AN INTELLIGENT COMPUTER-AIDED TRAINING SYSTEM (ICAT) FOR DIAGNOSING ADULT ILLITERATES: INTEGRATING NASA TECHNOLOGY INTO WORKPLACE LITERACY

Final Report

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ABSTRACT

An important part of NASA's mission involves the secondary application of its technologies in the public and private sectors. One current application being developed is the The Adult Literacy Evaluator, a simulation-based diagnostic tool designed to assess the operant literacy abilities of adults having difficulties in learning to read and write. Using ICAT system technology in addition to speech recognition, closed-captioned television (CCTV), live video and other state-of-the art graphics and storage capabilities, this project attempts to overcome the negative effects of adult literacy assessment by allowing the client to interact with a intelligent computer system which simulates real-life literacy activities and materials and which measures literacy performance in the actual context of its use. The specific objectives of the project are as follows: (a) To develop a simulation-based diagnostic tool to assess adults' prior knowledge about reading and writing processes in actual contexts of application, (b) to provide a profile of readers' strengths and weaknesses, and (c) to suggest instructional strategies and materials which can be used as a beginning point for remediation. In the first and development phase of the project, descriptions of literacy events and environments are being written and functional literacy documents analyzed for their components. Examples of literacy events and situations being considered included interactions with environmental print (e.g., billboards, street signs, commercial marquees, storefront logos, etc.), functional literacy materials (e.g., newspapers, magazines, telephone books, bills, receipts, etc.) and employment-related communication (i.e., job descriptions, application forms, technical manuals, memorandums, newsletters, etc.). Each of these situations and materials are being analyzed for its literacy requirements in terms of written display (i.e., knowledge of printed forms and conventions), meaning demands (i.e., comprehension and word knowledge) and social situation. From these descriptions, scripts are being generated which define the interaction between the student, an on-screen guide and the simulated literacy environment. The proposed outcome of the Evaluator is a diagnostic profile which will present broad classifications of literacy behaviors across the major areas of metacognitive abilities, word recognition, vocabulary knowledge, comprehension and writing. From these classifications, suggestions for materials and strategies for instruction with which to begin corrective action will be made. The focus of the Literacy Evaluator will be essentially to provide an expert diagnosis, and an interpretation of that assessment which then can be used by a human tutor to further design and individualize a remedial program as needed through the use of an authoring system.

INTRODUCTION

Secondary Applications of NASA Technology

As mandated by Congress, one of NASA's principal charters is to facilitate the transfer of its vast technological knowledge into the public and private sectors for the general benefit of the American populace. Further, NASA has taken a particular interest and lead in promoting educational programs and innovations which not only enrich American life, but also serve to maintain and sharpen this country's scientific and technological edge (Haggarty, 1990, Technology Utilization Office, 1991). The Adult Literacy Evaluator represents an important spinoff project which will bring to bear NASA's considerable expertise in artificial intelligence (AI) and intelligent computer-aided training (ICAT) upon the growing problem of adult illiteracy and diminishing workplace literacy skills. This project with its application of expert system technology to the diagnosis and evaluation of reading problems represents a significant advance over current computer-assisted instruction (CAI) in literacy which provides no intelligent feedback to either student or tutor. After a brief overview of some of the issues in adult literacy instruction, the following report will describe the current status of the project and its proposed development schedule.

Adult Literacy: A National Issue

While experts disagree on the exact magnitude of the problem of adult illiteracy both in the U.S. and elsewhere, there is no doubt that educators, industry executives and government officials are concerned about what seems to be a rising tide of workers who are ill-equipped to meet the requirements of an increasingly technological and information-based society. Not only does illiteracy impact a person's ability to participate fully in a democratic society, the cost of remedial education to U.S. corporations each year reaches into the billions of dollars annually (Barlow, 1991; Jennings, 1988). This expense coupled with the fact that the nation now spends more federal monies on education than on defense (U.S. Department of Education, 1991) presents an alarming picture which suggests that our current system of public elementary and secondary schooling may have reached a point of "diminishing returns" in preparing workers for jobs in an age where information is a primary commodity and its rapid and efficient management is of paramount importance.

In order to improve the quality of education and to ensure that America has a competent workforce in the 21st century, the President and the nation's governors identified in 1989 six national goals to be accomplished by the year 2000. In essence, these goals call for the participation of business and industry in education, the setting of national standards of achievement, and the elimination of illiteracy in the adult population. While the feasibility of this latter goal has been questioned (Mikulecky & Drew, 1991), the federal government's efforts to study adult learning and workplace literacy have intensified over the last few years with the establishment of the National Center on Adult Literacy at the University of Pennsylvania in October 1990 and by the recent passing of the National Literacy Act in July 1991 which will provide federal funds for the establishment of state literacy resource centers. Further, a new agency, the National Institute for Literacy, is in the development stage and will provide additional resources for research and evaluation of adult literacy programs (Lovell, 1991).

Workplace Literacy Assessment

Despite these widespread efforts to combat adult illiteracy and increase the quality of performance in the workplace, several problems present themselves to researchers and practitioners in this field. The first of these concerns the disparity between skills learned in school and those actually required on the job. Research has found that job site literacy materials not only are of a greater variety than those found in school, but are often more difficult. In addition, Mikulecky (1982) has found that in comparison to high school students workers actually spend more time reading on the job and perform higher level reading tasks such as self-questioning, summarizing or monitoring. Thus, one of the serious hindrances to an increased supply of competent workers is that traditional literacy instruction in school is very narrow and there is little guarantee that even the skills that are learned transfer easily to real-life reading and writing tasks.

Another area of concern is the lack of assessment instruments which adequately measure literacy ability as it manifests itself in real-world reading tasks. Although standardized tests exist which are commonly used in evaluating the progress of adult education programs, there is widespread consensus (cf. Askov, 1991) that these traditional pencil and paper tests lack content validity for indexing job site literacy skills and cannot reliably predict a person's actual reading and writing performance in the workplace. In an attempt to remedy this situation, the Department of Labor commissioned the development of the *Applied Tests of Literacy Skills* based upon the 1986 National Assessment of Educational Progress survey of young adults, ages 21-25. These tests use facsimile productions of newspaper articles, office memorandums job applications, tables, charts, etc. to simulate actual workplace materials and tasks. However, it remains to be seen if this non-situated, pencil and paper test can overcome the limitations of most psychometric measures of its type.

PROJECT DESCRIPTION AND STATUS

Project Overview and Objectives

The scope of the NASA Adult Literacy Evaluator aims at both incorporating real-life reading and writing tasks as well as providing through computer simulation actual situations encountered in the environment and workplace. The specific objectives of the project are to (a) develop a simulation-based, expert system diagnostic tool to assess adults' prior knowledge about literacy processes and materials in the context of their use, (b) to provide a profile of readers' strengths and weaknesses, and (c) to suggest instructional strategies and materials which can be used as a beginning point for remediation. The initial target population whom the project intends to serve is the two to six percent of the adult population whose facility with written language is extremely limited (Elkind, 1990). However, one assumption underlying the program is that even adults who've failed in school or on traditional pencil and paper tests of literacy skills still have considerable knowledge about written displays in the environment which are not tapped by present methods of testing. A fundamental premise of the project is that unless this prior knowledge about print in the environment is known, then corrective instruction will inevitably either over-or underestimate the adult's actual level of ability. In order to create these simulated literacy events, the project is in the process of experimenting with the following technologies: Closed-captioned television (CCTV), computerized speech recognition and production, live video, virtual reality and laser disk storage of video images. At present, all of the foregoing are being designed to run on a Macintosh IIci or better with touch screen and voice regulated response to be integrated as is possible.

Literacy Knowledge Base

, Range of components. The first step in developing the Adult Literacy Evaluator has been to identify the actual components of literacy that will be simulated and assessed. Drawing from the experience of literacy experts, reference materials and the professional literature in reading education, over 300 areas of literacy behavior have been categorized under six broad rubrics: (a) Aspects of metacognition, (b) word recognition, (c) vocabulary, (d) comprehension, (d) fluency, (e) writing, and (f) studying. Under each one of these major literacy topics, further subcategorizations have been developed in a logical hierarchy, subject to verification as the development process continues. Given the space limitations of this paper, it is not possible to display all of the 300 categories and their respective definitions. However, represented in Figure 1 below is a subset of components arranged under the topic of Written Language Awareness, one of the four subheadings under Metalinguistic Awareness which in turn is one of four topics under Aspects of Metacognition. Written language awareness is further subdivided into knowledge about written conventions, written symbols (graphemes), word boundaries, print orientation and direction, sentence boundaries and the relationship between different kinds of pictorial displays and the text in which they are embedded. Each of these topics in turn have further breakdowns into the specific graphic symbols which appear in written materials and the conventional processes or page formats which are used to render these written features into the intended meaning of the respective document.

Concepts assessed. Coupled with each component displayed in the tree diagram and representing the knowledge base of the system are definitions which outline the parameters of what each node means in terms of specific assessment. These definitions form the basis of the expert system diagnosis and interpretation which will be relevant as the subject proceeds through the simulated settings and literacy events as constructed by the program. An example of definitions is displayed in Table 1 for the major topic of Metacognition, the subheading Metalinguistic Awareness and for some of the components under Conventions previously represented (see Fig. 1). Presently, initial definitions for over 100 areas under Metacognition have been written and are currently undergoing revision and refinement. Additional descriptions of the knowledge base for the other six major literacy areas are yet to be completed.

Literacy Environments

Graphic displays. Although most of the estimated 30-60 million adults reading below the eighth grade level in this country consistently fail on school-based tests of reading and writing, they do not lack knowledge about the written environment and oftentimes manage adeptly to either cope with the level of knowledge that they have or to learn how to use others' knowledge for their benefit. The intent of the Adult Literacy Evaluator is to produce computer-based simulations of everyday and workplace literacy situations where print has a ubiquitous presence and give these adults an opportunity to display the knowledge that they have in the context in which they apply it. Some of the literacy documents intended for use include, but are not limited to, interactions with environmental print (e.g., billboards, street signs, commercial marquees, storefront logos), functional literacy materials (e.g., newspapers, magazines, telephone books, TV Guide, bills receipts, etc.) and employment-related communication (for instance, job descriptions, application forms, technical manuals, flyers, newsletters, memorandums, etc.). The range of the print in these environments will vary from simple one or two word signs to paragraphs. Examples of text to be used in the simulations are depicted in Figure 2.

Literacy scenarios. Unlike most testing situations where the knowledge assessed is completely out of context, the Literacy Evaluator will take subjects through a series of natural literacy activities encountered on common excursions in the environment. This type of assessment of environmental print knowledge and coping skills is not unlike a case study approach to remediation and diagnosis where the clinician or tutor accompanies an illiterate adult in a variety of situations and observes how the person negotiates encounters with others where written language is normally involved. Three "vignettes" currently being developed are a walk through a mall, a grocery store and a tour of NASA itself is being considered. Other actual job site situations are planned as well. In each one of these scenarios, several types of encounters with print are possible. At each one of these encounters, a "script" is being written in which the subject in some instances will converse with an on-screen guide who may, as a clinician would, ask a series of questions such as "What does this sign tell us?" "What symbols do you recognize?" "Where do you think it says, 'No Parking?'" In another type of encounter, such as with an ATM machine, the person will need to respond to the written screen prompts either by reading them aloud or simply pressing the right button in order to complete the task of getting money for some further encounter. Finally, in some instances, the subject may be directed to respond by using an electronic stylus to fill out an application form, write a check or complete an order form for a purchase. The goal of the scenarios developed is to simulate as many situations as possible where written language plays an integral role such that an accurate, in- context assessment might be made of the adult's full range of knowledge about and functioning with printed forms.

Graphical user interface and assessment. In order to have the widest possible range of response capabilities, the project is intending to incorporate along with the standard Macintosh interface, speech and handwriting recognition, touch-screen capabilities and voice recording. Each response of the adult will be classified, counted or evaluated by the appropriate assessment algorithm or AI program software. For instance, all of the print used in the scenarios will be classified as to its appearance on lists of basic words and the adult's response to each of these words will be monitored. Additionally, the use of neural networks may be used in the speech and handwriting recognition and fuzzy logic programming might be appropriate for determining whether a series of behaviors constitutes knowledge of a certain literacy domain. The eventual program output to a human tutor will involve not only the normal assessment areas such as would be gained by the administration of a diagnostic reading test, but also an interpretation of the person's knowledge of and concepts about written language displays as well as their behavior with specific print forms.

It is this latter knowledge, in particular, that is absent from traditional assessments. Tests routinely report results in the form of standard scores, grade or age levels or descriptive frequencies of words, letters, sentences, etc. that are right or wrong. What test results cannot provide is an interpretation of the relationship between scores or the reasons why a person responded this way or that. Thus, tutors working with adults with reading problems usually operate only on negative information, that is, what they don't know as revealed on non-situated, paper and pencil tests. Therefore, the purpose of the present project is to provide both *situated information* about a person's reading ability as well as *interpretations* regarding the person's performance and what concepts about written language would cause the person to respond in such a way.

Computing Platform

The research and development platform of the project is illustrated in Figure 3. While an early demonstration of the program made use of the VCR to incorporate live video, use of a digital video interface (DVI) board for use with a CD - ROM is faster for manipulating video. This technology in turn may give way to a new Apple System product call QuickTime, a software extension which would eliminate the need for extra hardware to compress video images. In addition, the current speech recognition system needs considerable processing power in the form of a workstation, something that would be too impractical and expensive in a commercial application. While the Macintosh can use a software system with an add-in board called Voice Navigator which allows the user to access menu items with voice commands, the system at present must be customized for every speaker. Further, the present technology of speech recognition computing systems is still at a relatively rudimentary stage, with no system being able to converse easily as would a human interlocutor (Smith, 1990). The project plan, therefore, is to incorporate the speech recognition component at the level of technology available and use it within whatever constraints are necessary. Finally, the intended delivery platform would consist of a Macintosh IIci or better with keyboard and mouse, a headphone and microphone setup, a large hard disk or writable CD - ROM and a software system which would handle the video features and speech recognition for multiple speakers. During the development phase, all of the above technologies are being evaluated for their utility in enhancing the demonstration of literacy concepts as well for their current stage of development and anticipated cost.

Development Schedule

The overall research plan and schedule specifies three phases for project completion given adequate funding: (a) Phase I - Development should be completed by Spring 1992, (b) Phase II - Field Test and Refinement would extend through the remainder of the year, and (c) Phase III - Commercialization would begin after January 1993. Currently, detailed planning with the development phase calls for a complete functional requirements document specifying the literacy concepts to be evaluated and the graphical user interface to be completed by early Fall of 1991. Following this, a detailed design document implementing the functional requirements is to be finished before the end of the 1991. Actual programming should then begin during the early months of 1992. Adherence to this schedule as mentioned is greatly dependent upon receiving the funding necessary to support the additional programmers and media specialists needed as well as to purchase equipment and software for development.

SUMMARY

The design of this project attempts to minimize the negative effects of past failures in school by allowing adults to interact with a sophisticated ICAT system, thus giving students some "psychological" distance between themselves and a human evaluator as well as providing an opportunity to demonstrate what literacy knowledge they possess in the actual context of its use. Further, the use of simulated environmental and workplace literacy settings also gives the Literacy Evaluator greater ecological validity than paper and pencil tests which measure literacy skills in isolation only. Finally, the true use of AI technology constitutes an advance over current computer-assisted instruction which is reduced to only the cataloging of information and which has no knowledge base from which to interpret learner characteristics.

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TABLE 1: DEFINITIONS OF LITERACY COMPONENTS

Literacy Topics

O Aspects of Metacognition

> Knowledge of one's own mental processes for acquiring, manipulating, and applying information derived from written sources. The ability to reflect upon and monitor one's own contents of "mind."

O Metalinguistic Awareness

> The ability to treat either oral or written language as an "object of thought," understanding that each language system is comprised of smaller units which have logical relationships among themselves as well as reference to objects both psychological and physical in the real world.

O Written-Language Awareness

> The ability to treat written language as an object of thought, recognizing that this system represents both oral language and meaning at the same time. Knowledge that written language is comprised of many smaller units each of which has a variety of invariant as well as relative features.

O Conventions

> Knowledge that the display of written language for the purpose of communication follows certain arbitrary rules which vary from language to language. These rules relate to all levels of the subunits of printed form.

O Capital

> Knowledge of the various functions of upper case letters such as
> (a) signalling the beginning of sentences,
> (b) designating proper names and adjectives,
> (c) indicating titles or specialized names,
> (d) referring to the Deity, and
> (e) using the pronoun I.

Written Language Awareness

Convention
- Capital
- Lower Case
- Italics
- Indentation
- Size and Font
- Headings
- Margins
- Letter Spacing
- Underline
- Double Underline
- Shading
- Boxing

Graphemes

Letters
- Names
- Sound
- Shapes
  - Upper Case
  - Lower Case
  - Orientation

Paralinguistic
- Punctuation
  - Comma
  - Period
  - Quotation
  - Exclamation
  - Semicolon
  - Colon
  - Apostrophe
  - Question Mark
  - Hyphen
  - Dash
  - Slash
  - Parentheses
- Logographs
  - Ampersand
  - Asterisk
  - Pound
  - Numerals
  - Percent
  - Dollar Sign
  - Degree
  - Mathematical Logographs

Word
- Letter Sequence
- Silent Letters
- Acronyms
- Abbreviation

Directionality - Orientation
- Directionality
  - Left-to-Right Line
  - Top-to-Bottom Page
  - Return Sweep Line
  - Left-Right Page
- Orientation
  - Top/Bottom Book
  - Letter Orientation
  - Line Orientation
  - Patterned Print
  - 3-D Print

Sentence Awareness
- Word Order
- First/Last

Picture-Text
- Cartoons
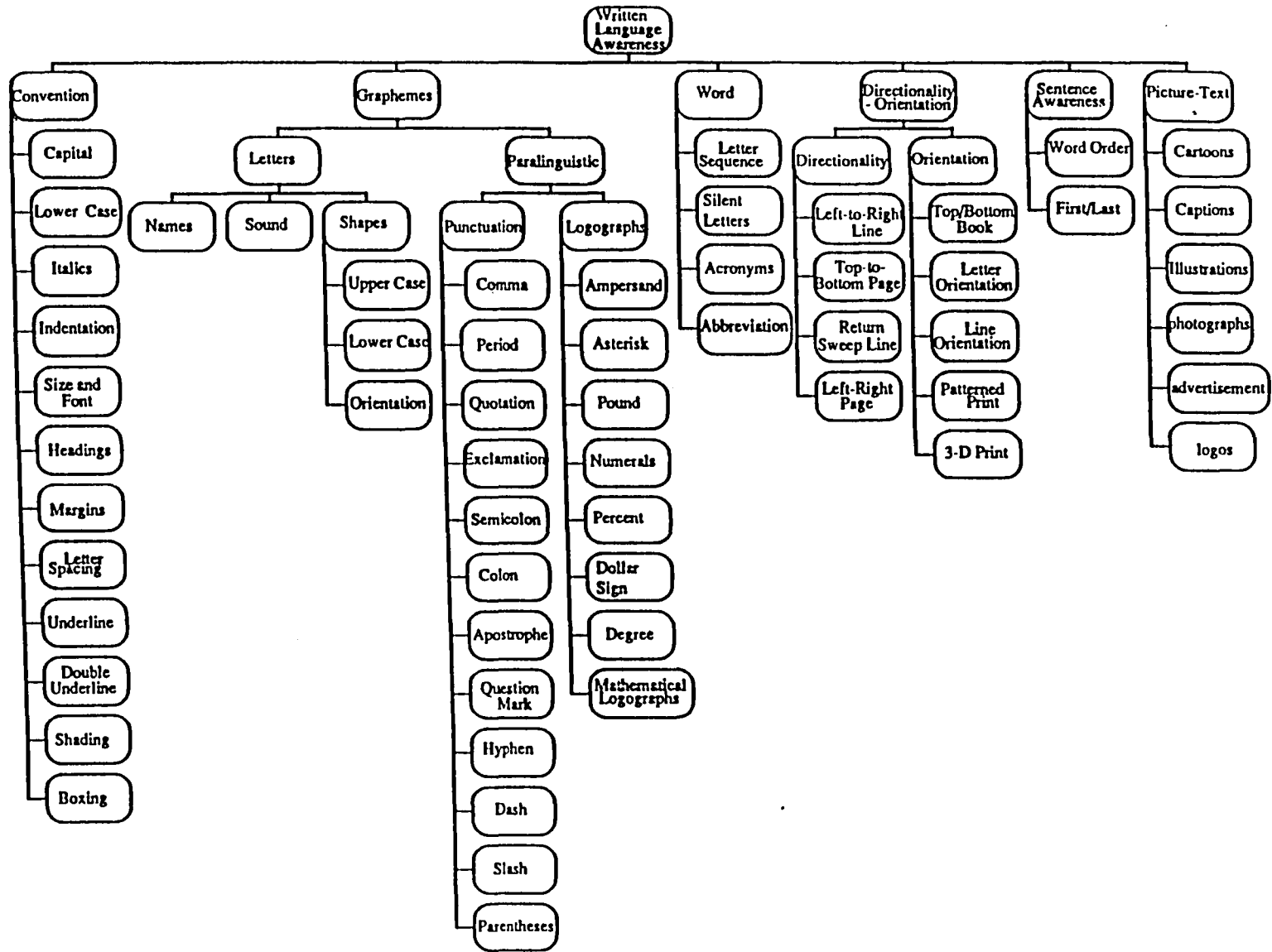- Captions
- Illustrations
- photographs
- advertisement
- logos

Figure 1: Components of Written Language Awareness
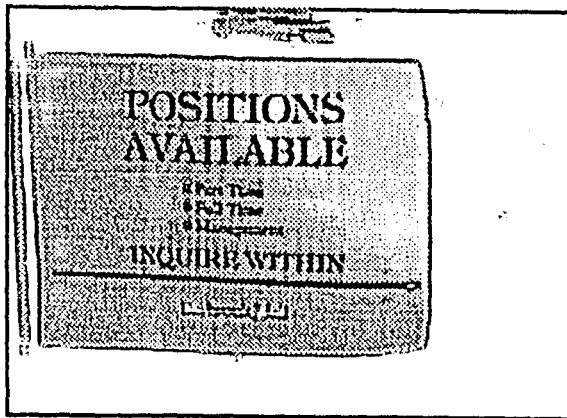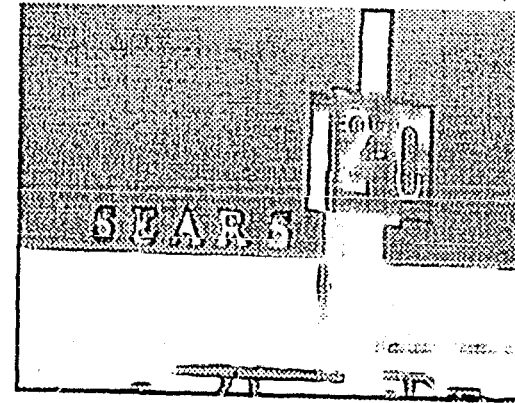
Figure 2. Examples of Environmental Print

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┌─────────────────────┐              ┌─────────────────────┐
│  Sun Workstation    │──────────────│   Macintosh IIci    │
└─────────────────────┘              └─────────────────────┘
   ┌──────────────┐        ┌──────────────┐    ┌──────────────┐
   │ SSI          │        │  RadiusTV    │────│   Monitor    │
   │ Speech       │        └──────────────┘    └──────────────┘
   │ Decoder      │        ┌──────────────┐    ┌──────────────┐
   └──────────────┘        │   PC VCR     │────│   Keyboard   │
        ┌──────────────┐   └──────────────┘    └──────────────┘
        │ Microphone   │   ┌──────────────┐    ┌──────────────┐
        └──────────────┘   │   Scanner    │────│    Mouse     │
                           └──────────────┘    └──────────────┘
                        ┌──────────────┐    ┌──────────────┐
                        │ MacRecorder  │────│  Hard disk   │
                        └──────────────┘    └──────────────┘
                        ┌──────────────┐    ┌──────────────┐
                        │  DVI Board   │────│   CD - ROM   │
                        └──────────────┘    └──────────────┘
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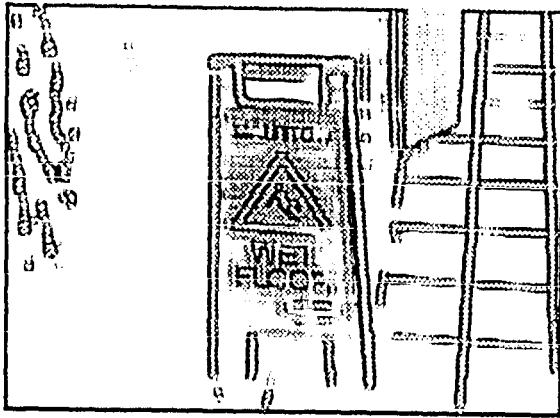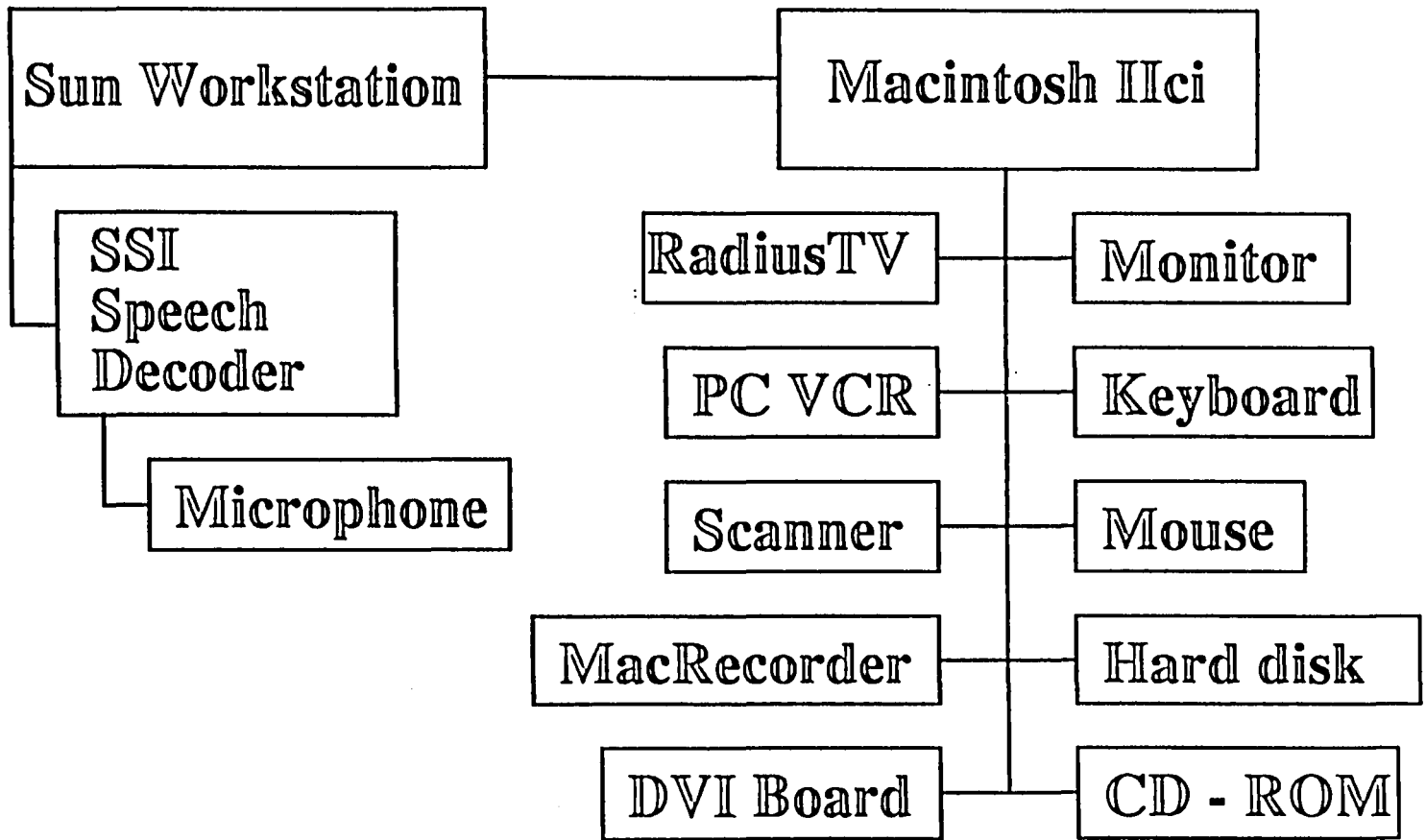
Figure 3.   Research and Development Platform