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New Information Technologies and Opportunities Regarding Input/Output Devices

Introduction

This paper presents a framework for looking at different kinds of input/output devices, and provides some general characteristics regarding input/output devices currently on the market. A more detailed version of this paper appears as a chapter in the 1981 *Annual Review of Information Science and Technology.*[1]

This paper will cover personal-use input/output devices. By "personal use" we mean those things that would normally be found at a user work station to support individuals in their work activities. These devices would also make it possible for them to communicate with one or more information retrieval systems. Not included in this particular group are card readers, line printers, floppy discs, hard discs, modems, point-of-sale terminals (which you probably have contact with every day in supermarkets), and automated teller machines (where you can get cash any time of day or night).

Table 1 shows an outline of areas covered in this paper and in more detail in the *ARIST* chapter. The upper part of the table represents data-entry devices; the lower part represents display devices. Input devices include tactile, optical and other types, while display devices include hard copy, transient image and others. Before describing these devices in more detail, we will cover briefly something about the scientific foundations that are contributing to input/output device development.

TABLE 1
INPUT/OUTPUT DEVICES FOR PERSONAL USE

Data-Entry Devices		
Tactile	*Optical*	*Other*
Keyboards	Bar-code	Speech devices for the physically impaired
Touch-sensitive displays	Optical character recognition	
Other	Light pens	

Display Devices			
Hard-Copy	*Transient-Image*		*Other*
Standard paper	CRT	Flat panel	Audio devices for the physically impaired
Electrostatic	standard	plasma	
Electrosensitive	graphics	light-emitting diode	
Thermal	viewdata	liquid crystal display	
		electro-luminescent	
		other	

Source: Turtle, Howard, et al. "Data Entry/Display Devices for Interactive Information Retrieval." *Annual Review of Information Science and Technology*, vol. 16, edited by Martha E. Williams, p. 56, Table 1. White Plains, N.Y.: Knowledge Industry Publications, 1981.

Scientific Foundations of Input/Output Device Development

The traditional technologies or sciences that have contributed in this area include electronics, optics and magnetics. But the current trend in research has a great deal more emphasis on human factors, or, borrowing from our British friends, ergonomics. Also receiving emphasis is the psychology of working with a terminal. One area, for example, where psychology is playing a crucial role is in the study of eyestrain. Studies are being conducted of people who are using terminals for extended periods of time during the day, and particularly in the newspaper industry, where video displays are used a great deal. The major emphasis is being put on psychology by researchers, who are finding that eyestrain is not just a physiological phenomenon, but also a psychological one. The feeling is that the key to market success in the future with terminals (CRTs, keyboards, etc.) will really lie with how well the manufacturers can take into account the ergonomic aspects.

There are several professional societies associated with input/output device research. Those listed in table 2 are ones that we found quite useful in putting together the *ARIST* chapter. The publications of these societies were quite rich with information on terminals. As an example, the International Research Association for Newspaper Technology (IFRA) report series includes a great deal of information on ergonomics. The material on keyboard layout presented later in this paper is taken from one of their reports.[2] Also, the Institute of Electrical and Electronics Engineers (IEEE) and the Institute of Electronic Engineering (IEE) have extensive information that is useful. If you include publications of the Human Factors Society, the Ergonomics Society and the Society for Information Display, you can find out almost everything you want to know about data-entry and display devices, in terms of what is available in the published literature.

TABLE 2
RELATED PROFESSIONAL SOCIETIES

Electronics Industry Association
Ergonomics Society
Human Factors Society
IEEE
IEE
IFRA
Optical Society of America
Society for Information Display
Society of Photo-Optical Instrumentation Engineers

Also associated with input/output devices are a series of standards. We do have some standards in this area. Table 3 presents these in three major categories: communications standards, standards related to character sets displayed on these terminals, and the ergonomics (primarily the keyboard layout). A companion to this list is a list of organizations concerned with these standards (see table 4). At the international level there is the International Telephone and Telegraph Consultative Committee (CCITT). The American Library Association has standards on character sets. The IFRA is involved in keyboard layout and radiation standards. The government is involved via the National Institute for Occupational Safety and Health in terms of radiation levels for terminals. We would expect to see more standards coming out in the future with respect to terminals, particularly because there is going to be approximately a 20 percent annual growth rate in terminals over the next few years. With more and more terminals, there will be more pressure for standardization.

TABLE 3
RELATED STANDARDS

Communications:
EIA RS 232
CCITT v. 24
Character Sets:
ALA
ASCII
EBCDIC
Ergonomics:
ANSI X4.14 (Keyboards)
BS 2481

Source: Turtle, Howard, et al. "Data Entry/Display Devices for Interactive Information Retrieval." *Annual Review of Information Science and Technology*, vol. 16, edited by Martha E. Williams, p. 59. White Plains, N.Y.: Knowledge Industry Publications, 1981.

TABLE 4
STANDARDS INFORMATION FOR DATA ENTRY/DISPLAY DEVICES

American National Standards Institute
Electronic Industries Association
International Telephone & Telegraph Consultative Committee
American Library Association
International Research Organization for Newspaper Technology (ergonomics)
National Institute of Occupational Safety & Health
Occupational Safety & Health Administration
National Bureau of Standards
International Standards Organization

Source: Turtle, Howard, et al. "Data Entry/Display Devices for Interactive Information Retrieval." *Annual Review of Information Science and Technology*, vol. 16, edited by Martha E. Williams, p. 59. White Plains, N.Y.: Knowledge Industry Publications, 1981.

Data-Entry Technology

Table 1 shows tactile, optical and other types of data-entry technology. All of these are mechanisms by which you can convert some kind of mechanical or physical effort into a machine-readable form or an electronic form. The earliest form of data entry for computers was actually a series of toggle switches. It was not very user-friendly, except to programmers. Programmers were the only ones who were really interacting with the machine. Actually, this technique is coming back now. There has been some experimentation with a series of five keys that can be played like a chord on an organ. You can get many different combinations from five keys, taken *n* at a time. On most keyboards, however, each key corresponds to one letter and translates the mechanical movement into a binary electronic impulse. We do not think about that when we push the key for *A* or for the number *1*, but what we are really doing is nothing more than setting a series of toggle switches, as it used to be done in the older systems.

Keyboards, which are currently the most widely used data-entry devices, can be characterized by a number of features: the number of keys, the layout, the coding technique used (i.e., the way in which the user can look at the key and see what the key stands for), and the cost of the keyboard. Typically, a keyboard layout will have anywhere from 12 to 220 keys. The 220-key keyboard layout would be for something like the Japanese alphabet, and even that would not be the full character set. An example of keyboard layout variation is presented to us every day. The data-entry Touch-Tone key pad and an adding machine key pad perform the same function, yet are laid out differently. The Touch-Tone pad begins with *1* in the upper left-hand corner and moves to the lower right-hand corner. The adding machine goes from the lower left- to the upper right-hand corner. So even with something as simple as that, we have not standardized the keyboard layout yet. The "QWERTY" keyboard is the typical typewriter keyboard, having *Q, W, E, R, T, Y* in the upper left portion of the top alphabetic row. As far as the coding is concerned, the legends may appear on the keys themselves, and keys may have multiple legends appearing on the top and front surfaces of the keys. There can also be as many as two or three on each surface of the key. That can be quite confusing, and probably anybody who does not touch type must really search to find the symbols.

There has been some development work recently at Bell Labs on a virtual keyboard that projects symbols onto just the keys which need to be used at a particular time. Because a telephone operator may have a keyboard with several hundred keys on it, only the keys that need to be used for the next function are lit, and symbols are projected onto them from above. The next function that an operator performs may be different, so the keys will have different symbols projected onto them. This represents a very sophisticated "overlay" approach, with the symbols being projected onto the keys. A much simpler approach involves a small plastic template which is laid over a keyboard and has a set of symbols on it. This template can be changed to alter the symbols. Finally, the caps on each key can be changed so that special symbols can be placed on particular keys. In putting together a keyboard with function keys, for example, special caps can be placed on those function keys with the label indicating what that key is to be used for.

Costs of keyboards now range between $25 and $100 for the keyboard itself. Terminal manufacturers used to rely on custom-built keyboards, but they are now moving toward more standardized and mass-produced keyboards. This helps to lower the cost of keyboard data-entry systems.

Figure 1 shows by individual finger of the right and left hand the work load that currently exists for each finger using a "QWERTY" keyboard. The right hand has actually less work to do than the left hand. Furthermore, the distribution of work across the fingers is not even. Despite these shortcomings, this keyboard has been around for a long time. Figure 2 illustrates the results of some research reported by IFRA with a different keyboard layout.[3] This layout distributes the work more evenly between the two hands, and actually puts more work onto the right hand. One might think that definitive research had been done years ago, but because there are so many terminals and people are using so many keyboards this is only now receiving major emphasis. Years and years ago, when typewriters first came out, many of the keyboards were arranged in alphabetical order. We may see a return to that, because also being considered along with the layouts in figures 1 and 2 is the alphabetic key layout. Practically speaking, when you are using a one-finger approach to data entry, the keyboard might as well be arranged in alphabetical order.

As for other data-entry devices, there is the touch-sensitive screen used in computer-aided instruction, industrial control, and information storage and retrieval. It involves picking out a spot on the screen and touching it, and thus allows the user to have a virtual keyboard like the one being developed at Bell Labs, but in a simpler form. In this case, the keyboard is on the screen. A system designer can lay out a new keyboard on the screen as it is needed. The techniques used in this kind of touch-sensitive approach include a criss-cross of infrared beams, wire arrays or acoustical waves. Another approach involves multiple layers of some kind of conductive material. A unique voltage is generated at each spot of the screen that is pressed, so the system knows where the screen has been touched. These techniques are typically applied to a CRT or a plasma panel.

Other devices used for data entry are not quite so popular. These include the joy stick, which can be used to move the cursor, and is simply a small control lever. This device is used extensively in arcade games. It is also used in graphics, because it enables rapid movement of the cursor and represents a low-cost alternative to the light pen or to some other kind of touch-sensitive entry device. Similar to the joy stick is a mouse, which is just a little device that can be moved around on a flat surface. The device has a tracking wheel which indicates how far and in what direction it has been moved, and correspondingly moves the cursor on the screen in the same way. It is another low-cost alternative to the light pen. Finally, there is a digitizing tablet, which is somewhat like a touch screen, except that it has a much higher resolution and cannot be mounted over a display screen. It is used to locate something very accurately on a page. Its use is not as great in information retrieval as in cartography or where fine drawings are involved. An 8½″-by-11″ digitizing tablet would typically cost about $1000.

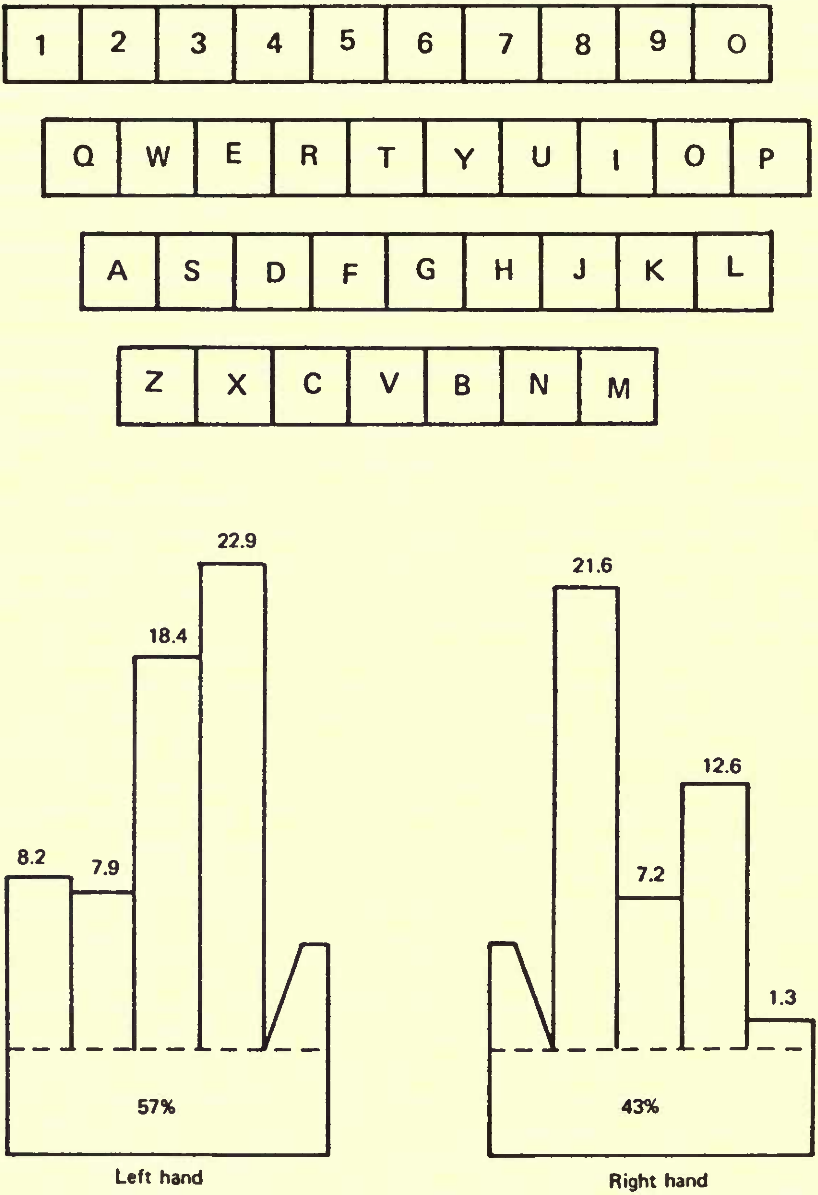

Fig. 1. The QWERTY Keyboard Layout and Workload Distribution

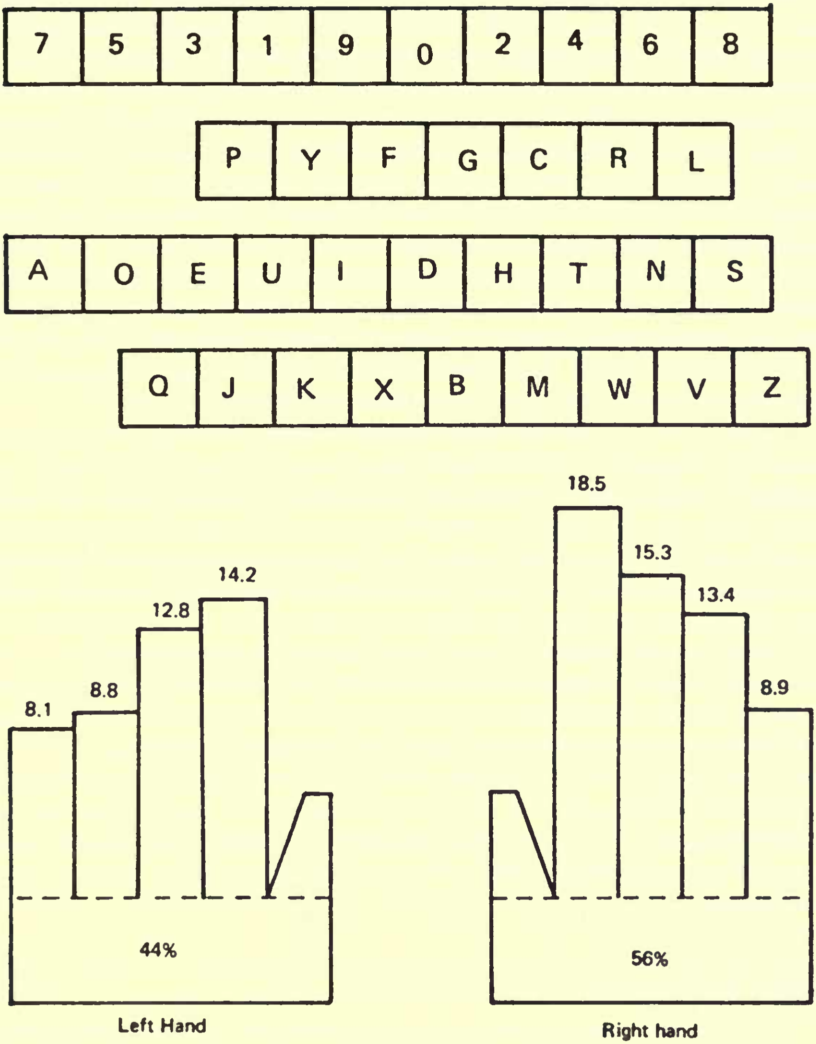

Figure 2

Source: Hart, David J. *The Human Aspects of Working with Visual Display Terminals* (International Research Association for Newspaper Technology Report No. 76/02). Feb. 1976. (Available from: IFRA, Washington Platz, 1-61 Darmstadt, West Germany.)

In addition to tactile entry devices, there are also other types of data-entry devices, the most widely used of which is the bar-code reader. It is used not only in circulation systems but, probably more widely, in inventory control systems. There are a number of different codes available, including Universal Product Code (UPC), Codabar and Code 39. These are all described in a 1978 National Library of Medicine report.[4] A bar-code reader typically uses either visible, infrared or laser light to sense the difference in hue and/or width of the bars and spaces between. Another type of device is an optical character reader, which is very much like a bar-code reader except that instead of reading bars, it reads a full character. There is an advantage to an optical character reader in that it operates on a human-readable image, but it also has a much higher error rate than a bar-code reader. Thus, there are tradeoffs, and the designer must decide what factors are most important for a particular application.

Light pens, unlike bar-code readers, respond to light rather than emitting it. Typically, they are used in conjunction with a CRT. The user touches the pen to a CRT, and the electronics of the device indicate where on the raster the pen was placed. In this respect it is like a touch-sensitive screen, and typically is used in graphics. It is also being used in information storage and retrieval systems where a menu-selection approach rather than a command-driven approach is involved.

There are other kinds of data-entry devices, such as speech recognition. While there is a lot now being said about speech recognition, practical applications are limited to a vocabulary of fewer than 250 words, and the device must be "tuned" to a particular speaker to be reliable. So while speech recognition has an exciting future, it is certainly a distant future. Also, there are devices with Braille keyboards that can be used by the visually impaired, and some work stations for quadraplegics are available at which programming and data entry can be done without the full use of one's hands.

Display Technology

The two basic approaches to data information display are hard copy and transient image. These approaches can be characterized in a variety of ways, including the manner in which the characters are represented. One method uses a matrix for forming a character, which is fast but not of print quality (unless the matrices are shifted and overlaid). Typically, a fully formed character rather than a matrix character is used for high-quality work, but is associated with higher cost and a lower print rate. Another means of characterizing display devices is by the method of printing. The two methods are serial (one letter at a time) and line (an entire line at one time) printing. Finally, display devices can be characterized by the kind of content to be printed, i.e., graphic and/or text.

With respect to hard-copy devices, one should consider the type of paper that is going to be used. Many printers use plain paper, particularly impact printers, which usually incorporate a fully formed character as opposed to a matrix character. Also there is xerographic printing, where a toner is bound to the paper through some electrostatic means; and ink jet printing, where the ink is charged electronically and adheres to the paper. There are also many hard-copy devices that use special paper—either heat-sensitive, light-sensitive, or electrical-charge-sensitive. Finally, there are some hard-copy devices that can produce color copies. At least three ribbons with three different colors would be required for an impact printer to produce a color hard copy. It is also possible to have multiple ink jets. Xerography can produce color prints as well, but it is quite expensive and not typically found at an individual work station.

Transient-image devices are very useful where no hard-copy record is required of the retrieval session. There are several advantages to transient-image output devices. They can operate at higher speeds, have lower purchase and operating costs, and are not as noisy as hard-copy devices. They also have lower maintenance costs and longer life, but they do have disadvantages. They are bulky, heavy and not easy to move around; they are more fragile than the newer hard-copy printing devices; and they operate at higher voltages. The most widely used transient-image device, of course, is the CRT which can be characterized by how the tube is scanned.

Raster scan means row-by-row, and is the most common method. Also found with some high-quality graphics devices is random scan or vector scan, typically used in very high-resolution devices. A CRT tube can be characterized as having low, moderate or high resolution. Low resolution, which we see when watching television, has 525 lines per screen. The moderate or normal CRT screen, used for most data input/output terminals, has 600-800 lines, with a 5 by 7 or 8 by 10 dot matrix. The very high quality graphic screen requires tremendously more storage than the regular CRT. It typically has a resolution of up to 4000 x 4000 pixels, or bits, on the screen.

The cost of a keyboard is $100 or less. The normal CRT cost is anywhere between $70 and $150. When these are packaged together, including the data-entry device, the CRT, the power supply, etc., the cost can be anywhere from $600 to $3000. For CRTs we expect to see a general cost reduction continuing, with color becoming more common and less expensive. There will be larger screens on the CRTs in the future, with improved resolution and increased intelligence via microprocesser technology.

In addition to the CRTs, there are other transient-image displays, including flat panel displays. These devices are typically compact and portable, with a character limit that is much lower than a CRT. One of the most widely used is the plasma panel which was developed at the University of Illinois. The plasma panel allows information to be projected via a rear screen projector in addition to displaying computer-transmitted information. Other types of flat panel displays include the light-emitting diode (LED), which is usually used for single-line displays. An LED is low in cost, operates on very simple circuitry, and is used extensively in small calculators. There is also a liquid crystal display (LCD) which, in many respects, is like the LED in terms of size and character capacity. Its physics are quite different, however, because it reflects light rather than emitting it. Therefore, the LCD works very well in bright light, whereas the LED may lose the image under bright light. Other device types include electroluminescent displays and audio-response systems. Texas Instruments has probably made the audio-response system most popular with a low-cost chip that is used in its game Speak and Spell. There are also output devices for the physically impaired involving tactile output and speaking terminals.

Table 5 shows how various input and output techniques are incorporated in user terminals today. Other combinations may be available, but this matrix represents what is typical in the marketplace. In many cases, more than one input/output technology is present in the same terminal. For example, it is now possible to find a CRT with a hard-copy printer built into it, instead of having a hard-copy printer attached to the side of it; a keyboard may have a joy stick or bar-code reader attached or built in.

Trends in Input/Output Devices

Finally, trends in the area of input/output devices may be divided for comment into two general areas: technology and applications. Improved technology will lead to lower prices. The less expensive terminals will be priced even lower than they are now. Some of the factors causing this decrease in price include annual reductions of as much as 40 percent in the cost of memory components, 25 percent in logic components, and 10 percent in communication components. Terminals that now cost just under $1000 will drop to under $600. There will be improved displays, and much more intelligence available in the displays. At the high end of the terminal line, where costs are $3000-$4000, there will be much more capability than is available today. None of these are fantastic predictions, but represent the most likely trends for terminals now and in the next few years. Do not look for use of voice data entry, for example, in the near future. Keyboard data entry and the CRT display will continue to dominate the

TABLE 5

COMBINATIONS OF INPUT AND OUTPUT TECHNIQUES IN USER TERMINALS

	Full Keyboard	*Numeric Keypad*	*Touch Sensitive Display*	*Mouse/Joy Stick*	*Graphics Tablet*	*Bar Code Reader*	*OCR*	*Light Pen*	*Speech Recognition*
A. Input/Input									
Numeric Keypad	X								
Touch Sensitive Display	X	X							
Mouse/Joy Stick	X	X							
Graphics Tablet	X	X		X					
Bar Code Reader	X	X							
OCR	X	X							
Light Pens	X	X			X				
Speech Recognition	X								
B. Input/Output									
Standard Paper Hard-Copy	X	X							
Special Paper Hard-Copy	X	X							
Television	X	X		X					
Standard CRT	X	X	X	X	X	X	X	X	X
Graphics CRT	X	X		X	X			X	
Plasma Panel	X	X	X						
Speech Synthesis	X	X							X

Source: Turtle, Howard, et al. "Data Entry/Display Devices for Interactive Information Retrieval." *Annual Review of Information Science and Technology*, vol. 16, edited by Martha E. Williams, p. 72, Table 4. White Plains, N.Y.: Knowledge Industry Publications, 1981.

market; millions of these will be in use. Resolution will improve on display units; custom fonts and better graphics will be available. Stand-alone work stations, as used for word processing, will also be used as terminals much more widely. Because these units will proliferate, there will be a desire to link them together, and there will be more and more high-speed local networks, as well. There will be more touch-screen capability because of the increased public use of input/output devices. (Somebody can make a fortune marketing a liquid that cleans fingerprints off the screens of CRTs.) We can expect terminal installations to continue to grow at a rate of 18-20 percent in terms of numbers of terminals in the field. Terminals already outnumber typewriters in many offices. There will be more flat panel displays, particularly in the hand-held devices, whether they be games or computers.

As far as applications are concerned, it has been predicted that 30 percent of the homes in the United States will have some form of videotex terminal by 1992. Actually many of them already do (in the form of a regular television set), but we will start to see more and more videotex terminals, whether they use a standard television set or a special terminal. There will be greater use of electronic mail as postage rates go up; as a result, there will be more terminals for people who want to use the electronic mail capability. Teleconferencing will increase as travel costs rise. Teleconferencing involves not just sending words back and forth, but also sending graphic images, drawings, or pictures of yourself, so a person can watch you talk and also look at an illustration. We will see more special-purpose terminals for teleconferencing. Word processing will have a major influence on the terminal market, with its requirement for displays with much larger capacities than we currently have. These applications require the display of multiple pages on screens accommodating up to 160 by 160 characters.

Finally, there will have to be significant improvement in human factors, including keyboard design. We need a good virtual keyboard. Display devices that lend themselves to the use of multiple windows for displays will be required. With such devices one can arrange a display the same way he or she would arrange sheets of paper on a desk, or arrange three-by-five-inch index cards. We still have a long way to go in entry/display device development, but the market is there, and so are most of the technologies. The human factor will be the key to major improvements.

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3. Ibid.

4. National Library of Medicine. Lister Hill National Center for Biomedical Communications. *Machine-Readable Identification Systems for Library Materials* (Lister Hill Contract Report CR 7801). Washington, D.C.: Lister Hill National Center for Biomedical Communications, 1978.