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AUTHOR	Francis, Larry
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ABSTRACT

This report examines the knowledge and experience gained from the implementation of three PLATO IV terminal devices: the microfiche system, the touch panel, and the random-access audio device. These devices, when attached to a PLATO IV terminal, serve to expand the types of input and output which can be managed by the terminal. For each peripheral device, the report documents the operating characteristics and their adequacy, the efforts and skills required to use the device, and alternatives which were considered. Also included are managerial considerations and some brief comparative data. As an evaluation report designed to aid decision makers, it contains no instructions detailing how to acquire, maintain, or operate these devices. It concludes that the touch panel is generally reliable, the slide selector is adequate but good microfiche are hard to produce, and that early audio devices are barely satisfactory. It is noted that on-site testing and maintenance are needed for reliable performance and that authors wasted time and money trying to take shortcuts. (Author/SC)

Computer-based Education Research Laboratory

University of Illinois Urbana Illinois

PLATO IV

TERMINAL PERIPHERAL DEVICES

LARRY FRANCIS

MTC REPORT No. 9 DECEMBER 1976

PLATO IV TERMINAL PERIPHERAL DEVICES

Larry Francis

COMPUTER-BASED EDUCATION RESEARCH LABORATORY
UNIVERSITY OF ILLINOIS, Urbana-Champaign

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". . . finally, we wish to apologize to our women readers for our use in this book, of a sexist grammatical convention. We were unable to find or invent a stylistically graceful substitute for the pronouns _he_ and _him_ in instances where we obviously mean to refer to both male and female."

Neil Postman and Charles Weingartner, _The School Book_, (New York, N. Y.: Dell Publishing Co., 1973), p. v.

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Abstract

This report examines the frustrations and rewards experienced by the users of three PLATO IV terminal peripheral devices: the microfiche system, the touch panel, and the random-access audio device. These devices, when attached to a PLATO IV terminal, serve to expand the types of input and output which can be managed by the terminal. During 1972-1976 these three devices were manufactured and delivered to PLATO users for the first time. Few guidelines and no previous experience lighted the path for the authors who attempted to employ these new devices to instruct their students. In this report are collected some of the empirical knowledges and results stemming from this initial implementation.

For each peripheral device, this study reports the operating characteristics and their adequacy, the efforts and skills required to use the device, and alternatives which were considered. Also included are managerial considerations and some brief comparative data. As an evaluation report designed to aid decision makers, it contains no instructions detailing how to acquire, maintain, or operate these devices.

Main conclusions were that the touch panel is generally reliable, the slide selector is adequate but good microfiche are hard to produce, and that early audio devices are barely satisfactory (and too few data are available for new models). It is noted that on-site testing and maintenance are needed for reliable performance and that authors wasted time and money trying to take shortcuts.

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Introduction

The versatility and usefulness of the basic PLATO IV terminal with keyset input may be considerably extended by the addition of several peripheral devices controlled by the terminal. The most common of these--the touch panel, the slide selector, and the audio unit--have been built in considerable numbers and distributed to many PLATO users. This report will examine the implementation, usefulness, and problems associated with each of the devices. In most cases, the use of peripherals by the ARPA sites was not broad enough to warrant general conclusions; hence data and opinions from other users were obtained. Nevertheless, an interrogation of all users of the various peripherals was not possible because of time constraints. The non-ARPA users contacted were mostly the large curriculum development groups who have a reputation of experienced use of peripherals. Two groups who provided a great deal of information and experience were the PLATO Elementary Reading Curriculum Group (PERC) and the University of Illinois College of Veterinary Medicine PLATO Project Group (Vet. Med.).

The ARPA Sites

The authors working at ARPA sites may have had experiences less favorable than those of the typical non-ARPA user. The following somewhat atypical conditions characterized the use of peripherals at ARPA sites.

1. Many of the ARPA sites were established comparatively early in the history of the PLATO system. The technology was new and undergoing development at a time when the sites were attempting to use it operationally. Following these early, frustrating attempts some users

decided that the effort needed to employ the terminal peripherals was too great to justify. They retained this opinion even after improvements to the original devices.

2. The remote locations of the ARPA sites were a considerable disadvantage, especially early in PLATO history. Because of the distances involved, repairmen from CERL made fewer visits, and replacement parts which could be installed by on-site staff were delayed by the need for postal delivery. Around the University of Illinois there grew a nucleus of users who worked together and shared information about the optimal ways of using the peripherals. This information filtered only slowly to remote users such as the ARPA authors. Much of the information being exchanged was related to hardware problems. Although some programming and instructional design techniques could be viewed easily at remote sites, the techniques for coaxing high performance from the hardware had to be witnessed to be learned.

One more effect of long distance was the problem of increased communication errors. The high rate of phone line errors occurring during the first year of the ARPA project, interacting with the inherent hardware and software problems of the peripherals, substantially reduced the viability of some of the peripheral devices for remote ARPA authors. Since errors are randomly distributed, the "active time" for each device corresponds to its susceptibility to these errors. The touch panel, while turned on by the lesson, is able to input information (and errors) 100% of the time. Hence experienced users activate it only for limited periods. The slide selector and audio unit require little information and thus are less often affected by communication errors. The susceptibility of the plasma panel is lower than that of a continuously active touch panel, but higher than that of the slide selector, audio device, or carefully programmed touch panel. The high frequency of errors for the plasma panel occurs because a great deal of information is needed to generate a screen display. Errors may garble text or displace points in line drawings. The plasma panel is active (i.e. generating displays) about 20% of the time.

3. Some of the peripheral devices required skills or equipment which the curriculum developers had not budgeted for or found hard to obtain from standard military base services. For example, tape recorders and small electronic interfaces substantially aided the PERC group in creating audio disks. Similarly, the skills of illustrators and photographers were often available on an informal consulting basis at the University, but the ARPA sites did not have informal access to such resources.

4. A number of the ARPA sites viewed their projects as having more limited objectives in terms of time and depth than did other sites. Several of the smaller (four terminals or fewer) ARPA sites felt that they could not afford to invest the time to learn new technologies which may not transfer to other uses.

The Slide Selector and Microfiche System

Officially called a "random-access image selector," the slide selector was, for the first few years of growth of the PLATO IV system, the most widely distributed terminal peripheral. As directed by the terminal, the random-access slide selector displays from the rear of the plasma panel any one of 256 images stored on a 4-inch square microfiche. Pneumatically powered, it can access any image in .3 second. The microfiche contains color and black-and-white images which, when projected on the plasma panel surface, may have computer-generated displays superimposed over them. The microfiche is inserted via a door in the front of the terminal and focused with a wheel located near the microfiche door.

The ideal slide selector would be swift and silent, always finding the proper image, always projecting the image exactly the same way on each terminal. The perfect microfiche would not suffer from distortions of color, contrast, or position. It would be made quickly, cheaply, and easily at the site of the user. The actual performance characteristics and problems associated with the slide selector, the microfiche, and the 35mm slides used to make the microfiche will be described in the aggregate because of the close relationship of each of the components.

Component Performance

Registration/alignment. Unfortunately, two terminals projecting the same image from two different copies of the same microfiche will not position the image identically. This difference results from variations in the mounting of the slide selector unit, positioning of the mirrors, insertion of the microfiche, and the orientation of the images within the microfiche. Experimentally, most of the variation seems to be accounted for by the first two causes. Getting a slide selector aligned and keeping it from shifting was the main problem experienced. Another related problem involves the preparation of the 35mm slides needed to make the microfiche. If the 35mm film is not mounted squarely in the 2"×2" cardboard mount, the resulting microfiche images are askew. Difficulties in handling these small pieces of 35mm film plagued some users.

Overall, registration was too poor for precise interaction with the touch panel or with circles, arrows, and drawings superimposed on the plasma panel. Most users who coordinate microfiche with touch inputs, for example, use wide margins and avoid asking the student to touch objects in narrowly defined areas.

Another manifestation of poor registration occurred in several lessons developed at Chanute AFB. The authors accompanied microfiche images with writing on the plasma panel. In order to make the writing easily read, portions of the projected image were left black. (Plasma displays backlit with white or light-colored backgrounds lack contrast and are very difficult to read.) When the microfiche was used on some terminals however, the registration shifted sufficiently so that the text was backlit. In addition to checking registration more frequently, the authors must leave larger margins between text and the projected image.

Some users needing precisely registered fic' ≥ have resorted to including on the projected image one or two points whose position on the plasma panel the student indicates with a movable cursor. Knowing the locations of these two points, the lesson author can use the relocatable features of TUTOR commands to precisely place arrows, drawings, and labels.

This method is reported to work very well; however, none of the ARPA authors, and only a few non-ARPA authors use it.

Number of images per microfiche. None of the users surveyed felt that 256 images/microfiche were too few. No single lesson was known to use more slides than that and frequently several series of lessons shared a microfiche. At Chanute, all the slides for a six-week course were fitted onto a single microfiche. Non-ARPA users investigating alternatives to the PLATO microfiche system (see later discussion) felt a Kodak system offering 98 images/fiche would accomodate an adequate number of images.

Resolution. According to Vet. Med. staff, the resolution and contrast of PLATO microfiche require that lettering 50% larger than standard PLATO characters must be used for text. When the Vet. Med. staff compared PLATO and Kodak microfiche (projected through either system), they found the main difference to be one of contrast, not resolution. These informal experiments by Vet. Med. indicate that the several layers of glass and plastic between the image and the viewer's eye have an insignificant effect on resolution. On the other hand, in an experiment by the Modern Foreign Language laboratory, text in a microfiche image displayed on a screen by a 35mm slide projector was readable, whereas the same image projected by a PLATO terminal slide selector was not.

Color. The color of the projected image is often imperfect because of contrast or lighting problems in the 35mm slides used to make the microfiche, sometimes because of dimming (but not burned-out) slide selector projector bulbs, and always because of the absorption of violet light by the glass used to make the plasma panel. The success of attempts to correct for the green tint is currently an unresolved dispute. The Vet. Med. PLATO project feels satisfied with the effect of inserting a violet gel filter into the optical path. They installed such filters on 60 terminals for $12 in materials. Instructors at other sites using Vet. Med.-produced microfiche with the violet filter found that variations in the color of the polarizer on the screen were large enough to distort the final results. Until the design of the terminal becomes completely stabilized, such phenomena will continue to annoy users.

Without any modifications the color has been found to be completely adequate for highlighting drawings, illustrating children's stories, etc. It was found inadequate for medical use, e.g., for diagnosing diseases via the color of a diseased organ.

Contrast. The film used to make microfiche has very high contrast; hence it is very good for enhancing and retaining the high contrast necessary for displaying text. However, this characteristic causes problems in some displays such as X-rays. The current PLATO microfiche capabilities are good enough for some Vet. Med. X-rays, but fall short of many of the needs for human X-rays. (It should be noted that medical standards are very high.)

Both Chanute and the Vet. Med. group reported problems associated with the high contrast when they attempted to photograph metal objects. The reflections from polished metal surfaces obscured important details.

Slide production. As has been indicated previously, many of the most severe problems associated with microfiche were actually rooted in the production of the original 35mm slides. The causes for this were several. The 35mm slides needed by PLATO are of a higher quality than is required for wall projection. Many of the authors and group managers had not previously attempted to create new educational materials; they were naïve to the techniques and problems for the production of quality graphics and illustrations. Some took shortcuts or tried to use cost-cutting methods which caused more trouble and expense than would have occurred if experienced staff had initially been contracted to do the work.

Pneumatic control. The pneumatically powered cylinders provided adequate power and accuracy for positioning the microfiche. The number of problems resulting from loose air hoses and sticking cylinders has been reduced, but many small sites found the requirement for air pressure a nuisance and expense; hence, many of the few-terminal sites have never attempted to use their projectors.

Shutters. Because the projector bulb life is limited and because a communication error may cause the slide selector shutters to be closed even though the bulb is on, some users removed the slide selector shutters. Changes to PLATO software reduced the effects of these errors by turning off the bulb automatically in appropriate situations.

Microfiche duplication. Contact printing methods do not produce sufficiently high quality copies. Therefore, if additional copies of microfiche may be needed at a later time, the author(s) must retain possession of an ordered set of the original 35mm slides.

Miscellaneous. The .3 second access time for selection and registration of an image was judged to be adequate (the random-access carousel projector which some sites used as an alternative has an access time of 1-2 seconds). The operation of the piston mechanism is generally regarded as noisy, but within the limits of tolerance. Neither the microfiche nor the selector mechanism has shown evidence of wearing out during the 3-year span of their existance. Lastly, the insertion of the mounted microfiche into the terminal seems relatively easy even for grade school children.

Alternatives

In addition to various off-line hardcopy substitutes, PLATO users have examined two hardware alternatives to the PLATO microfiche system.

Standard Kodak microfiche. The Eastman Kodak Corporation offers a microfiche system and service which might reasonably be used on a modified PLATO terminal. Modifications would not be trivial because the image sizes are different, and the images are rotated 90° in orientation relative to those on the standard PLATO microfiche. Unless a vendor willing to manufacture and support the modified components becomes available, few users would be able or willing to switch even though they could gain access to substantial libraries of already-prepared microfiche. The Control Data Corporation has indicated interest in becoming such a vendor but has made no committment.

A cost comparison is instructive. Currently the prices for producing 20 Kodak or PLATO microfiche (enough for the average size class) are roughly comparable. The price for 20 completely full Kodak fiche (98 images, about the average used by ARPA authors) is $165. Copies from the master microfiche cost $1.50 each in quantities smaller than 75. A similar set of PLATO microfiche would cost about $150 with additional copies at about $7. However, PLATO microfiche containing more than 100 images cost less per image, and most experienced users cut costs by completely filling their microfiche. Kodak offers its customers an extra service: for a small extra fee ($4/medium) Kodak will accept varied media as input (text, photos, negatives, 35mm slides). The rate structures differ as follows: PLATO has a low charge for making the master microfiche ($10-$40 vs. $75-$135), but higher duplication costs (5.1¢ vs. 1.5¢ per image). Even if both systems were equally available and attractive, the current rate structure for PLATO microfiche would probably be preferred by most current users because they have small classes. Turnaround times for producing each type of microfiche are approximately equal. According to Kodak, customers who do not wish to see and edit a proof wait three to five weeks, those wishing a proof wait six to eight weeks. Kodak quality is claimed to be sufficiently high so that only 1% of the users request proofs.

Random access 35mm slide projectors. Controlled by the PLATO terminal, these devices will select any one of 81 35mm slides and project it on a small screen beside the terminal. The projector and the interface to the terminal can be purchased for about $1000 from private contractors. Six such devices were purchased by the Vet. Med. project for use for their classes. Lowry AFB developed an interface and terminal modifications to allow the projector to display the slide into the back of the terminal and through the rear of the plasma panel. They built several such devices. Sheppard AFB used one of them and found it to be quite useful for early development of lessons and microfiche, but not for operational training. Because Sheppard found too many difficulties with the microfiche system, they retreated to a system that minimized hardware. They supplied each terminal with a tray of numbered 35mm slides and a battery powered viewer.

The greatest disadvantage for systems based on 35mm slides is high duplication costs. The Vet. Med. project pays 27¢/image (unmounted) for two to five copies. Ten or more copies drop the cost to 13¢/image, but time and supplies for mounting must be added. As noted earlier, PLATO microfiche cost about 5.1¢/image.

Summary. The director of the Vet. Med. PLATO project summed up his experience with random access slide projectors this way (Silver, J., personal communication, September 10, 1976):

> The convenience and simplicity of microfiche is in striking contrast to that obtained with the Kodak equipment. It looks as though any type of in-terminal microfiche system would be more convenient than carousels of 2"×2" slides, as regards storage, student access and operation, and cost of replication.

Effort and Skills Required to Use Microfiche

Ease of programming. The single command needed to control microfiche can be learned the first week of new author training. The techniques for educationally sound use of microfiche are learned more slowly.

New authors sometimes routinely included photographs of the equipment or components which were covered by the lesson. Unfortunately, the purpose for including these slides was never made clear to the student. A typical lesson might show three or four slides sequentially, while describing the contents only with a label, "This is a framis, This is a widget, This is . . ." More careful users employed arrows, circles, and boxes to focus the student's attention and asked questions to make sure the picture had achieved its objectives (e.g., "What will happen to the framis if the do-dad is rotated 90^{o}?" or "What do all the parts labeled in red have in common?").

Preparation time. For many small sites and for authors not associated with a major curriculum development effort, the time and effort required to learn the techniques for producing microfiche of adequate quality was frequently so large that most of them found it more efficient to use line drawings on the plasma panel. The ease of making illustrations (by using plasma panel drawings) seems to have contributed substantially to their decision.

ARPA site personnel estimated (Francis, 1976) that from .5 to 1.0 manhour is spent selecting each graphic to be converted into a microfiche or in directing an illustrator to prepare such a graphic. The illustrator's time expenditure has a range of at least .5 to 5.5 manhours. In our experience, when authors perform the tasks of an illustrator or photographer, graphics preparation consumes 100-200% more time than it would if professionals are employed. This is not necessarily bad. In many cases, do-it-yourself techniques are the only ones which are practical and available.

In summary, because of the substantial time investment required, the choice to incorporate microfiche images in a lesson should not be made lightly. If an author is fortunate enough to be able to find a suitable uncopyrighted graphic, he may be able to spend very little time (.5 hour) readying it for microfiche production. If the author has a professional illustrator's services available, from one to six more manhours of their time may be expended. An author performing the functions of an illustrator may spend from one to twenty or more hours preparing a graphic. (There are, in addition, quite a number of cases when an author can create a simple, but adequate, "stick figure" or uncomplicated sketch in five to ten minutes. Typically, such illustrations are made for the plasma panel, not as microfiche images.)

Delays introduced. Because preparation of microfiche requires several cycles of photofinishing, delays which do not consume the time of the author are introduced. Microfiche production time has gradually been reduced from four weeks to one week. To this time must be added delays encountered in the production of the graphics and the resulting 35mm slides. These include illustrator queuing, securing copyright releases, and photographer queuing. Remote sites such as Sheppard AFB, Texas experienced one week mailing delays on each one-way trip. The result of these delays is such that the total amount of time between initiating the preparation of illustrations for a lesson and receiving the production run of fiche to accompany it is likely to be more than six weeks--longer than many authors will spend writing the lesson. In order to do formative evaluation efficiently, such an author must work at several lessons simultaneously. In fact, careful advance planning and time management are essential for efficiently authoring lessons which use microfiche. Because selecting graphics for a lesson too far in advance may result in inclusion of extra slides "just to be sure" or worse, may omit important visuals, experienced users such as Vet. Med. have adopted special formative development procedures. Very often a new lesson is accompanied with an album of numbered photographs. At the point in the lesson where a microfiche image will eventually be placed, the student is referred to a numbered photograph. Though some effects cannot be achieved with this procedure, many of the problems of lesson development are alleviated. For example, new photographs can simply be added to the album. When major development on a lesson has ceased, the 35mm slides used to make the photographs are submitted for microfiche production (along with slides for other lessons). Thus, time and expense are minimized. Rather than producing several developmental microfiche and incurring set-up charges each time (for a relative handful of images), only a full, final-form microfiche is made.

Unfortunately, this hard-won experience is not always employed by other users. For example, at one ARPA site authors were unwilling to adopt procedures such as the ones outlined above. They spent a substantial amount of time shooting and re-shooting 35mm slides and microfiche, then slowly assembling the slides into larger and larger microfiche. Each time this was done, reprogramming was required to adjust to the new positions of the images on the microfiche.

Perceived reliability[1]. Although ARPA users complained about the reliability of the slide selector mechanism, to our knowledge none ever abandoned the microfiche system merely because of hardware unreliability. All the ARPA users who abandoned use of microfiche did so because of difficulties in producing microfiche suitable for their needs.

The hardware problems encountered were usually recognized as such by students; they were not misled by receiving false information caused by a malfunction. Problems which caused the wrong image to be displayed occurred only occasionally. Though both CERL and the ARPA sites have learned much about the successful operation of slide selectors, neither

[1]Measured reliabilities will be reported in a separate, but related study in this series, "Assessment of PLATO IV Operating Reliability," by R. A. Avner (in preparation).

Sheppard nor Chanute authors felt the device could be considered highly reliable.

Maintenance. Only the slide selectors required servicing; the microfiche needed little or no attention. Nearly all the users responding to comments in an on-line notesfile "peripheral" agreed that slide selectors require too much on-site maintenance. The director of the Vet. Med. project summarized the hardware problems as indicated in Table 1.

Table 1

Typical Slide Selector Problems

Frequent Problems:	Manifestation
Sticking valves	Incorrect image shown
Scratched plastic inserts	Scratches are projected
Misalignment	Part of image missing or mispositioned
Air hose leaks	Inoperative projector or an incorrect image displayed
Vibration of Microfiche door	Distracting noise
Occasional Problems:	**Manifestation**
Focus	Focusing mechanism inoperative or insufficient
Missed detents	50% of image missing
Mis-inserted fiche	Non-operation and potential microfiche destruction if not remedied quickly
Diffuser detachment	No image formed

Slide selector maintenance was performed by both CERL and site staff. The amount of servicing required by the slide selectors was reduced by several modifications to the original design. Modifications were made by CERL personnel while visiting sites to repair terminals. In one case when a substantially new model of slide selector became available, ARPA sites using microfiche were furnished with the new model very shortly after it became available (May 1973).

Until 1975 no reliable standards for adjusting mirrors and lenses were available. In 1975, microfiche mounting jigs, mirror alignment guides, and a maintenance manual were prepared. The manual (Skaperdas & Propst, 1975) provides information so that users can more effectively service their own slide selectors. The existence of the manual plus the formation of a separate slide selector maintenance group considerably reduced the complaints about slide selector problems, especially at sites at or near the University of Illinois.

The best procedures for successful slide selector operations involve regular testing and minor repair supplied by on-site (i.e., non-CERL) staff. It seems that infrequent use of the slide selector contributes significantly to maintenance problems; exercise keeps it operational. For example, following a three-week Christmas vacation in 1975, 80% of the 30 terminals in a chemistry classroom had developed problems. Now that the manual is available, site personnel perform a greater proportion of the total maintenance that CERL staff. The Vet. Med. PLATO project director estimates his staff spends the following amounts of time to maintain 33 terminals:

Effort	Function
2-3 hours/week	Testing and reporting problems
8 hours/2 months	Cleaning lenses
35-65 hour/year	Dismantling, cleaning, and oiling

total = 5.5 to 8.5 hours/terminal/year

A Chanute staff member estimates that project staff spends from one to two hours/week maintaining slide selectors for 30 terminals. They do not clean lenses nor perform the cleaning and oiling which the Vet. Med. staff do.

Implementation and Use of the Microfiche System

Perceived need. Few people questioned the usefulness or their own potential need for microfiche. For some purposes, there were few alternatives available. However when line-drawn figures sufficed, many users substituted plasma panel drawings for microfiche. In compairson of the two media, fiche offered: color, shading, no extended core storage (ECS) charge, greater detail (because digitized lines on plasma drawing produce stair-stepping), minimal illustrator training time (no computer language training is needed), and reduced interference by communication line errors. On the other hand, plasma panel drawings could be easily edited at any time, could be easily shared and transferred to other lessons, could be animated, could be prepared with virtually no delays, allowed lessons to be widely critiqued and used without need for copying a microfiche, could be created by an author, and did not depend on a peripheral device of uncertain reliability.

Principally because plasma panel drawings were available immediately and were editable, the authors at one ARPA site with a highly talented illustrator on t staff felt compelled to use plasma panel drawings even when they were nc completely appropriate. That is, they used extremely complicated line drawings which were slow to construct and sometimes difficult to understand, because of the fast turn-around time they could depend upon.

Use by sites. Eight of the eleven ARPA sites having four or more terminals made at least one effort to produce a microfiche. Three large sites actually used microfiche operationally (Chanute AFB, San Diego NPRDC, and Aberdeen PG). Only Chanute used a large number of microfiche images throughout a long series of lessons to train a substantial number of students (see Appendix I for details about microfiche usage). A total of about 200 microfiche were prepared for all ARPA sites, approximately 75% of these for Chanute. The large number of sites which tried to use the microfiche system confirms that it is potentially useful, but the description of a typical user suggests that the effort needed to successfully use it was too large for a small site to muster.

Unsatisfied needs. At least one need remains unsatisfied: the ability to rapidly produce a trial microfiche on-site. It is unfortunate that the requirements of the microfiche do not allow a Polaroid-type microfiche, usable for lesson development, to be produced. The Lowry AFB device that projected 35mm slides onto the rear of the plasma panel was found very useful by Sheppard AFB for selection of slides and for development of microfiche. Chanute used a random-access projector to aid the selection of 35mm slides, but their projector was not controlled by the Lowry interface. They used the projector to avoid excessive handling of slides, but did not teach any students using the device.

Unused potential. It would seem possible to produce pseudo-three-dimensional images by projecting line drawings made in two colors from two perspectives while the student viewed the result with red and green glasses (as was suggested by Dr. Stanley Smith of the University of Illinois). The result would be similar to the "3-D" comic books and movies of the 1950s.

It might also be possible to project soft background colors behind displays not using microfiche. By varying the colors, the student could be given the information that his class session was nearly over, that he was in review material rather than mainline course materials, or that his performance level was satisfactory. There may be some advantages to supplying this information in this way, without interrupting the flow of the lesson. These innovative ideas have been proposed and discussed from time to time but never implemented, to our knowledge. Perhaps the needs these techniques would serve are imaginary or as yet unrecognized.

The capacity for random access of images was useful to ARPA sites more because it allowed the images for several lessons to be placed on one microfiche than because the lesson itself accessed the images in a random order. This is a case of sometimes unneeded potential built into a general device.

The Preparation of Microfiche for Chanute AFB: An Anecdote

As an example of the problems and solutions required to use microfiche, let us consider the saga of Chanute, one of the first sites to try to use it. The story is both typical and unusual of other peripheral devices and other sites. This particular case is portrayed because the MTC group was more closely involved and because the Chanute effort spanned a broad spectrum of hardware sophistication, site management, and project maturity. If Chanute seems to have suffered especially numerous or severe problems, it is because they chose to try to solve their microfiche problems rather than abandon the microfiche system.

The first attempts to use microfiche were made late in 1972.

Black-and-white drawings printed on pulp paper stock were cut out from existing technical manuals, hand-tinted with watercolor pens, and sent to CERL to be photographed. At that time no microfiche camera had been built; rather the position and focal length of a camera were adjusted to create a positive "Kodachrome" image of the correct size. This was the very first microfiche which was prepared by the CERL microfiche staff. Registration, color, contrast, and resolution were all poor.

During the several months while a microfiche camera was designed and built, the authors attempted to use their personal photography equipment to prepare the 35mm slides which were to be used by the new camera. Typically they photographed engine parts, but a few tried copying existing drawings and illustrations. In succession, several of the authors "made a stab" at preparing slides, but none of them felt they had succeeded. The resulting microfiche failed to point out and highlight the desired engine components. Colors were muddy and contrast was too high to allow isolation and identification of the desired objects of interest.

Because the traditional course staff were using 35mm slides produced by Chrysler Motors in their training, the PLATO staff tried to prepare microfiche from these slides. Unfortunately, that was not feasible. The Chrysler slides were poorly exposed and just adequate for use with a screen projector. Lastly, the square format of the PLATO screen vs. the rectangular image of a 35mm slide meant that important parts of the Chrysler slides were sometimes cropped. Therefore Chanute and MTC staff attempted to borrow the original graphics from Chrysler for production of higher quality 35mm slides. After many months, it became apparent that

Chrysler would not provide the materials.

During part of this same period the Chanute base photography and training aids staffs were employed to prepare 35mm slides by photographing equipment and scenes from the automotive laboratory. As described earlier in the report, this effort was only slightly successful because the staff was not experienced in this type of photography. It was arranged for the base photography group to spend some time at CERL learning first-hand the needs and peculiarities of 35mm slides for microfiche production. Chanute slides improved, but were still largely inadequate.

In hopes of finding an ultimate solution for Chanute's microfiche problems and a potential source for campus users of microfiche, CERL authorized a University of Illinois graphics production group to supply photography and illustrator services to Chanute. MTC limited its participation to monitoring the time spent by the photographer and the quality of the product. The Chanute authors submitted requests directly to the photographer without checking to see if a suitable photograph had already been made or if another author could also use the slides being prepared. As a result there were a number of cases when unnecessary duplicates were made. Similarly, because few authors had a filing system for the slides, some were lost and others were damaged while sitting on an author's desk. Finally, the quality of the product delivered was judged by the microfiche staff and MTC to be only mediocre, despite, in some cases, rephotographing and extensive retouching. By the time MTC could close out the contract, the costs had reached a level twice that which was originally estimated. In the final analysis a total of 400 to 600 35mm slides had been prepared at a cost of about $2400. Between 250 and 300 were ultimately used in Chanute's courseware.

The variable quality of these slides, combined with a CERL production policy, served to further frustrate Chanute authors. The CERL microfiche staff had decided that in order to speed production and reduce waste for their fledgling microfiche operation, they would examine the 35mm slides submitted and sort out those which obviously could not be used to prepare a satisfactory microfiche. These were to be re-done by the user until a set of "probably usable" slides had been generated. From these, a trial microfiche would be produced, hopefully with fewer revision cycles and less time required by all. However, for Chanute this meant that the production of their trial microfiche was seriously delayed while authors, base photography, Chrysler, and the University graphics service tried to provide or prepare adequate 35mm slides. Following a trouble-shooting meeting, CERL waived for Chanute the need for submitting high quality 35mm slides. Thus Chanute authors were able to have trial microfiche available for developmental use while other staff continued to try to improve the originals so that the final microfiche would be adequate.

Following the reorganization of lesson production after May 1974, the Chanute ISD (Instructional System Design) requested that MTC determine how many microfiche could be prepared for them without incurring an extra charge. They wished to have as large a maximum as possible so that they could have maximum flexibility in deciding how to design their lessons. In order to most completely fulfill Chanute's request, CERL agreed to let the Chanute photography laboratory do the photofinishing for <u>all</u> ARPA sites. Thus they not only reduced the cost for each Chanute microfiche, but also earned a "credit" for processing microfiche for other ARPA sites. This credit was to be used to "pay" CERL for preparing additional microfiche for Chanute. By this arrangement, production of at least 500 microfiche for Chanute was assured. CERL provided Chanute with special equipment for handling and mounting the microfiche as part of the agreement. This arrangement had been working well for more than a year when suddenly all the microfiche from Chanute developed a purplish cast. When CERL microfiche staff investigated, they found that this resulted from a modification of procedures by the Chanute photography lab personnel. In a cost-cutting attempt, they had diluted their chemicals and increased developing time in an effort to compensate! Since that incident, all developing has been done at CERL.

Midway through the lesson development phase, ISD personnel came to MTC looking for solutions for three problems relating to the use of the microfiche system. They wanted better slide selector maintenance; they needed MTC's help resolving microfiche problems which the authors blamed on errors in TUTOR software; and their 35mm slides suffered from the reflection problems described elsewhere. The first problem was solved independently by the formation of the slide selector maintenance group. The second problem was spurious: though some authors claimed that the position of text placed by default conditions varied from time to time, no errors in TUTOR were found. Instead, slide selector problems combined with careless authoring habits (too-narrow margins) were the culprits. The CERL microfiche consultant advised that the reflection problems could be solved by use of a special mask. Because the Chanute laboratory had no funds for special materials, CERL purchased and delivered the highlight mask film to Chanute. The film was never used, however; either it was too hard to use or the perceived need for better quality microfiche diminshed. MTC evaluators have found a lack of consensus about how easily the masks may be made, and the basis for the decision is no longer clearly remembered by those involved.

The final product of all this effort was two microfiche containing a total of 342 images, 250 of which were needed. In order to eliminate the need for switching between two microfiche, Chanute staff decided in Fall 1975 to merge the images into a single microfiche. They announced their plans to Parkland college, another group using their lessons, and advised them to be prepared to adopt the new microfiche for their Winter 1975 quarter. However, microfiche for Chanute (and Parkland) weren't prepared until April 1976. Because it appears that some needed images might be missing from the merged version, plans for implementing are uncertain as of this date (November 1976).

The Touch Panel

The touch panel is perhaps the most easily used of the standard PLATO peripherals. Unlike microfiche or audio, it requires no additional equipment or materials. However, for a variety of reasons, its use by ARPA sites was not broad and was only occasionally intensive. Therefore, much of the data and many of the conclusions presented here were based on the experience of other users. Among the most experienced and accessible users were the PERC staff. The data they supplied were based on nearly two million touch responses made by children using their lessons.

The touch panel allows a user to enter information into the computer by (apparently) touching a location on the plasma panel. Actually the user's finger (or pointer) interrupts a 16×16 grid of infra-red beams at the surface of the panel. The terminal transmits the position of the beam interruption to the computer. The ideal touch panel would allow the user to make rapid, precise, error-free inputs. As a piece of hardware the touch panel performed reasonably well; however, the difficulties in programming required to overcome communication errors and human factors reduced its effectiveness.

Device Characteristics

Input sensitivity. Because the beams were close to the surface of the plasma panel, few parallax problems occurred. Alignment of the touch panel relative to the plasma panel, once properly established, was retained until the terminal was moved. The resolution and beam size were appropriate for adult fingers to register touches; however, the smaller fingers of children sometimes fell between beams and hence were ignored. If needed, a twin beam touch panel compatible with the current terminal could be built. It would not increase resolution, but would eliminate the possibility of touching between beams. Ambient light levels in any but the most extreme and unusual[2] conditions do not affect the touch panel.

Input confirmation. Confirmation of a touch was a problem. In its present configuration, touching anywhere on the screen causes the touch panel to "beep" as an indication that the input was registered. This beep is a function of the hardware and is not controlled in any way by software. In many applications there are areas of the screen which are not expected to be touched; they do not correspond to either a correct or incorrect response, but rather are completely undefined. In such cases it would often be preferable to have NO confirmatory beep unless a defined area were touched. As it is now, two problems may occur. The most frequent problem is that a student touches an undefined area adjacent to a defined area. Getting a beep, he feels he successfully entered his answer, but seeing no appropriate response, he is confused. A second problem occurs apparently exclusively for young children. They find the beep so reinforcing that they will touch all over the screen regardless of what is occurring on the screen. Software control of the confirmatory beep (or perhaps selection of beep tone) would solve both these problems.

Input rate. Up to four or five touch inputs may be registered each second. This is adequate for many applications. It was, however, too slow for letter tracing exercises which the PERC group wished to design.

[2] In one case, light from a setting sun struck the touch panel at a small angle and caused temporary failure.

Experimental touch panels designed at CERL have higher input rates and higher resolution, but they will not be discussed in this report since there are few data on their operational use.

Alternatives

Though no hardware alternatives to the touch panel were available,[3] several scftware techniques allow the same sort of information to be entered. The "arrow" keys of the keyboard can be used to control a cursor, or a map-like grid structure can be superimposed over the screen and coordinates typed in, or points of interest on the screen may be simply labeled with letters or numbers. On this basis it might be argued that the need for touch is small--any lesson that uses touch can be rewritten to use any of the techniques suggested above. However, experienced users of touch have developed lessons whose strategies depend so completely on touch-panel input that many could not be written in any other way. Examples of such lessons include:

> Elementary Reading lessons for pre-readers. Young children learning to read could not be expected to enter coordinates, move a cursor, or type a letter or number.
>
> San Diego NPRDC submarine tracking simulator. It includes a touch-sensitive, computer-simulated keyboard and trackball. The lessons contain almost no keyboard input; the touch parel was critical to the simulation.
>
> Elementary Math lessons. In one lesson students indicate fractions by "painting" a section of the plasma panel with their fingers.

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[3]Recently the Control Data Corporation has produced a non-beam touch panel for use with a cathode ray tube (CRT) display. The front surface of the CRT has vertical "stripes" of a transparent conductive coating applied to it. A clear plastic window with horizontal conductive "stripes" covers the tube face. When the plastic is touched, a current flow through one vertical and one horizontal stripe may be sensed.

A data collection device for practicing physicians. The physicians select patterns of dots which are then used to shade the portions of a torso which they touch. Each pattern indicates a type of injury and may be superimposed over other patterns.

Effort and Skills Required to Use the Touch Panel

Ease of programming. It seems very easy to program for the touch panel; unfortunately this apparent ease is deceiving. There are at least two ways one might wish to use a touch panel:

- to rapidly enter a large amount of data such as in designing an alphabet or "painting" an area of the screen, or
- to select a single point, hence entering a small amount of information rather infrequently.

The first task requires somewhat different programming than the second, but this fact has not always been recognized by authors.

By writing PLATO lessons which do not adequately control touch inputs, authors may frustrate students by (a) allowing multiple inputs when only single inputs make sense, (b) inappropriately choosing whether or not to allow additional touch inputs during the presentation of feedback, (c) failing to provide an "untouch" facility to erase errors without penalty, and (d) failing to provide visual feedback concerning the touch input made (i.e., when the student touches a word or response, circle it, flash it, or otherwise confirm the input). Most inexperienced authors failed to recognize all of these potential problems, and when these pitfalls were pointed out, they tended to underestimate their importance. The fourth point above caused problems especially at remote sites such as the ARPA sites, where phone line errors were often misinterpreted by the terminals as touch inputs. Sometimes students were scored or were branched on the basis of these false touches. An example of the importance of the third and fourth points listed above was documented by University of Wisconsin users who gave standardized tests via PLATO and found that students scored lower on PLATO than when given comparable tests on paper. The students were in the early elementary grades and made a single touch on the screen to indicate each answer. When the scores were discovered to differ because of the medium, the staff rewrote the lessons so that each correct answer would have to be touched once to get it circled, then touched again to verify that this was the intended choice. Thus, in order to be recorded, an answer had to be touched two consecutive times. When this modification was implemented, differences between media vanished (Venezky, Bernard, Chicone, & Leslie, 1975).

Touch programming for young children requires deviations from the rules given above. The fourth pitfall mentioned above is not in fact a programming defect when used in lessons for young children. Getting the terminal to react in <u>any</u> way is often regarded by them as being successful and hence they may find reinforcement in any response to an incorrect answer. A better strategy for these students is to ignore incorrect responses entirely. That is, the circling or flashing of touch areas suggested above is not done, nor is any feedback made (even that with negative connotations, like crossing out a response or erasing it from view). For older students however, all four pitfalls should be avoided.

The commands for programming the touch panel are only moderately difficult to understand. Programming effective lessons using them <u>is</u> difficult, however, because the software for controlling t' ouch panel is relatively unsophisticated. At least three difficulties complicate the author's task.

> First, there is no simple way to specify which of the two kinds of inputs (single or multiple) is expected or to prevent the four types of frustrations cited above. Programming would be considerably simplified if several of the desired characteristics could be specified via familiar existing commands. Without an easy way to prevent multiple inputs, for example, an author often does nothing or invents an unreliable solution which alter causes a problem for his students.
>
> A second problem concerns locating the touch-sensitive areas. The 16×16 grid used by the touch panel is referenced by the 32×64 grid system used to locate PLATO text. The conversion between these two systems is a tedious, mistake-prone task for the author.
>
> Third, the collection of student data for touch responses is crude. System-supplied information about which responses the student made is very limited and hence most authors must program their own routines.

It may seem difficult to understand how this area of software development could lag so far behind. Actually, the explanation is uncomplicated. Initially, few users had touch panels; thus comparatively few requests for touch software were made. Some users realized they would have to depend heavily on touch inputs; they therefore invested relatively large amounts of time to perfect their own routines for automatic feedback, data collection, prevention of double touches, etc. Because their needs were satisfied, their requests for new features in this area decreased. Perhaps, because their ability to succeed with the existing software was known, other users' requests were given less credence. Unfortunately, these well-polished routines were not widely disseminated. Each was built for a highly-specific purpose and no one provided a generalized, documented version for general use. Occasional users of the touch capabilities were and still are faced with a substantial amount of "overhead" and training time.

It should be noted that during the last two years access and use of these routines has been simplified and promulgated. However, by this time most ARPA users have decided not to use touch input. The on-line information source "aids" now includes sample programs as well as human factor considerations.

Some improvements to touch programming have been made recently (1976), but at least one obvious gap in touch programming still exists. In the opinion of the author, the greatest unsatisfied software need is for an editor exclusively useful for producing touch-sensitive displays. This would circumvent the grid location problems cited above and could effect savings of programming time by doing for the touch panel what the "ID" (i.e., interactive display) editor has done to simplify creation of displays. Combined with modifications to allow a semi-automatic specification for the type of touch input expected and the data collection desired, such an editor could substantially increase touch panel use.

Programming time. "How much longer does it take to program a lesson to use touch input?" is a frequent question asked by authors at sites that have just received touch panels or by staff who know how to program but haven't used touch input in their lessons. When PERC's head programmer, an author very experienced with programming required to use the touch panel, was asked this question, he remarked that he was so familiar with the PERC routines for handling touch input that he would find it slower to program a lesson without touch than with it.

For most purposes, however, the above query seems to ask the wrong question. It presumes that decisions about the design and programming of a lesson are made separately from decisions about whether to install touch input. It also seems to presume that cost is the sole criterion for incorporating touch input in a given lesson. A more important consideration is the instructional benefits to be had from using touch input in a particular application. If they are minimal, then the additional effort required for touch input probably can't be justified. There are many applications, however, in which the benefits of touch input are overwhelming; the lesson cannot be effective without it.

An answer to the original question might be found in lessons which had been converted from keyboard input to touch input (e.g., multiple choice questions for technical training students who have trouble finding keys on a typewriter keyboard). Unfortunately, such conversions have been done infrequently, if at all, and hence the time needed to complete them is not known.

Perhaps the best answer that can be given to the initial question is that a familiarization and training period will be necessary for an author to learn the programming and human factor considerations that accompany use of the touch panel. In this sense, it will take the author longer to prepare a lesson using touch than to prepare a lesson which only uses keyboard input. However, the same sort of self-training period would be necessary for the author to learn to use <u>any</u> unfamiliar feature of the TUTOR language (e.g., concept judging, student routers). Once an author has learned the potential power and usefulness of touch input, he will hopefully consider using it during the design stage when planning future lessons rather than as an "add-on" after the lesson is written. When this stage of experience is achieved, the question of "extra time" becomes moot--the author simply has developed a variety of techniques and strategies which he can use to meet objectives. The characteristics of relative cost and effectiveness of these techniques then would depend on the particular application under consideration. An author who has developed a large repertoire would be in a good position to judge which of a variety of techniques should be applied.

Perceived reliability. ARPA authors perceived the touch panel as a moderately reliable device. Five problems served to lower its apparent reliability.

> First, the early models of the Magnavox-produced touch panel provided a poor first impression to authors: the initial version had a poorer-than-average repair record (virtually every unit required repair at least once during the first three months of use.
>
> Second, communication errors prevalent in remote site operations mimicked touch panel inputs and provided considerable frustration (see later discussion).
>
> Third, in contrast to the terminal, the slide selector, or even the audio device, there was little on-site repair that could be performed for the touch panel.
>
> Fourth, many repair jobs could not be performed by the traveling maintenance staff. Rather, the touch panels had to be detached, boxed, and mailed to CERL (often by project personnel). Because few, if any, spare panels were available, no replacements could be sent. The site had to wait while repairs were made, and until the panel was again packed, mailed, and re-attached to the terminal.
>
> Fifth, because of the patterns and styles of usage, there was a significant chance for the occurrence of undiscovered partial failure. If the beam for a seldom-used row or column failed, it was often some time before it was discovered. Further, because touch sensitive areas often spanned several beams' width, a beam failure often caused a problem for only a few lessons or users. Such a failure was sometimes erroneously termed "intermittent." Of course, a regular testing and

preventive maintenance plan would have allowed rapid detection of such problems, but few sites adopted such a procedure. Both the perceived reliability and the measured reliability have been affected by the situation described in the fifth point above. That is, the low usage at many sites combined with the susceptibility to partial failure and the lack of a regular testing program probably distorted the reporting of touch panel repair requests.

Needs for maintenance were initially high at a number of sites which waited until they had their full complement of touch panels (one per terminal) before beginning to use them. Once the final shipment was installed, they found that several of the touch panels previously installed had developed problems. The excitement and interest that might have been generated with the initiation of programming and use of touch panels was thus dampened unncessarily.

Perceived need. The need and usefulness of touch panels as perceived by ARPA authors seemed to be dichotomized. None of the users felt that the touch panel was useless or completely unsuitable for their needs, but some author groups treated touch panel input as a gimmick to gain the student's attention or offer him a change of pace. These authors apparently perceived only moderate need for touch input in their lessons, because when deadlines pressed or when difficulties and constraints developed, they stopped using touch input and/or converted previously written lessons to keyboard input. Other authors felt a stronger need for touch panels. They designed their lessons around touch input and modified or re-optimized their touch input routines when problems arose.

Authors who found only moderate use for touch input were also authors who found they had sometimes introduced problems into their lessons when they added touch. For example, some authors felt that multiple choice problems could be answered more quickly and reliably by eliminating the need for finding and typing the correct letter. They converted some of their lessons, but failed to include feedback/verification characteristics and thus may have nullified any advantages which touch input gained. Authors at another site made it possible for the student to go to the next display at any time by touching anywhere on the screen. This had many disastrous side-effects. Students who pointed at the screen to ask the proctor a question or to hold their place while taking notes experienced an unexpected and unwanted loss of their current display. In some cases they could not return easily or directly to the page they had been reading. Even more frustrating was the fact that this remote site sometimes suffered 20-40 second bursts of noise on the phoneline to the terminals. This noise was often interpreted as a series of, say, 10 touch inputs which might advance the student 10 displays further into the lesson. These problems not only forced the site to remove this programming, but also left them with an overly cautious attitude about further use of touch input. Most of their problems would have been solved if only a small portion of the screen would have triggered the advance to the next display.

As discussed previously under "Alternatives," many authors who were experienced with touch input perceived a great need for it and avoided problems such as those given above. Hence, there is divergent opinion about the usefulness of touch panel capabilities.

Use by sites. Two ARPA sites (USC and San Diego NPRDC) incorporated touch panel input extensively in their lessons and tested it with students. Sheppard AFB and Orlando NTEC used it in many of their lessons. See

Appendix I for details of usage by site.

Unsatisfied needs. As was mentioned previously, the PERC group could have used a touch panel with a higher rate of input and greater resolution. A research model of such a device (which requires a higher input bandwidth) has been built by a CERL research group. That device was not tested by ARPA authors and will not be discussed in this report. For details see the semi-annual report to ARPA for January 1, 1975–June 30, 1975.

Unused potential. Use of a touch panel connected electronically, but not attached physically to the terminal has been implemented at two or three sites, but has not yet seen wide adoption. The Vet. Med. group has placed a touch panel over a radiograph (an X-ray) to allow the student to locate points as directed by the lesson. Another group similarly combined a touch panel with a map.

Evaluation: Use by Elementary Students

Some kindergarten students using lessons which expected touch input preferred to use the keyboard. In fact, because 5-10% of all questions which expected touch responses were instead answered via the keyset, all PERC lessons were programmed to accept either kind of input. Three factors seem to have contributed to this unexpected neglect of the touch panel by the children. First, the teachers and the PERC staff coming into the classroom interacted with the terminal primarily via the keyset; hence keysets were seen as an adult input device. Second, the similarity of the keyset to an adult machine, the typewriter, may have made it preferable to some young students. Third, the audio device's imperative to "Tap the word" may have been heard as "type the word." (Virtually all the PERC lessons used both touch panel input and audio message output.)

The extensive touch response data gathered by the PERC group presents an interesting picture of the interaction of young children with the touch panel. From 18-25% of the touch responses by elementary reading students were made in unexpected, undefined locations (neither right nor wrong). PERC group staff feel this fraction is too large. The students were not ignorant nor were the lessons too hard, since 80-90% of the questions were answered correctly the first time the student touched a defined (i.e., either right <u>or</u> wrong) area. Some of the touching of undefined areas may be attributed to hardware and human factors (too-small fingers, touch panel errors, and motor-coordination problems), and some are no doubt due to the exploratory behavior of the children. In any case 75% of these undefined touches occurred only once, with the child making an acceptable response without further aid (self-remediation), 10% of the students made a second error before touching a defined area, and another 7-8% of the students made a third thus triggering an audio message which caused them to resume touching defined areas.

The Random-Access Audio Device

The PLATO audio device was the least available and least used of the peripheral devices discussed in this report. Its development lagged behind that of the slide selector and the touch panel and, although each of the major ARPA sites possessed an audio, few lessons using audio were written and tested with students. Other users such as the PERC group did acquire many audio units and gained much experience about how to use audio. The discussion of the audio device presented here is followed by an independent report written by the head programmer for the PERC group, Robert F. Yeager. Though the Yeager paper follows a slightly different format and style, it contains information not included here. It should not be regarded as an appendix or only as a supplement.

An ideal audio device would select any one of several pre-recorded audio messages and play it with high fidelity for the listener. The actual performance characteristics will be discussed below. More details can be found in the Yeager paper and in a technical manual which will be referenced later in this report.

Device Parameters

Length of longest possible message. This was not a problem for the users questioned for this report. In fact, for many uses it may be supposed that the 42-second maximum exceeds the ability of the student to maintain close attention. Some other users (e.g., music instructors) may need extended message length. The PERC group would not have been constrained by a considerably shorter message length.

Minimum message size increment. This parameter defines the shortest message possible and also the "fineness" to which the message start and stop points can be adjusted. Typically, a script was first read and then the silence at the ends of sentences was trimmed. Generally, one segment (1/3 second) of "silence" preceded and followed each message. Closer trimming eliminated the sound of aspiration (inhalation) necessary for understanding and deleted the "ring" of certain trailing sounds (e.g., "seen"). The 1/3 second editing increment was viewed by PERC staff as appropriate.

Total information stored. For users such as Vet. Med. the 22 minutes of storage available was adequate. For example they recorded the heart sounds of dogs suffering from various diseases or abnormalities and constructed a lesson to teach discrimination of the sounds. Relatively few Vet. Med. lessons use audio and the total number of recordings and copies is small. In this environment disk changing is infrequent. In contrast, virtually all of the PERC lessons employ recorded audio messages. Though a great deal of effort has gone into packing related materials on the same disk, as much as 40-45% of the student's time is spent changing disks. This situation can only be alleviated by expanding the total storage available.

Message access time. The total delay until the audio output begins is the sum of the audio message access time (1/2 second), the time for the play head to drop to the disk (unmeasured, but short), and the recorded silence at the beginning of a message (1/3 second). The total time before the message begins varies from one-half to one second. PERC staff felt that longer delays would become objectionable. It has not been found satisfactory to construct sentences from fragments (e.g., "This is a . . . tree"). Though mechanically it is possible to do, the uneven flow of the sentence and the small savings in recording space have not justified the technique.

Tracking/alignment. Although individual machines seem to track well, standardization of the track position has been a severe problem. In one case, the master recording audio, the duplicating audio, and the verifying audio were all misaligned. These problems caused a large group of unusable copies to be produced.

Sound quality characteristics. Wow, flutter, bandwidth, linearity, and other sound quality measures are discussed in detail elsewhere (Skaperdas, 1974). The audio device has been used mostly for recording human voices. Reproduction quality is sufficient for understanding. One well-known non-verbal recording is that for heart beat sounds of dogs. The quality of the audios built by CERL was sufficient for that task. The study of human-heart sounds is sufficiently more refined that even the commercial audio device cannot provide sufficient reproduction.

The New Generation Audio Device.

The previous discussions ignored the fact that several different versions of the audio device have been manufactured and implemented by the various users. While many of the conclusions are generalizable to all models of the device, the more substantial changes introduced to the Education & Information Systems (EIS) model deserve recognition. In general, this model was delivered to most sites too late to make a thorough evaluation possible. The discussion here is based mostly on data gathered by PERC.

The only characteristic that seems poorer in the new device is that it is heavier and harder to carry. Other changes seem uniformly to be improvements over previous models. A PERC staff member was especially pleased with the improvement in the tone and the reduction in the variation of tone quality from inside to outside tracks. Tracking accuracy has improved though more is still needed. On the new device, it is difficult to test or adjust the tracking quickly. Test records are now available as an alignment aid. An improvement which allows the new audio to be self-loading should reduce wear-and-tear on the disks. On the previous model, some of the positioning and drive holes punched in the magnetic disk became enlarged after use by students with brute-force disk loading techniques. On the new audio there seems to be virtually no misaddressing (incorrectly determining the start point for a message). After model "C" audio devices (the most advanced model built by CERL) were first implemented in elementary classrooms, PERC staff studied reported difficulties with the audio and determined that the device misaddressed about 5% of the time. That percentage of errors was highly objectionable for any instructional use. Two new features are useful: a pause control and an electronic signal to indicate that the message has been completed. New software will have to be written to take advantage of the latter feature.

Effort and Skills Required to Use the Audio Device

Ease of programming. Few of the ARPA authors became familiar enough with the audio to enable them to make comments about programming. Whenever an audio device was delivered to a site, an MTC staff member provided a demonstration of the operation, maintenance, and programming needed for it. After that each site was able to write one or more demonstration lessons which required them to learn how to use the audio commands. Only at USC and Orlando NTEC did use of the audio device go beyond the production of demonstration lessons. Orlando eventually decided not to use the device, but USC trained 100 students with it. The lead author at USC was a former employee of CERL (PERC) and acquired experience with the audio device at that time. In general, the same comments that were applied to touch programming apply to audio programming as well; that is, unsophisticated programming is easily learned, but the routines which are necessary for the fail-safe operation of students must be carefully designed or copied from experienced users.

Several moderately sophisticated editors are available to aid persons making recordings. Less than an hour is required to learn to set up the equipment and control the audio device in record mode. PERC programmers find it useful to be able to simulate audio messages until the lesson is nearly complete and to then prepare the master recording from the script thus generated. This provides for easier methods of showing the lesson to others and editing the script. The text for the simulation of the audio is retained after development so that users without the appropriate audio disks can view the lessons. Because of the need for maintaining and storing two forms of the information, the PERC staff felt that software databasing the audio would have greatly aided their work. They suggested that both the text and the parameters for the audio message be put with the lesson in computer disk storage via an audio editor. When the lesson was needed by a student or other user, either the text (for simulated audio) or the location parameters (for the audio device) would be attached to the lesson, depending on the peripheral equipment available. Other options would serve to do routine bookkeeping (e.g., checking to see if a message already existed before recording a new one).

PERC indicated that designers of audio lessons need a more keenly developed sinse of esthetics than do designers of displays. For example, an audio message confirming a correct answer, "Nice job!", can sound sarcastic if it is received after several unsuccessful attempts to answer the question.

Preparation time. No one was able to accurately estimate the time needed for preparation of the messages for a lesson. Even more clearly than in the case for touch, users wrote their lessons with audio in mind from the start and did not add it on later. In fact, most PERC lessons were written around the script, rather than the script written to accompany the lesson. PERC recording sessions were often set up so that the scripts for many lessons were recorded during one session; hence very little time was actually spent making each recording. Because each message is listened to at least five times while editing the silence from the ends, a factor of 10 or 15 times the message length seems like the minimum investment of time possible. This is nevertheless only an estimate, not a measured quantity.

The PERC group found that for their audience speakers should use exaggerated inflection and emphasis. Naturally the speaker must know what the lesson is about in order to give the feedback phrases proper tone and style. Finding and/or training a speaker is a slow process without complete selection standards; user feedback is mandatory. PERC suggested that a patient perfectionist might possess the best personality characteristics for the job. They also indicated that designers and programmers should not expect to make their own recordings; instead, recordings should be the chief responsibility of a single person. PERC found that recording a script first on a conventional tape recorder, then converting the tape to audio disk was preferable to recording the speaker directly into the audio device. Otherwise, interruptions in the flow of the script gave choppy quality to the completed recording.

Perceived reliability. The ARPA users of the noncommercial model "B" and "C" devices regarded the audio device as unreliable. Part of this reaction was no doubt due to the crude appearance of the device. However, the cynicism was not unwarranted. The machines had many mechanical and electronic failings. The lack of supportive hardware and software contributed to the negative feelings to the point that it is difficult to differentiate between problems arising from hardware reliability, the quality possible from even a well-tuned audio, and the lack of software support. Although many of these problems have been remedied in the commercial model, no specific information is yet available. Users are unanimous in their general praise of the new device, however.

Maintenance required. Early models required a great deal of servicing. Because no standard shipping crate was available, the strange protrusions of the early model audios had to be carefully packed. Many audios were hand delivered to minimize damages. Even now, the staff who perform regular terminal maintenance carry few audio repair parts and perform only minor repairs on it. None of the remote ARPA sites returned malfunctioning audios, probably because of the packing and shipping problems. Chanute's model "B" audio was returned for repair many times, however (Chanute is only 15 miles from CERL).

Non-ARPA users have provided additional insight. To a greater extent than the touch panel or the slide selector, the audio device requires regular preventative maintenance. Because CERL provided none, the PERC group included that as part of their classroom monitoring duties. It is probably because of the close proximity to the audio maintenance staff and the testing and preventative maintenance done by PERC group that the elementary reading classrooms experienced significantly fewer problems than did the ARPA sites.

Despite hard use by elementary students, the magnetic recording film did not exhibit evidence of wear. However, it would have been difficult to discern small degradations in quality since no standards were available.

The repair record for the EIS audio device seems to be improved; however preventative maintenance is still necessary. The heads reportedly need to be cleaned about every two weeks. The new version also suffers from alignment (tracking) problems. Though it is factory adjusted, the unit may require readjustment after shipping. Adjustment reportedly necessitates partial disassembly and it is not possible to visually verify correct alignment externally.

The personnel of the various ARPA and non-ARPA sites made very few repairs themselves. Several users disconnected or inhibited the record feature so that phone line errors would not cause the audio device to accidentally erase a pre-recorded message.

Implementation and Use of the Audio Device

Perceived need. It is probably evident by now that only a few ARPA users had critical or even significant needs for audio output. Although many sites thought of interesting uses for it, few ever put their plans into practice. For example, Chanute AFB intended to teach diagnosis of engine malfunctions by playing recordings of motor noises, like the Vet. Med. heart-sounds lesson. However, when new management took over, it was decreed that no new instructional strategies or peripheral devices were to be used. Furthermore, the vehicle maintenance course did not have as an objective to teach students how to diagnose problems by listening to the engine. Sheppard also considered including respiration sounds in a discrimination exercise. Orlando tried to use the audio device to demonstrate tone of voice (with pre-recorded messages) as well as to record statements from the student so he could later analyze his own statements for tone and style. However, hardware problems kept them from exploiting this use. Therefore, they used the external output of the terminal to control a conventional tape recorder. One of the ARPA sites felt the audio was so useless to them that they tried to trade it for spare parts for terminal maintenance. In summary, most of the ARPA curriculum development sites simply did not perceive a significant need for any audio output. A few could have used it for one or two lessons. Only USC actually trained students with it; Orlando found an alternative. Non-ARPA users such as PERC and University of Illinois Foreign Languages, on the other hand, had a great and broad need for audio output and solved the problems necessary to be able to use it.

Unsatisfied needs. Some problems involved with making copies of recordings are not solved. A variety of hardware/software combinations have been used to create the recordings now in use. None of the methods are easily learned or used by novices.

Additional hardware and software are needed for a wider and easier use of the old or new audio devices. Many special purpose devices to aid recording, duplicating, and editing have been built. Unfortunately, most of them are one-of-a-kind devices or programs. Although they perform satisfactorily, they are typically devised for a special use or a special group of users. Thus they are not always generalized in form and often abandoned and unused after the creator has finished his production. Without maintenance, documentation, or distribution, few people find out about these auxiliary devices and fewer still could repair and use them. However, the potential of such devices is suggested by these examples of machinery which has been built.

- An electronic recording controller is reportedly able to pack twice as much information on a disk as are manual methods. The device uses the commercial version of the audio, a tape recorder, and a $75 interface. Operating by squeezing out the silence between messages, it also deletes deliberate pauses the speaker uses.

- Another device transfers a message from one location on disk 1 to a new location on disk 2.

- A series of user-written editors (there is only one simple, system-supported editor) take care of bookkeeping, editing, and interfacing with master tape recordings.

Unused potential. Few, if any, users have made recordings of students via the audio. The audio could be used in occasions when the display is already over-loaded or requires substantial plotting time. Directions for use or response to student requests for help could be given via the audio without disturbing the display. Many PLATO animations smoothly move objects around the screen; however, when arrows, descriptions, and notes must be plotted, the motion must temporarily stop--the plasma screen cannot write in two positions simultaneously. However, once triggered, the audio device CAN output simultaneously with the plasma display and it is interruptable if student input requires it. For example, an audio message might say, "Watch the input valve close as the piston compresses the gas and air mixture; maximum compression is reached right---NOW."

USING AUDIO WITH CAI LESSONS

Experiences of the PLATO Elementary Reading Project

Robert F. Yeager
Computer-based Education Research Laboratory
University of Illinois at Urbana-Champaign

For the past five years, the PLATO Elementary Reading Curriculum (PERC) Project has been developing activities primarily for use in first grade classrooms. In the 1975-1976 school year, twenty-five classrooms with over 750 students used PERC materials.

The typical classroom has two PLATO terminals in the classroom; each terminal is equipped with a touch panel, slide projector, and an audio unit. Students normally spend about fifteen minutes at the terminal; and they manipulate all of the hardware themselves; that is, they insert a microfiche into the slide projector, and they change records on the audio unit.

Random Access Audio

PERC uses a random access audio unit which is connected directly to the terminal. The command to play a message is sent from the computer, through the terminal, to the audio unit; the computer tells the audio where to start playing and how long that message will last. The computer retains control so that other processing can continue, such as displaying graphics on the terminal which coincide with what the audio is saying.

The audio record holds up to twenty-two minutes of recorded information. A single message can be as short as one-third second, or as long as forty-two seconds. Any message on the record can be accessed within one-half second after receiving the command from the computer. The records are made from large sheets of magnetic recording tape (the type used in tape recorder). Therefore, the audio unit can both play messages and record directly on to the record. Records can also be erased and used over and over again.

Using an audio unit that allows random access has been very important in developing PERC lessons. The alternative would have been to use serial audio (such as a cassette tape recorder) which would have required that lessons be organized so that all messages would be played in a predetermined order.

The most obvious advantage is that PERC has been able to produce some unique activities which allow each student to explore the activity in his own way; for example, one lesson puts a list of sight words on the screen and allows the student to hear any word by touching it.

Many PERC lessons are in such a stable condition now that they could almost be used with serial audio; all of the directions and items in the exercise are in an optimal sequence. But because of the random access capability PERC has been able to implement some powerful pedagogical strategies which would not have been possible with serial audio. For example, when a student misses a drill item, he not only is given immediate correction, but that same item will reappear in the drill as the third and fifth items after the error. Such strategies have been very successful with students.[1] Thus, pedagogical strategies are not overruled by technological limitations.

An added bonus of random access audio has been that lessons have been easier to develop. When a lesson had to have an audio message changed or added, all that had to be done was to find an open area on the record and add the new message; with serial audio such changes would have been much more tedious.

Guidelines for Using Audio in Lessons

The PERC Project has developed four simple guidelines for using audio in lessons. But as obvious as these guidelines may appear, PERC has experimented with lessons in the past which follow completely opposite conventions. These guidelines have emerged as the ones that work best with our six-year-old population.

Guideline 1: Keep it short. The paradigmatic audio is, "Do it!," and PERC tries to translate all direction giving messages into something only slightly less cryptic. Elaborate explanations and rationales are eliminated; the audio must focus the student on the task and let him interact with the lesson as quickly as possible.

That guideline comes from years of watching children become distracted while a long audio message is recited to them. They "tune out" in the middle of the message and often miss the cue telling them what to do; then they either fail to respond or respond inappropriately.

Obviously not all children follow that pattern. Conventional children will put up with anything (perhaps these are the college-bound students?). But a large number of six-year-olds view the terminal as a place where they can express themselves; and they do not have the patience to listen to the terminal express itself. PERC has had more success in aiming lessons at these expressive students than in trying to make the expressive students conform to conventional patterns.

It may seem as though PERC is shirking its duty to teach the expressive students to pay attention. Nevertheless PERC teachers report that one of the fringe benefits of using PERC lessons is that students develop better listening skills.

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[1] Siegel, M. A., & Misselt, A. L. A corrective feedback and criterion teaching paradigm for computer-assisted instruction. Unpublished report, Computer-based Education Research Laboratory, Urbana, Ill., 1974.

How long is a short audio message? The average PERC lessons runs about 2:50 minutes of which forty-seven seconds is audio. The average lesson has seventeen audio messages; each message lasts an average of 2.8 seconds. That means the student gets about three seconds of audio every ten seconds (based on data from 113,312 uses of PERC lessons in 1975-1976).

Eight of the seventeen messages are short messages less than 2.4 seconds; they are the drill items, such as single words, letters, or sounds. If the short messages are excluded so that only messages greater than 2.4 seconds are counted, the average audio message is still a brief 3.94 seconds.

Not only are audio messages kept short, but audio is usually faded in each lesson. There is usually a great deal of audio at the beginning of a lesson while the activity is being set up; but audio is quickly withdrawn once the student demonstrates that he understands the nature of the interaction. Audio feedback is severely limited with an emphasis being put on visual feedback. For example, the first few times a student makes a correct response, the audio might say, "good," and there would be an appropriate screen display; but then the audio is withdrawn and the student is reinforced by the visual display only.

Audio is limited because it intrudes on the pace of an interactive lesson. Students want to make the terminal "work," not listen to long explanations. A good lesson strives to make students active learners rather than passive listeners.

<u>Guideline 2</u>: Give the cue at the end of the message. For example, if the audio says, "Tap the word <u>up</u> to make the elevator go up," the student is likely to start responding as soon as he hears, "Tap the word <u>up</u>...." A better audio message would put the cue at the very end: "Make the elevator go up. Tap the word <u>up</u>."

A corollary to this rule is that complicated sentence structures should be avoided so that the cue is easily identifiable. Conditionals, for example, always cause problems; in a message like, "If you want the elevator to go up, then tap the word <u>up</u>," the if-then construction can complicate things sufficiently so that the student fails to comprehend what he is expected to do.

<u>Guideline 3</u>: The student must always be able to interrupt an audio message with a correct response. At one time PERC lessons would not accept any type of response until the directions on the audio were completed. But students often understand the nature of the task before the audio message is completely finished; and because they respond by simply touching the screen, students can enter several responses during the last second or two of an audio message. Students were observed to enter the correct response, get no feedback because the audio message was just finishing, and switch to an incorrect response just as the audio message ended.

The same problem occurs on remedial messages after an incorrect response. The student often recognizes the tone of the message and moves immediately to his second choice for an answer. While it may seem pedagogically desirable to explain to the student why he was wrong, in practice it does not work. People make explanations; machines do not. Machines are simply expected to perform in specified ways; so when the student enters the correct response, he expects that the machine will respond appropriately. If a student makes a correct response while an audio message is in progress, the audio message is immediately stopped, and the positive feedback is begun. This avoids the paradox of having the audio continue to tell the student to do something that he just did.

While an audio message is in progress, incorrect responses are ignored; the audio continues uninterrupted. This is really done out of necessity. If an incorrect answer was accepted before the audio had given the cue, the lesson would have to contain special remediation which would explain the task that was supposed to have been explained in the interrupted message; and that remedial message itself might have to be subject to interruption. In PERC's very early years, a few lessons were written that way. Some students quickly learned the joys of making the audio unit go crazy by repeating incorrect answers every second or two; this caused the audio to restart the same message over and over and over again.

The strategy of ignoring incorrect responses while audio is in progress is effective. It takes advantage of the students' strong desire to make the terminal "work." Receiving negative feedback is perceived by students as making the terminal work; and it is sufficiently reinforcing that students will persist in making the wrong response. But receiving no feedback at all discourages students from responding unless they are fairly certain that it is going to have an effect.

There is a glaring loophole in that strategy, however. If the student makes all possible responses while the audio is in progress, the incorrect responses will be ignored and the correct response will be rewarded. In fact, that happens very seldom. In the few cases where it did happen, the lesson was changed to stop it. One change that worked was to not display the answers until the audio was completed. Another method was to stop the audio, erase the screen, and restart the frame after telling the student that he had to start over because he had answered too soon; the success of this latter mathod has not been evaluated yet.

Guideline 4: Audio should be embedded in a context. Messages like, "Touch the word boy," were effective with some students but many students seemed to have difficulty comprehending what the audio said; they lacked the proper psychological set to handle the directions. Students sometimes verbalized what they thought they heard; their errors could be loosely grouped into four categories: 1) homonyms (boy-toy); 2) words conceptually linked (boy-runs); 3) words prompted by the sequencing in the exercise (if word one was "cat," and word two was "frog," the student might hear "dog" both because it sounds like "frog" and because of its relationship to "cat"); and 4) other answers on the screen (note that the students had to read the other answers).

There are two ways to provide context for an audio message: add more audio, or add a visual display. Sometimes the only thing that can be done is to add more audio despite the fact that this violates guideline 1. But students are more likely to tap the word "up" if the audio cue is prefaced with a short statement like, "Make the elevator go up."

A better way of providing context is to add a visual display; if the audio says, "Tap the word boy," a picture of a boy can be shown on the screen.

Data was gathered during the 1975-1976 school year which tend to support the importance of a visual context. Records of errors were kept for forty auditory discrimination exercises; all forty exercises operate in the identical way except for the fantasy used for motivation; in a -t- exercise the student adds men to a tug-of-war team; in an -h- exercise, he adds horseshoes; etc. The task is for the student to decide whether or not a word presented by the audio begins with a specified sound; for example, does "telephone" start with /t/. This would seem to be a listening task; the student should not even have to understand the word in order to decide whether he hears a /t/ or not.

Twenty-five of the forty exercises presented the word via audio only; for the other fifteen exercises a picture was displayed on the screen while the audio said the word. After 44,268 trials, words given by audio alone had an error rate of 21%; words given by audio accompanied by a picture had an error rate of 12%.

Ninety-three of the words were used in both ways; they were used with pictures in some exercises, and without pictures in others. This was done primarily because many exercises were on the same record and they shared the same pool of words; hence the students heard the same recording of the word both with and without pictures. Approximately the same error rates held: for 17,572 trials, words without pictures had a 22% error rate; words with pictures had only a 12% rate.

Future Plans with Audio

There are two areas in which PERC would like to experiment with audio. First, students could record their voices on the record; this is essentially a language lab approach. The student could compare his voice to a pre-recorded model in order to decide when he is close enough; and a teacher could spot check her students' recording to make sure they are performing adequately. This would by no means be a substitute for the teacher listening to the student recite in the classroom; but it may be a way of giving students added practice in producing speech without putting a great deal of overhead on the teacher.

The second area would involve a much more radical change. Currently audio is delivered automatically throughout a lesson but PERC has now developed a few lessons in which the student has to request the audio either by touching someplace on the screen or by pressing a key. Thus the learner gains control over the flow of information that is directed at him. He can be somewhat selective about what information he wishes to receive; for example, students who have seen a few of those forty auditory discrimination exercises do not usually need even the minimal directions given at the beginning of each exercise; with "learner-controlled" audio they could skip past the directions.

The few lessons that have been developed with "learner-controlled" audio have been in a very narrow range. Various types of lessons will have to be developed before the usefulness of this strategy can be evaluated.

Summary

PERC follows the principle that the best audio is the least audio. That principle is put into practice by, 1) keeping messages as short as possible; 2) making cues easily identifiable; 3) allowing students to interrupt audio; and 4) providing minimal context to aid understanding. And it would be extended even further if learner-controlled audio were implemented.

The guidelines described have been found to be effective with six-year-olds. But they are probably somewhat valid for all age groups although older students may put up with slightly longer audio messages, and may require fewer prompts.

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Overall Evaluation

Comparative Performance Evaluation

Comparisons of the problems associated with the various peripherals are difficult to generalize because of variations in local maintenance equipment and personnel, the quantity and type of use, and the age and skills of the users. Nevertheless, the data gathered by the PERC staff may offer insight. They anonymously gathered opinions from 21 elementary teachers whose students used their lessons. It should be noted that CERL maintenance staff were located in the same city as the terminals and that the PERC staff supervised and participated in much of the maintenance program, especially with respect to the peripheral devices. It should also be remembered that the teachers made these ratings, not the actual users, the school shildren. Most classrooms had two terminals in them. The following items have been extracted from the more general survey. The responses are listed in Table 2.

Table 2

Performance Ratings for PLATO Hardware

Item	Performed Well	Few Problems	Many Problems
Terminal	5	12	4
Audio	4	10	7
Touch	7	11	3
Slide	11	9	1
Air pressure	14	7	0

Thus all peripherals except the audio seemed to perform about as well as the terminal itself, or better. PERC staff were slightly surprised that the audio was rated as well as it was. Students were observed to use the audio device with the wrong disk in place, with the headphones not over their ears, and with the play heads not in contact with the disk! The fact that some children could successfully complete lessons in spite of the fact that they could not possibly hear any audio messages suggests that some could read before entering first grade and that the visual cues in lessons with well-known formats were in some cases powerful enough to obviate the need for the audio messages. Although such cueing and prompting are probably good instructional design, it leaves unanswered the questions about the efficiency and quality of the audio messages.

Comparisons of the problems with peripheral devices to problems arising from other sources were made. The results are found in Table 3.

Table 3

Comparison of PLATO Problems

Potential Problems

1. Students have problems with the audio or slides
2. System crashes
3. Phone line errors
4. Keeping the hardware repaired

Item	Not a Problem	Minor Problem	Major Problem
1	3	12	6
2	4	12	5
3	5	11	5
4	4	12	5

All problems were seen to be of roughly equal magnitude.

A PLATO-wide call to all authors for evaluation data about any of the peripherals or a comparison of them yielded no results. A survey such as the one above would certainly produce less positive results if it were conducted at one of the ARPA sites. The PERC survey results should thus be viewed as the potential which these devices can exhibit if programmed and managed by an efficient organization.

Managerial Considerations

From the point of view of some of the managers of CBE curriculum development sites, peripherals such as the touch panel were a mixed blessing. Although the peripherals allowed them additional instructional flexibility, the managers were somewhat reluctant to adopt a policy of using them throughout the lessons and becoming dependent on them. Dependence on the peripherals seemed dangerous because deliveries were slower than had originally been promised; the reliability of the early models was initially low; peripheral maintenance was needed frequently; and maintenance programs were just being set up. Finally, the managers realized that the use of these new media would require additional time for learning new instructional design techniques, new commands and programming, and the operating characteristics of the device. Some of the managers felt that it would not be feasible to operate a classroom in which only half of the terminals had peripheral devices. That is, because of scheduling or administrative constraints or unwillingness of the managers, it was considered impossible to separate students who needed audio or a touch panel for a lesson from those who didn't. Given this situation, some ARPA site managers directed their authors to wait until, for example, one touch panel was available for each terminal before learning how to use the new device. In other cases the authors created lessons in which the use of the peripheral device was optional and could be turned off quickly for all students. The fact that such lessons worked perfectly without the touch panel did little to suggest that the touch input had more important uses.

By the time the full complement of peripherals had arrived, most projects were straining to meet the projected goals. It was easy to forgo implementation of a device which had thus far been unused. A site deciding to implement touch panels mid-way into their project would have faced increased short-term training costs with little perceived chance of long-term savings. Since the sites had not specifically requested the peripherals, they felt no obligation to use them.

Other groups, such as PERC, realized their future depended on the use of peripherals. They used the few peripherals available initially to design and test lessons. In one case, elementary mathematics authors expected that the student audience (fifth grade students) would be able to read and understand simple directions; therefore they incorporated a cursor simulation of the touch panel in their lessons. This allowed authors to write lessons which took full advantage of the touch panel, but which were still operable on terminals lacking one.

At the time the lessons and students were ready for a field test, most of the peripherals had fortunately been delivered, many of the hardware and software problems had been solved, and full advantage could be taken of all peripherals without making last minute modifications. In general, those groups that needed the advantages offered by the peripherals wrote lessons which depended on the delivery of reliable devices. They accepted the risk that these uncertainties and problems might not be resolved, and they were rewarded for their faith. Groups who did not perceive a strong need for peripherals did not use them, and though they did not reap any rewards when improved devices were actually delivered, neither did they suffer badly from their conservatism. Unfortunately however, the breadth of any evaluation of the performance of terminal peripherals was thus narrowed.

Conclusions

The conclusions of this study reflect on the hardware itself and on the decisions of the users of the hardware.

Human Decisions

The conclusions of this study can be stated briefly as "dabblers seldom succeed, shortcuts frequently aren't, and casual use is unfortunate." Phrased in these general terms, these maxims seem only common sense. Alas, this study shows that with regard to the use and implementation of peripheral devices, common sense issues plagued the authors and managers. Lacking experience, some made decisions which accented the existing hardware/software problems.

Dabblers seldom succeed. This is probably true in many aspects of PLATO use and in life generally, but it was especially valid here. An isolated author sprinkling a few -touch- commands in his lessons, converting a few slides into microfiche, or recording a few messages may never gain enough experience to make his lessons teach reliably. The investment to learn how to reliably program and operate these devices is perhaps two to five days (one day spent with an experienced user) per device. This much time is reasonably invested by an author or project which expects to make extensive use of the peripheral, but is unreasonable if little use is expected and alternatives are available. It is also true that every author need not learn all the subtleties of each device: colleagues or group members can share their experience and help review and debug lessons rather efficiently. When authors have forged ahead without experience implementing as best they knew, the results have frequently been frustrated students and discouraged authors. The students keep finding and having problems with the devices, and the author keeps investing more and more time, less and less willingly. The dichotomy between types of uses, casual or intensive, leads to significantly different opinions about the quality and value of a particular device.

Shortcuts aren't. Faced with uncertainties about the need, usefulness, cost, and reliability of a peripheral device, most authors adopted a pilot-study approach: they patched together some equipment and materials for a quick, but conclusive, tryout. In those cases when the decision was made to proceed, some authors unfortunately continued to use makeshift equipment, shortcut methods, and substandard materials for their production work. The following lessons have been learned by sad experience.

- Every owner of a sophisticated camera is not a photographer.
- Every photographer is not a qualified copy photographer.
- Every artist is not an illustrator.
- Every author cannot produce easily intelligible audio recordings.
- Many professional photographers are experienced only in portrait photography and have little expertise in "creating" illustrative photos or using artificial light to illuminate machinery components.
- The results of any shortcuts or cost saving techniques should be carefully compared to the results from standard techniques before they are implemented.
- Careful bookkeeping procedures must be adopted to prevent 35mm slides and audio messages from being lost and/or needlessly duplicated.

The findings above do not mean that only the most expensive workers and processes must be used, but rather that time and money were often wasted while trying to utilize or improve techniques and personnel which were inadequate for the job. Indeed, some very professional individuals failed to perform as well as other people who understood better the audience, the objectives of the lesson, the requirements of the PLATO system, or who had some hard-to-define "artistic" talent. For example, a University of Illinois educational graphics service group (NOT the CERL microfiche group) performed poorly in producing slides for Chanute, yet some of the best microfiche are produced from slides taken by experienced amateur photographers. Similarly, a radio announcer who prepared some elementary reading scripts did less well than PERC staff members with no professional speaking experience. The conclusion one can draw is that quality performance may be found anywhere, but it must be searched for until it is found. The products and processes associated with peripherals are highly sensitive to seemingly small factors. Therefore new users should have their lessons examined by experienced users in order to avoid obvious pitfalls.

Casual use. What may be an invigorating and novel programming experience for an author may be only boring or irrelevant to a student. The ARPA authors, given peripheral equipment they hadn't requested, sometimes implemented it simply because it was there. The result was superficial, incongruous, and unrelated to the objectives of the lessons they were writing. Experienced authors, ARPA and non-ARPA, used peripherals sparingly and focused the students' attention to meeting the objectives. For example, they made audio messages succinct and used as few as possible. They used a few well-chosen images to illustrate their lessons, focused the student's attention with circles and arrows, and tested his understanding of the information portrayed. They used the touch panel for specific limited purposes and made sure that the student knew what and where he had touched. In contrast, inexperienced users recorded long, rambling audio messages and showed slide after slide without ever telling the student what he was supposed to learn from them. These "slide shows" often seemed unrelated to the lesson objectives, but were included because the site already had the images on a microfiche. It is noteworthy that microfiche images seldom appeared in the final tests for these lessons.

Hardware Performance

Conclusions about the hardware performance must be based on incomplete information. Nevertheless, it seems warranted to draw the following conclusions.

1. The touch panel and slide selector, with adequate maintenance, are capable of supporting a great variety of educational needs. They were able to meet or exceed the requirement of most users. However, a very significant constraint may exist for users who need high color fidelity in their microfiche images. The 35mm slides needed for microfiche production must be higher than average in quality--so high, in fact, that users found them difficult or impossible to prepare. There are not sufficient data available to conclude that the audio device can support a majority of instructional needs. The only large scale test of the audio appears to have been successful, but ambiguous circumstances were present.

2. None of the terminal peripherals are so reliable that they can be used by groups unwilling to invest their own time in a regular testing and preventative maintenance program.

3. Hardware modifications for optimization of the beam touch panel have ceased. The limits of the infra-red beam technology have nearly been reached according to the inventor of the beam touch panel, Fred Ebeling. He expects the newer "conductive stripe" technology to provide higher resolution and lower costs.

4. The performance and reliability of the audio and microfiche systems have improved substantially and can be expected to continue to improve. The experience of users is being translated into genuine gains through the use of new processes, hardware modifications, new equipment designs, and continued hardware/software support. In addition, comments from ARPA authors, as well as opinions given by other users in well-read PLATO notefiles, concur that the performance of the microfiche production staff is now considered quite satisfactory.

5. There is a need for additional improvements to the software for the touch panel and the audio device and for the development of hardware support devices for the microfiche and audio systems (e.g., audio recording or duplicating aids, cameras).

6. The peripherals produced thus far can best be regarded as a series of prototypes. Many variations in design were made throughout the production periods. A definitive evaluation of terminal or peripheral performance is not possible with the current data.

7. In general, new product designs cannot be expected to be on the market for at least a year. Therefore, potential users should consider whether currently-available equipment will meet their needs, rather than relying on hardware advancements.

Appendix I: Use of Peripheral Devices by ARPA Sites

During the Summer and Fall of 1976 the lessons produced at many of the ARPA sites were examined for evidence of use of terminal peripheral devices. In order to use these devices, certain commands or coding structures must be placed in the program or lesson. These constitute "phrases" or computer-searchable strings which may be easily counted. There are limitations to the reliability of this technique: because authors often use drivers or subroutines, a single command (e.g., -slide-, -touch-, -play-) can take the place of dozens of individual commands. In fact, experienced users of the touch panel and audio device advocate using these routines. Such routines were found in only a few cases: at USC, for touch and audio commands; at North Island, San Diego, for touch commands; and to a lesser extent at Sheppard AFB, for touch commands. When this technique was employed, the use of peripherals at the above sites was under-represented in Table 4. The affected table entries are followed with a plus (+) sign. It should also be noted that the survey examined alternate forms of the above commands including -keytype-, "keys", "key", -audio-, -touchw-, -ext-.

The Aberdeen and Chanute lessons surveyed included only mainline sequence lessons listed in their student router. The Maxwell lessons surveyed were selected by the MTC staff as apparently completed lessons (the project had been terminated). The Sheppard lessons surveyed included all lessons, complete and incomplete, and probably a few non-lessons. All lessons begun 3/1/76 or earlier were surveyed on 7/1/76. For other sites, all available lessons (and unknowingly, some non-lessons) were surveyed.

Table 4

Use of Peripherals as Evidenced by Programming

Site name	Total lessons surveyed	Lessons with slides	Total commands found	Lessons with touch	Total commands found	Lessons with audio	Total commands found
Aberdeen	25	1	34	B	-	B	-
ARI	30	0	0	1	12	0	0
Chanute	39	12	261	B	-	A	-
Maxwell	10	A	-	0	0	0	0
Orlando	17	A	-	7	110	A	-
San Diego							
NPRDC	30	5	124	6	59	0	0
N Island	20	0	0	20	C	0	0
Sheppard	99	A	-	16	61+	0	0
USC	7	0	0	5	114+	1	3+

Key:

A = unsuccessful experimental use only, no student testing.

B = successful experimental use, no student testing.

C = too many commands to count easily. The San Diego, North Island lessons used touch panels as essentially the only input device.

Because the basis for sampling lessons varied from site to site, it would be inappropriate to compare between sites the percentage of lessons using a peripheral device.

The following observations about peripheral use by the ARPA/PLATO sites are supported by the data in Table 4.

1. Although many different ARPA groups tried to use touch panels, none of those listed experienced what could be considered failures. The explanation for the large number of people who attempted to use touch panels is probably based on its comparative ease of use: no extra equipment was needed to use it.

2. Many groups tried microfiche, but fewer were successful. Apparently many authors tried to use microfiche because they needed illustrations. The difficulty and slowness for preparing microfiche reduced the number of successful users.

3. Few groups saw a need for audio or had confidence they could use it. Hence only a handful of attempts to use it were made by ARPA groups.

4. Except for the use of touch by USC and San Diego, North Island, there were no users who implemented any peripheral device widely throughout all their lessons. In fact, most non-zero entries on the table reflect only one lesson or one author.

References

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