: <input type="checkbox"/>	

## Appropriate Applications

This program is best used to teach:

Enabling Skills     Processing Skills     Performance Skills