KEYBOARD DESIGN AND OPERATION:
A LITERATURE REVIEW

Texas Transportation Institute
Human Factors Division
Texas A&M University System
College Station, Texas

Keyboard Design and Operation:
A Literature Review

R.D. Huchingson
L.J. Lampen
R.J. Koppa

Contributions By:
S.L. Stealey
S.A. Wolstein

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Review of recent literature on data entry devices, keyboard layouts, slope, height, and other ergonomic considerations, chord keyboards, touch screens, and panels, and comparisons of alternative methods of data entry. The topic of abbreviations relevant to data entry is also briefly considered.

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PREFACE

This research was sponsored by the U.S. Army, Human Engineering Laboratory, Aberdeen Proving Grounds, Maryland under Task Order DAAD05-84-C-0153. This is volume 1 of 2 volumes under the general title of "QWERTY Literature Search and Research Recommendations." V 1 contains the actual literature review. Vol. 2 consists of fiv ports of individual studies conducted in this project. Research Recommendations have been submitted to the U.S. Army as an unsolicited proposal entitled Human Factors Studies of Data Entry Devices and Techniques on February 14, 1985 and are reproduced as part of Vol. 2.

The project team for this effort included Rodger J. Koppa, P.E., Ph.D. Principal Investigator, R. Dale Huchingson, Ph.D. Task Leader, Literature Review, and

Lowell J. Lampen, B.S. Researcher
Sheryl L. Stealey, B.S. Researcher
Sheldon A. Wolstein, B.S. Researcher
Ruth E. Fleming, Technical Writer
Martha J. Kacer, Senior Secretary
Teresa T. Tenorio, Word Processor Operator.

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INTRODUCTION

D.G. Alden, R.W. Daniels, and A.F. Kanarick, Human Factors Principles for Keyboard Design and Operation - A Summary Review, St. Paul MN: Honeywell, Inc., S&RC Research, March 1970.

All literature reviews on keyboard layout start with the definitive article published by Alden and his associates in 1970.

This was the most comprehensive review of keyboard design up to 1970. After reviewing the literature, Alden did what all human factors articles should do--abstract certain conclusions and design recommendations (p. 289-290). However, there were some contradictions, e.g., recommending 0.5 diameter keys, but then saying that miniaturized keyboards had little effect on self-paced or sequential operation. The question remains: when are keys too small? It may be when their diameter is less than a 95% male finger width. Anything smaller may require a tool (like a pencil eraser) for random operation. Pocket keypads are used by maintaining the 0.25 key separation, but there are occasional bumping-error entries.

Alden's review deals with ergonomic (physical interface) issues, rather than processing issues. On layout he advocates the touch-telephone format for numbers, but takes no design position on alphanumerics. The Dvorak and alphabetic key layouts are mentioned (p. 283). There is substantial evidence against the alphabetic for text entry (the QWERTY wins hands down), but the issue may not be dead for occasional entry (one hand) by the novice. Regarding the Dvorak, it is certainly not the ultimate layout, but a slight improvement over QWERTY. Alden states the QWERTY is the "de facto standard for communications and computer interface keyboards." However, more recent sources state that ANSI permits the Dvorak as an alternate layout.

Numeric keyboards were limited to only the telephone and calculator layouts in Alden's discussion (except for the obvic inferior levers and knobs). Nothing was given on function keys, and even today calculators are not standardized on the order of +,-,X, and -, much less other mathematical functions. This is a major area for research.

Alden also mentions research on using touch-tone telephone keypads for alphabetic entry. The issue is raised of how to best map multiple letters into one key and select a given character. Left and right control keys to select one of three characters was proposed by Davidson while Kramer tested that concept against multiple presses to designate the position. Kramer found control keys more accurate, but both methods had high error rates. Smith and Goodwin even recommended ignoring which of the three letters was intended, presumably on the assumption that longer names would still be unique in their patterns. This sounds very risky. Neither would split-function keys be trustworthy if this refers to striking one of two surfaces. Shift keys are used in Japanese keyboards, of necessity, but multiple shift presses would invite errors (like Kramer found) and greatly retard typing speed.

In summary, the Alden review was a landmark paper in its time, but new problems and technology have dated it. It is an excellent source of research topics.

DISCUSSION

DATA ENTRY DEVICES (General)

This review begins with a group of three articles that (cross many different topics in data entry hardware and associated software. The first, by I.G. Umbers, covers state-of-the-art and recent research on a wide variety of input approaches. Recent revisions to MIL-STD-1472, the definitive standard for human factors in the Department of Defense and related industries, bring in much new material specific to data entry. The most recent revision in hand (MIL-STD-1472C, Revision of 1 Sept. 1983), is summarized with commentary.

Paragraph 5.4.3.1.3, "Keyboards," in MIL-STD-1472C (1981 Revision) is also critiqued in this section of the literature survey. This paragraph in upcoming revisions to 1472 will expand into a section in its own right, but to date it still references 1280 as the governing standard for keyboard arrangements.

Finally, a wide-ranging software design review by Williges and Williges gives a number of insights into user input devices. These insights are discussed to complete the review of what are considered to be the most helpful reviews of data entry devices in general.

I.G. Umbers, Review of Human Factors Data on Input Devices for Process Computer Communications, National Technical Information System, NTIS #PB83, Report #259366, December 1983, 17 pages.

An excellent review of recent research on new devices. This document begins with a brief review of Alden's criteria and the layout issues. Under "other types of keyboards," Umbers discusses the use of unlabeled pushbuttons and CRT displays of functions. One "virtual" keyboard uses a mirror image somehow to display functions in the same plane as the keyboard surface. Obviously, computer control provides more flexibility than "dedicated" keyboards but what it does to lea ng and error rates is unknown.

Another feature is double action. Lightly touching a key back-lights the button on the screen; heavier pressure executes the function backlighted. This is said to overcome the problem of association of buttons and labeling shown on the screen.

Computers may also aid inputting by backlighting those which should be struck (for syntactical correctness) while locking out those not backlit, thus making certain errors impossible.

Other input devices are discussed. While knobs and levers are slower than keyboards, touch devices, where applicable, are faster and easier to learn than keyboards (for air traffic control applications, for example). Voice is also fast, but Klemmer found that for entering digits it was tiring, boring, and disliked in comparison to keyboard entry. Another study found that light-guns and light-pens were faster than keyboards for tasks involving positioning of cursors on a point of the screen. Light-pens are faster than joysticks or tracker balls for designating targets on a screen. However, another study dealing with cursor positioning on words found the mouse was faster and less fatiguing than the light pen. The mouse tends to jump and skip occasionally.

Data tablets (analog of the screen activated by a stylus) were found in one study (English) to be slower than the mouse for target identification, but good for word selection rather than individual characters.

Touch-wire displays are faster than typing for pointing applications, but their unreliability tends to make operators [illegible] more slowly. Touch displays are also faster for entering alphabeti[illegible]a, but only when a limited vocabulary is used (as in process control situations). For text entry, they would not likely be as fast.

From <u>MIL-STD-1472C</u>, Paragraph 5.15 User-Computer Interface
Revised 1 Sept. 1983. (Notice 1)

Approximately 18 pages on User-Computer Interface have been appended to 1472C, the Military Design Guide. There is little evidence of quantitative criteria except Table 24 giving maximum acceptable <u>system</u> response times for various keying tasks. These refer to how long it takes the system to react to a human input, not human response time.

Paragraph 5.15.2 (Data Entry) is broken down: (1) General (2) Keyboard (3) Fixed Function Keys (4) Variable Function Keys (5) Lightpen (6) Joystick/Trackball. Paragraph 5.15.3 (Data Displays) is broken down into (1) format (2) content (3) coding (4) dynamic displays (5) tabular data (6) graphic displays (7) textual data displays (8) text/program editing (9) audio displays.

In addition to data entry and data displays, other subtopics include: interactive control, feedback, prompts, error management/data protection, system response time (above), and "other" - avoid overlays and provide hard copy.

Do not expect very definitive guidelines. This is a first effort and tends to avoid specificity with words like consistency, standardized, and "as required." Largely, it reflects the state-of-the-art in technology as it existed in 1980 rather than exclusions of certain technology or designs based on research. The following are extracts paraphrased by the reviewer (Data Entr: ~ ~y):

(1) General

- o Data entry shall be user paced.
- o Provide positive feedback.
- o System must provide indication of delay to user.
- o Explicit action (e.g., depress ENTRY key) must be required.
- o Data entry should be validated before another transaction can begin.
- o User is not required to enter data already in the software.
- o Cursors must have a "distinctive visual attribute" and not obscure display entities.
- o Cursor home position should be consistent across types of display.

(2) Keyboard (See also p. 30 of the 1981 1472C)

- o User to enter alphanumeric and special characters.
- o Configuration - See MIL-STD-1280.
- o Key inputs are echoed within 0.1 s.
- o Automatically justify columnar data (left, right, decimal point).
- o Keypad required if "substantial numeric input."
- o Minimize amount of keying by numbered lists and abbreviations.

(3) Fixed Function Keys

- o Use for time-critical, error-critical, or frequently used inputs.
- o Standardized (how?).
- o Once assigned, do not reassign for a given user.
- o Minimize lockout. Function controlled is continuously available.
- o If non-active, use blank key.
- o Group them logically and place in a distinctive location.
- o One press or activation only.
- o If no immediately observable natural response, provide system feedback.
- o Labels on keys are displayed always (direct marking preferred).

(4) Variable Function Keys

- o Use for programmable menu selection or entry of control functions.
- o Display status when the effect of a function varies.
- o Provide visual warning for keys with labeled default function which are turned off.
- o Provide for easy relabeling.
- o Do not use shift keys to select a variable.

(5) Light Pen

- o Use when a non-critical, input function is required (item selection mainly).

- o Discrete actuation device. Prefer a push-tip switch (?) of 2-5 oz force.
- o Feedback required on placement, pen actuated, and inp received. Preferred placement technique is an illumin circle projecting from pen to screen.

(6) Joystick/Trackball

- o Use when precise input functions are required. Design according to paragraphs from 1981 MIL-STD-1472.

Conclusions

As stated earlier, the guidelines are largely telling the designer to use what is available on the market (with a few restrictions). For example, it does not say a light pen sensor must be responsive to a certain range or that the pen must be designed a certain way or that the display must be tilted. What limited research exists has not impacted design standards in MIL-1472C.

From MIL-STD-1472C, Paragraph 5.4.3.1.3 Keyboards. 1981.

The 1983 Revision is better organized than the earlier 1981 guidelines reviewed here. However, the guidelines are much less specific. Keyboards are listed as one of the many topics in Paragraph 5.4 which include rotary switches, thumbwheels, knobs, cranks, pushbuttons - all mentioned before keyboards. It is simply an arrangement of pushbuttons.

The following is information not already mentioned in the 1983 Revision.

1) Use 3X3X1 matrix (with zero in center) for numeric entı (Note: the word "keypad" is not used.)

2) See 1280 for configurations. If the application varies from numeric sometimes to alphabetic other times, two options exist: (a) with no separation between alpha and numerics; (b) separate keyboard to the right for numbers.

3) Table 10 lists criteria for dimensions, resistance, displacement, and separation. Although 0.5 inch is preferred, 0.385 to 0.75 inch is permitted. With arctic mittens, use 0.75 inches. Separation is 0.25 at edge.

- o Resistance - 0.9 to 5.3 oz for alphanumerics and "dual function." 3.5 oz - 14.0 oz for numerics. (Note the greater resistance. No accidental actuation for critical military applications.)

- o Displacement - 0.05 - 0.25 inch for alphanumeric, but slightly less for numerics and dual function (0.03 - 0.19 inch). Not clear why less displacement, but more resistance for numbers. (Membrane keyboards are banned.)

4) Although ranges are given in (3) a given keyboard must be uniform for all keys. (Select one value and live with it.)

5) Non-portable keyboards shall have a slope of 15-25 degrees

(17-18 preferred). (Low-profile keyboards are banned in the military.) However, if it is portable no restrictions exist except user preference. (Not clear if this means to provide an adjustment capability.)

6) Standardize configuration when systems have more than o-- keyboard.

7) Feedback required is (a) a particular key was pressed (b) the next operation as applicable. (Does not say if feedback is in the form of kinesthetic, click sound, or visual cue. Kinesthetic implied in resistance above.)

Beverly H. Williges and Robert C. Williges, Dialogue Design Considerations for Interactive Computer Systems, Human Factors Design Review, 1984.

Although this was principally a review of software design consideration, one section titled "User Input Devices" may be helpful. Here are a few design recommendations:

- o Use single-entry devices to avoid wasting time switching between devices. (Not sure if this means use one or means avoid chording.)
- o When there are many selectable items in a menu, type rather than use the light pen. It is faster for inexperienced users.
- o In graphic applications where very-high-resolution location is required and a command language, enter screen locations by keyboard.

Special-Function Keys

o Use special-function keys for cursor control when both data entry and position designation are required. Keys are used when the command language is limited and there are many commands rather than parameter values. (They avoid syntax errors and input time in typing out commands.) Examples: NEXT PAGE, BACKUP, CONTINUE, HELP, OPTIONS, DITTO, HARD COPY. Also, a key to turn off noncritical alarms is necessary.

o Never have the pushing of another button twice for CONFIRM.

o Direct marking is preferable, but key caps and overlays are okay if "use of keys varies across users." When a single key is used for different functions, provide alternate self-illuminated labels to tell which function is current.

o If direct marking or overlays are impossible, display assigned key functions on the screen. However, never reassign a key a different function for a given user. Avoid "shifted characters" if possible.

o If a special-function key is not needed for input it should be temporarily disabled by computer control. When it is enabled it should be backlighted (if it is not always active).

o In general, repeated activation is discouraged. (This is assumed to mean avoiding shift keys or certainly multiple presses.)

Cursor Control

o Cursor "dialogues" are for interactive graphics and menu selection.

o Make the cursor move at a rate of at least 9 to 12 inches per half second, in any direction. If cursor position is in discrete steps, the step size should be the same - vertically and horizontally - and the step size should be the same as the selected character size. Also, if there is "proportional spacing" of text, cursor movement should be automatic. (This probably means that if there are spaces between lines, the cursor should move directly to the next entry line.)

o If the cursor is used in interactive graphics, the displayed target for the cursor should be at least 10 times the size of positioning accuracy required (or a quarter inch minimum). Tł recommended tremor is needed because of inaccuracies in placing a cursor directly over a target position.

o Continuous locators (like a trackball) are faster than special-function keys. If actuated by keys, they should be able to direct movement up-down-left-right and not be limited to lines. Provide a "point designation" feature for fine position accuracy (unillustrated). Cursors are usually limited to one character accuracy.

o Placing a cursor correctly is not the same as data entry. An "explicit user action" should effect actual entry of a position into the computer.

o Sometimes one cursor controls alphanumeric entry and another cursor controls tracking. These cursors should be "distinct"; if the same control is used for both there should be a clear indication which cursor is under control; if different controls are used for entry and tracking they should be "compatible" in operation.

Pointing Controls

Non-cursor (direct pointing) controls are light pens and touch panels. However, nothing is given about touch panels, other than that they should be "considered for menu-based dialogues." Both are good for item selection (menus) and position designation (when it is the primary type of data entry).

o Light pens are recommended for gross drawing or tracking moving objects and/or when the operator is unfamiliar with commands and functions of the system.

o Do not use pens for precise control because of "the [illegible] aperture, distance from display surface, and parallax." The [illegible] s said to be awkward to use and, left-handed users should be excluded.

o Having said this, they say accuracy in graphics can be improved by changing the scale of the drawing (enlarging details) and in item selection by permitting anywhere "within the area of the word or number" to specify the character. (The sensitive area should be the <u>label size plus one-half</u> the character's distance around it.)

o Writing on vertical surfaces may be tiring so the screen should be horizontal if there is over 15 minutes of continuous work or if used more than once every five minutes.

<u>Continuous Controls</u>

o A trackball (assumed to include the mouse) is better than a light pen or joystick for drawing straight lines or circles (Ramsey and Atwood, 1979). The only mention of the mouse is for text editing (word selection) where it is said to be faster and more accurate than tab keys or other cursor control keys. The trackball again should be used in graphic applications requiring positioning and selection. Joysticks are not as accurate, however, the available design recommendations relate to the joystick. They are (1) support the user's palm or forearm; (2) use a rotatable center shaft for 3D positioning tasks; (3) use a miniature isometric joystick.

o When the task involves controlling objects on a graphic display, direction of motion of the users hand should be identical to direction of movement of the displayed object.

o When graphic editing with mouse or trackball, "the use etches a simple pattern which is recognized and matched to a set of p fined patterns associated with commands."

Graphic Tablets

Graphic tablets were not defined or illustrated. Nothing is given on their merits in comparison to a trackball or light pen. However, the flat statement is made that a stylus with graphics tablet should be used for graphic entry. The guidelines relate to hand-printed characters. (Forty characters per minute recognition is very slow compared to 200 per minute when typed.)

Graphic tablets are also used for technical illustrations (block diagrams rather than freehand).

Summary

The Williges' literature review is of secondary interest to dialogue design. They extracted statements from 16 primary references and numerous secondary references. But no background information was provided so that only a person very familiar with the technology is likely to understand what they are discussing. The review needs illustrations and examples of succinct statements and lingo.

Many of the guidelines indicate when to use a particular device, but the recommendations are contradictory coming from different sources. Which statements are based on research is not known. Neither is any attempt made to summarize in a table, as others have done, when to use certain devices. The design recommendations are more for inferior systems (light pen, joystick) than for the more promising systems they recommend.

KEYBOARD SPECIFICATIONS AND EVALUATIONS

The classic specification for keyboard arrangements in the Department of Defense is MIL-STD-1280, "Military Standard Keyboard Arrangements" dated January 1969. There is an excellent chance t this standard will not be revised to the present, but incorporated in the more general MIL-STD-1472, "Human Engineering Design Criteria." In paragraph 5.4.3.1.3, "Keyboards," the same topics would still be addressed. MIL-STD-1280 requires deletion of references restrictive to "typewriter" which is an obsolescent device, and, of course, to manual versions of the typewriter (type II). Sixty-four character teletypes will undoubtedly be obsolete when this standard is updated, and need not be covered. A number of function keys unknown in 1969 must be added to 1280, and the whole area of designatable function keys and their location needs to be addressed.

Commentary on MIL-STD-1280
Military Standard Keyboard Arrangements

1.1 Scope. 128 keys corresponding to MSCI II in "typewriter-like" keyboard for application where textual information has a h alpha content....(and) high numeric content.

- o Should not restrict to "typewriter"
- o Should include mixed alpha-numeric explicitly
- o Uses of keys not MSCII code related e.g., functions, cursor movement.

1.2 Purpose. OCR probably unnecessary as separate call out.

2.0 REFERENCED DOCUMENTS

(Needs updating from our bibliography)

3.0 DEFINITIONS

Add: Keypad

Enter

CR

Alt

Control

Scroll

Line Feed

3.2.0 Type I and II distinction no longer required.

3.2.1 No more manual typewriters.

4.0 TYPE I, CLASS 1 ARRANGEMENT

4.2 This language should be in 1.1 Scope, as it defines limit- -f specification. The 1280 does not deal with

- o Key spacing
- o Keyboard slope
- o Size/shape of keytops or spacebar,

only layout.

Research question: should MIL-STD-1280 be expanded to encompass one or more of these aspects of entry devices?

4.4 Partial Sets. This paragraph would be the logical callout for keypads, although these devices might be better handled by a separate paragraph.

4.5 - 4.17 General Comment - Somewhat obsolete restrictions and options on miscellaneous function and character keys. Suggest complete rewrite, either referring to a comprehensive layout drawing or explicitly to

(a) character key designations

(b) special character key designations

(c) function key designations.

Only those designations required should be listed.

Options/alternates should be handled in separate paragraphs.

Current keys addressed:

SHIFT	BACKSPACE
DEL	0
UNDERLINE	
COMMA	TAB
PERIOD	RPT
	LOC
	LF
CONTROL	SPACE

4.13 "Monocase" (No Shift on Alphabetic Characters).

It is questionable that any 64 character teletypes still be around when this MIL-STD-1280 is revised.

4.17 Outboard Numeric Cluster. Relates to keypad.

5.0 TYPE I, CLASS 2 ARRANGEMENT

Same comments as in Section 4.

Current keys addressed:

BACKSPACE	.	
TAB	,	
REPEAT	+	-
DEL	.	for typing equations and
LOC	.	computer program
	*	- CODE (FORTRAN, BASIC)
CR		

CTL

0

LF (OR NL)

SPACE

6.0 TYPE II, CLASS 1 ARRANGEMENT

Delete in entirety as obsolete.

KEYBOARD LAYOUTS

Although there are any number of articles over the years which deal with "the one best way" for the designer of a full keyboard entry device to lay out the designation of the keys, five particularly pertinent contributions were found which adequately sum up current thinking on keyboard layout.

The first, by Francas, Brown, and Goodman (1983) compared three layouts - the QWERTY, the alphabetic, and a numeric code method. Several previous studies are cited that support the inferiority of the alphabetic layout, but this study was unique in using a miniature keyboard for each layout. Two experiments are reported.

An anonymous review in the International Journal of Man-Machine Systems reviews several keyboard layouts as well as ergonomic designs. The alphabetic layout is again mentioned as not being as fast for non-typists, a population for which it was proposed originally. However, the advantages of QWERTY and Dvorak (DSK) over alphabetic are lessened when multiple characters are mapped into a single key. (Reviewer's conclusion)

Goodman, Dickenson, and Francas (1983) raised an issue in keypad as opposed to alphabetic design - the 3x3 array versus a horizontal layout. The major intent of the study is to address evaluation procedure, rather than design. The study reported had other differences so it was not as clear as the classic Deininger study (1960). However, the recent introduction of diverse layouts in the telephone consumer market suggests that the advantages of the compact 3x3 may not be understood and novelty is encouraged.

Research on typing behavior typically accepts the QWERTY as a given. The advantages of other designs such as the Dvorak or DSK have been largely set aside.

The 10 to 20% extra typing speed is not worth the ex[illegible] training and conversion costs. However, the principle of the Dvoral [illegible] consonants on the right and vowels on the left to permit rapid alternation of fingers on opposing hands - could be incorporated in any single press design to expedite data entry.

Papers from Proceedings of the Human Factors Society, 1983

M. Francas, S. Brown, and D. Goodman, Alphabetic Entry with Small Keypads: Key Layout Does Matter.

A full-sized typewriter keyboard used for a "technical telephone system" results in constrained key size and spacing. Two experiments were described comparing the alphabetic keyboard, the QWERTY, and a numeric code method of entry. Both Michael (1971), and Hirsch (1970), had previously shown that the alphabetic keyboard was inferior to the QWERTY for non-skilled typists. Norman and Fisher (1982), confirmed these findings, but each study used a full-sized keyboard and a lengthy typing task. Francas et al were interested in small keypads with individual keys for each character. They found the telephone was equally accurate but slower.

Experiment 1

No pictures of the three layouts were given and the descriptions were inadequate. The alphabetic keys were 0.6 cm by 0.4 cm with 0.3 cm edge-to-edge spacing (much smaller than recommended). Nowhere is the number of keys given, but one keyboard was laid out in QWERTY format; a second was the same keyboard in alphabetic order; a third used an undescribed "numeric code (NC) method" based on Butterbaughs best keying logic.

The task involved keying names from a telephone directory. Results showed the NC method was significantly slower than the other two methods, but they could maintain equal accuracy with the NC method. The NC method was also disliked.

Experiment 2

Experiment 1 found no difference in the ABC and QWERTY layouts. Instructions in Experiment 2 were that speed and accuracy were equally important. However, only speed was measured. Task completion time was 54.4 seconds for QWERTY and 97.5 seconds for ABC. Norman and Fisher (1982), found QWERTY was 67% faster. Nineteen of 20 subjects preferred QWERTY. Norman and Fisher felt the alphabetic search method was soon abandoned by typists in favor of a random search. Existing skills with the QWERTY layout are transferable even to a one or two finger keying task. This paper largely supports others discouraging the alphabetic for the QWERTY. However, failure to show the exact QWERTY layout is a limitation. We must assume it was a miniature typewriter keyboard.

From Proceedings, 1983.

D. Goodman, J. Dickenson, and M. Francas, Human Factors in Keypad Design.

The abstract for this study does not do it justice. The abstract suggests the only purpose was to show that prototypes (drawings only) could be used to evaluate layout in lieu of simulation with moving part keys. The subject was a public access terminal featuring seven function keys and ten numeric keys.

Actually, the study presented interesting data comparing the horizontal layouts of numbers and the 3 x 3 telephone layout. With the horizontal, five function keys were horizontally arrayed above the numbers, whereas with the 3 x 3, three keys were on the left vertically and two (delete, help) were on the left and right of the zero below. Both systems had the "start/finish" bar on top and the "enter" bar on the bottom.

Results were slightly confusing. One study showed a high (68%) preference for the 3 x 3 layout; no difference in performance. e authors then modified the task (for reasons not clear) and replicated the study. This time they found an almost 50/50 split in preference, but the 3 x 3 was 10% faster. Error rates were low, about 0.6 for both conditions.

Other research (Dieninger, 1960) has suggested that the telephone pad layout is slightly faster also. The function keys added a new dimension because the 3 x 3 pad's "delete" and "help" keys were number-pad sized whereas on the horizontal layouts they were twice as wide as a number.

Although vague, this report tends to support a 3 x 3 layout as opposed to a horizontal linear layout of numbers, but due to other variables which are slightly different, it is not as clean as the earlier study by Deininger.

Noyes, J. The QWERTY Keyboard: A Review, *Int. J. Man-Machine Studies, 1983*, *18*, 265-281.

Probably more has been written on the QWERTY vs. DSK (Dvorak) controversy than any other, and the issue never seems to die, even in the popular news magazines. The article mentions many other proposed keyboards (minimotion, Rhythmic, Klockenberg/Kroemer, P.C.D. Maltron). Some are of only historical interest, e.g., the Minimotion with 11 keys on each row. Kroemer's tilted keyboard with two sections has biomechanical advantages, while Maltron went a step further and "cupped" the keyboard to take into account varying finger lengths and to provide tactile feedback whenever they strayed on the wrong row. Some of these innovative ideas could be incorporated in conventional QWERTY designs.

The alphabetic keyboard, which both IBM and Bell Labs ha ɔund recently to be inferior for text entry, is proposed for speciaı-purpose keyboards such as airline reservations. (This also has precedence in telephone alphabetics.) But the alphabetic keyboard also requires search until it is learned well and it lacks the advantage of QWERTY, DSK, and others of having the most frequently used letters in the center of the board (home row, or fore/big finger usage). As more people train on computers, the number of "non-typists" will decrease. Michaels found the alphabetic was not faster for non-typists.

The strongest argument for the alphabetic comes when there is a modified design (3x3, 4x4, 5x5) where keys cannot be assigned to their QWERTY locations anyway. Given that constraint, the alphabetic may be a logical alternative. Also, for coded or highly technical material (no sequences or digraphs) the advantages of QWERTY disappear.

Norman, D.A. and Fisher, D. Why Alphabetic Keyboards Are Not Easy To Use: Keyboard Layout Doesn't Matter Much. San Diego, CA: Center For Human Information Processing, California University, Report No. 8106, November 1981.

Norman's work is, unfortunately, not design-oriented. It takes the QWERTY typewriter layout as a given and measures keystroke timing or error percentage. Typing is a function of skill level, type of typing material, and character sequences. They are more interested in task modifications to improve typing skill (novice versus expert studies).

On page 92, there is an interesting comment on layout. Interstroke intervals are reduced by arranging that common digraphs are laid out so that successive keys are typed by fingers on (a) opposing hands or (b) different fingers on the same hand. These permit overlapping stroke intervals. This, of course, was one of Dvorak's theorems when placed all vowels on the left side, home row and common consonants on the right side, home row. This would result in opposing-hand finger strokes whenever vowels and consonants appeared in succession.

Since 4 x 4 keyboards have one-hand operation, this would not apply. However, function keys used frequently should not be assigned to the same finger.

KEYBOARD SLOPE AND HEIGHT

The so-called low-profile keyboard has recently become very popular in computer systems. The Emmons and Hirsch (1982) study was one of several studies exploring the issue of keyboard angle. Suther and McTyre (1982) and Miller and Suther (1981) studies explore the interaction of keyboard angle and home row height. Burke et al (1984) have also pursued the height topic while keeping the angle fixed. There is some suggestion that the ergonomics of optimal slope may be related to the height of the operator and her hand size.

The issue of keyboard slope is timely because MIL-STD-1472C, based upon earlier research, has adopted a 15-25 degree range for tilt while most low profile keyboards are less than 15 degrees.

W.H. Emmons and Richard S. Hirsch, Thirty Millimeter Keyboards: How Good Are they? (IBM, San Jose)

On the basis of German observational data, Cakir, Hart, and Stewart (1979) concluded in their VDT Manual that keyboards would be best operated on the thighs, but certainly the home row thickness should not exceed 30 mm. If it does the keyboard should be lowered into the table top. (From this it is inferred they are talking about keyboards placed on a standard 29 inch table, although this is not clear from either Emmons and Hirsch or Cakir et al. Typing tables are 26 to 27 inches typically.)

Emmons and Hirsch looked at three IBM keyboards with home row heights of 30, 38, and 45 mm. These were achieved by varying the slope (5, 12, and 18 degrees). The table height was 72 cm (29 inches equivalent). They measured throughput (keystrokes/total time), free keying rate (same minus wasted time), and corrected and uncorrected errors.

The results were essentially no significant difference in errors, but the throughput and free keying rates were significantly impaired at the 0.05 level for the 12 and 18 degree slopes compared to the 5 degree slope.

On feelings of fatigue, 4 of the 12 subjects expressed fatigue with the 5 degree slope, while no one complained on the other two slopes. In terms of preference also, the lower slope was rated lowest and the 18 degree slope was rated highest.

The small sample and obvious vested interest of IBM limit confidence in the findings although (as noted in a later review) MIL-STD-1472C calls for a minimum of 15 degree slope. I suspect there are many interacting variables affecting performance: the cont of the keyboard, key size and shape, etc. Cakir et al seem to be mai concerned with the height of the keyboard relative to the wrist and forearms. Reducing tilt is only one way to achieve it. But a steep angle at a low height (e.g., 25 inches) would throw the wrists back and introduce fatigue. Similarly, a flat keyboard on a high table (e.g., 31 inches) would likely bend the wrist forward (assuming in each instance, a chair of constant height). Thus, the issue of fatigue is more complex than simple tilt angle.

Proceedings, 1982

T.W. Suther III, J.H. McTyre, Effect on Operator Performance at Thin Profile Keyboard Slopes of 5, 10, 15, and 25 degrees. (IBM)

This was one of a series of studies investigating keyboard tilt in response to the Cakir et al (1979) study supporting a low profile keyboard. (German Safety Regulations specify a home row not exceeding 30 mm (30 mm actually).)

Sixteen skilled female typists typed in 16 sessions of 35 minutes each on keyboards of four different slopes. The 15 degree slope employed a thick profile keyboard cover. The others (5, 10, 25 degrees) used a thin profile cover. The repeated measures design was excellent, but there were several methodological flaws. (1) Different hard copy stimulus material was used in each session. There was no discussion of balancing the material, so there could have been uncontrolled differences in difficulty. (2) Table top height was set at 27 inches rather than the conventional 29 inches. Cakir's results applied to a conventional table. (3) The operator's chair was adjusted for ---fort. This permitted the keyboard to be presumably very low relative the typist's forearm and elbow.

Results

No differences in performance. Performance was measured by accidental key activations rather than throughput or speed measures. Typists all were above 55 wpm by selection criteria, but failure to measure throughput on the tests was a flaw because reduced speed could be traded off against error scores.

On a questionnaire, typists clearly preferred the midrange of slopes - 10 to 15 degrees. No one liked the 5 or 25 degree slope. An interesting observation was that one tall typist (5 foot 7 inches) thought she did best on the 5 degree slope while three medium and short typists (5 foot 5 inches to 4 foot 11 inches) preferred the highest slope. Correlation between right hand length and estimated performance was r = -.65. Long-handed women preferred lower slopes. The same was found for the left hand length.

Muscle strain was also reported at the extreme positions. The authors mention that the heels of the palms had to be raised due to a new orientation imposed by the 5 degree keyboard. (It would seem that the steeper slopes would necessitate a raised palm, but the biomechanics is complex because forearm angle is not clear.)

Relative to key layout, they complain that the "ENTER/NEW LINE" key forced typists to remove their hands from the home row and stretch three columns to hit the key. They recommend it be like it is on the IBM Model 5251, next to the "P" key. Frequently used function ' ; like "field exit, shift, and shift lock" should be a column clo The goal is to make it unnecessary to remove hands from the home row and search for a key.

Conclusions

The 5 degree (30 mm) condition was uncomfortable for most. The 10 to 15 degree slope differences (a difference of 17 mm) were not detected even though the difference was greater than from 5 to 10 (14.5 mm difference). The 25 degree slope was disliked and uncomfortable although it was only 6.25 mm higher than the 15 degree slope at the home row. In essence, the relationship is not a simple linear or curvilinear function of home row height increases.

IBM research supports a range of 10 to 18 degree slope for "average" users assuming a fixed slope is required. Flexible slopes should be 10 to 25 degrees (earlier IBM Selectrics permitted a 10 - 35 degree adjustment capability). However, this research opens a new Pandora's Box by suggesting that stature and hand length are related to this issue. A 5 foot 7 inch female would be tall, but that height would be below average for male military personnel. Men may prefer and work better with a less steep keyboard, if the author's theory has any merit.

Proceedings, 1981

I. Miller and T.W. Suther III, Preferred Heights and Angle Settings for CRT and Keyboard for a Display Station Input Task (IBM, Rochester)

This early study selected a sample representative of the . and Japanese adult men and women, and permitted users to adjust both seat and keyboard heights and angle to preference levels. Preferences were also documented for the CRT height and angle, and document holder.

For all operators, they found the following: (a) seat height = 408 mm; (b) keyboard height = 630 mm; (c) CRT - angle = 3 degrees; CRT base height = 925 mm (36.4 inches); (d) keyboard angle = 18, max = 25, min = 14 degrees.

Focusing on the angle, they found a correlation of -.71 between keyboard angle and seat height, i.e., the shorter the person, the greater the preferred angle. The 18 degrees exceeds the German recommended maximum of 15. Correlation between stature and preferred keyboard angle was -.43. Since stature and hand length are also correlated (+.645), the explanation offered was increasing the angle shortens the reach distance slightly from home row to either the top row or the space bar. This would accommodate the tiny hand better.

Two historical studies were mentioned (Scales and Chapanis, 1954; Galitz, 1965). Both studies found no difference in performance as a function of slopes ranging from 0 to 40 and 9 to 25 degrees, respectively. However, the first study found 15 to 25 degrees was preferred and the second study agreed that 21 degrees was preferred. At that time, the standard typewriter slope was 16 - 17 degrees. So they actually preferred a slightly steeper slope. They recommend adjustable slopes and long-term research on speed and error (typing for long durations).

The preferred keyboard height (630 mm) had a home row height of 77 mm above table or 707 mm (27.8 inches) above the floor. A shocking conclusion was that the data actually supported the German (Ca 1979) recommendation of a minimal thickness of keyboard. Their reasoning was that most keyboard supports (tables) are 27 inches (without keyboard) and therefore, the 27.8 inches was suggestive of a need for a thin keyboard. Not addressed is how to achieve a thin keyboard and yet provide the preferred 18 degree slope.

CRT centerline height was preferred at 925 mm (36.4 inches). To accommodate 95 percent, a fixed 27 inch table won't do. The CRT angle (3 degrees) was to prevent glare; they conclude that 0 degrees is okay otherwise.

From Proceedings, 1984

T.M. Burke, W.H. Muto, and J.C. Gutemann, Effects of Keyboard Height on Typing Performance and Preference, Xerox, Dallas

This research was assumed to relate to tilt angle and keyboard height. A German study by Cakir, Reuter, von Schmude, and Armbruster (1978) led to a standard European flat keyboard (30 mm maximum from table to home row). Emmons and Hirsch (1982) studied 30, 38, and 45 mm keyboard home row heights and found performance favored the two higher heights. Suther and McTyre (1982) found no difference between 5, 10, 15, and 25 degree tilts with respect to performance, but the 10 to 15 degree angles were preferred.

For unexplained reasons, the Xerox study selected a fixed 11 degree angle, but varied the height of the home row: 35 mm, 64 mm, 84 mm, and 104 mm. The tabletop was a constant, 660 mm, from the floor. So the study was actually varying only the height of the work surface. Unfortunately, typists were allowed to adjust their chairs 100 (432-533 mm)! This would most likely "wash out" any effect due to keyboard height. In fact it did. There was no significant difference in typing performance. Preference data supported a higher height: 1st - 84 mm, 2nd - 64 mm, last - 35 mm. The conclusion was to use 64 - 84 mm (724-744 mm from floor). However, if the chair was adjustable, the meaningfulness of the research was largely negated.

This paper notes that tilt angle and home row height may not be mutually exclusive issues; other research has suggested that a typist's elbow is best at 90 degrees. If this is true, the home row may be adjusted to provide a height such that the wrists are not flexed (forward) or extended (backward). But this ergonomic issue is one apart from that of the best tilt of the keyboard itself. The fingers shouldn't have to reach up or down significantly (by a steep incline). However, a flat keyboard, as mandated apparently by the European market, may reduce the angle formed by the finger and key surface to the point of increasing bumping errors. There is no definitive performance study which substantiates the "low profile" keyboard which is popular today. Apparently, Xerox was willing to accept 11 degrees although MIL-STD-1472C (page 90) still lists a preferred slope of 17-18 degrees for stationary keyboards and a permissible range of 15-25 degrees. Less than 15 degrees violates paragraph 5.4.3.1.3.4. Portable keyboards are at the operator's discretion, presumably adjustable in tilt.

KEYBOARD DISPLACEMENT, RESISTANCE, AND AUDIO FEEDBACK

These issues are all related because feedback to the operator that he or she has pressed a key seems to be a major issue in acceptability. The traditional position was that there should be some displacement to provide kinesthetic feel and verification of activation. MIL-STD-1472C (see Data Entry Devices) requires a displacement of 0.05-0.25 inch for alphanumeric keys and a resistance of 0.9 to 5.3 oz., with slightly different criteria for numbers only.

The popular membrane keyboard would fail to meet these specifications. Therefore, a critical issue is: how can feedback be built into such keyboards to improve acceptability and performance? Roe, Muto, and Blake (1984) report research employing the use of tones, embossed key outlines, and domes or crowns applied to membrane keys. Cohen (1982) compared membrane and conventional keyboards with touch and non-touch typists to see if level of typing skill interacted with performance. Monty, Snyder, and Birdwell (1983) measured typing speed and error performance on a variety of keyboards some having a clicking sound as feedback. Bruner and Richardson (1984) evaluated keyboards with various levels of resistance and with a clicking sound. Results apply mainly to typing tasks rather than occasional entry.

From Proceedings, 1984

C.J. Roe, W.H. Muto, and T. Blake, Feedback and Key Discrimination on Membrane Keypads.

Flat membrane pads displace only 0.006 - 0.008 inch compared to 0.05 to 0.25 inch for pushbutton keys. To supplement the loss of tactile feedback, visual and auditory feedback (8209 Hz tone) have been used. Embossed key overlays (a thick sheet of polyester), are used primarily to provide key separation cues for finger positioning. Metal domes are also used. Application is to infrequently used function keys such as microwave oven minutes and electronic mail for an executive.

The study involved four (4 x 4) membrane keypads mounted on a 25 degree (from horizontal) slanted surface. The pads were telephone-array numerics, 6 letter keys, and a zero. Key separation was standard. A 2x2x2 factorial examined the variables: tone/no tone, dome/no dome, emboss/no emboss (eight conditions). Subjects keyed in 50 5-digit sequences on one of the keypads. Only six subjects per condition! Preferences were made by all subjects after keying a few digits on each, so the preference data would be valid.

Results

A paired comparison test of preference data showed the tone and dome were most important - the embossing less - in ranking conditions. However, the subjects liked the embossing on the Semantic differential.

The tone seemed to reduce errors. Granted that embossing and domes may aid in finger placement and the physical separation of keys tactually; granted also that an auditory cue may provide a cue to verification of activation (normally provided by kinesthetic feedback in a pushbutton); granted also that in the absence of a tone, a domed key may help. But the effect may not be quite the same as the kinesthetic cue. Note that the application is primarily to occasional entry, not text entry or continuous usage. The effect of typing on a surface (with embossing and dome) should be studied.

Failure to use a repeated measure design and using a small sample per cell would largely invalidate the performance results of the present study. Slight difference in six subjects could account for differences reported.

From Proceedings, 1984.

H. Bruner and R. Richardson, Effects of Keyboard Design and Typing Skill on User Keyboard Preferences and Throughput Performance (Honeywell)

This paper dealt with tactile and auditory feedback effects. They studied four keyboards: A - high feedback via snap feel and hysteresis (spring principle); B - moderate feedback (double peak force/travel with elastomers) it was silent; D - moderate feedback (B) with electronic click option timed to switch closure; C - light feedback initially, but doubling at the point of down (spring action).

Another variable was typing skill. Folklore has it that experienced typists require little feedback while novices like a longer keystroke and heavier key action. Otherwise, the typist keyboards were identical.

Each subject typed on all keyboards for one hour according to a Latin Square Design. Error, output, and preference were measured.

Results

Initially, D was most preferred and C least preferred. [illegible]d B were in between. The novice liked D even more. After an hour of typing, A, B, and D were deemed equal, but C was still worse. Conclusions were that initially auditory feedback was important (B being rated poorer than D which had a click), but later the click was less important. An interesting finding was greater wrist fatigue reported with C, the keyboard with the least feedback. Both groups rated their performance as worse on C than on their normal typewriter.

The subjects typed faster on B and D, the elastomer key action, than with spring action. The most "insertion" errors occurred on C, but there was no difference in omissions, transposition, and substitutions. (Two to three times as many insertions!)

Conclusions

Light keystroke resistance and nil hysteresis lead to spurious insertions, especially with the novice. Double-peaked force/travel in B and D plus electronic auditory feedback accounted for their superiority.

The findings are cited as support for the elastomer action as opposed to spring key action. The support for an electronic click is not clear since B was noiseless. Little resistance was disliked by both experts and novices. Again, this was a typing task - not an occasional entry task, and lasted four hours per typist. Therefore, the results should not be construed to apply to pushbuttons on microwaves or occasional military entry systems.

Proceedings, 1982

K. Cohen. Membrane Keyboards and Human Performance. Bell Labs, Holmdel, N.J.

This was an abstract only of an in-house study comparing the new membrane keyboard with a conventional, full-travel keyboard. Sample was 21 and duration was three days on each (one hour per session).

Results were discussed only in terms of "performance." It was reported that non-touch typists performed the same. Touch typists performed better initially on the conventional keyboard, but with "a few sessions" of training the difference was reduced substantially. However, there was still some advantage for the conventional. Future research would extend the duration of practice and, also, "better design" the membrane keyboard.

No mention is made of such features as a click or tone for feedback, or domes or embossing to control finger placement. This was an early investigation and lack of full details limits its usefulness.

From Proceedings, 1983

R.W. Monty, H.L. Snyder, and G.G. Birdwell. Keyboard Design: An Investigation of User Preference and Performance.

This small-scale research was performed by Virginia Polytechnic Institute (VPI) with contractual support from Texas Instruments (TI), Dallas (Jerry Birdwell). Eighteen employees typed standard text passages using 6 different keyboards for 10 trials. The major interest was in a clicking sound. Two keyboard models had a constant click "on" while the other four had a switchable electronic click option (not explained). The investigators tried to control nuisance variables such as: (1) all white keys, with black characters; (2) slope, 9 degrees (it was noted that U.S.A. recommends 12 to 15 degree slopes while Europe wants a maximum height of 30 mm at home row - a much flatter keyboard apparently). Size and shape appeared to be slightly different. This was not discussed as a variable, but was discussed in user evaluation.

They measured errors/trial, task time, and preference. Keyboards were identified by letter only so it is not clear if these are all TI models; it is assumed that they were.

Results

Keyboards W and N reported more errors (N was all capital letters). However, W and N also had the fastest times, so little can be concluded. Keyboard W was reported to be "too sensitive" with unintended key entries. Subjects were faster with the artificial click on, than with it off. Experienced typists, as opposed to the novice or programmers, were faster but made almost twice as many errors.

Subjects also evaluated keyboards in terms of touch quality, firmness, and key travel. Data are <u>meaningless</u> since the particular attributes of the various keyboards are unknown (photos are shown). Subjects liked the large return key (reverse L shaped) on keyboard R. With smaller (standard key) returns, they reported having t[illegible]arch. A conclusion was that the return key should be oversized and in the standard typewriter location. Subjects also liked the audible click feedback with each keystroke and keystroke time was "marginally faster" with the click.

Again, they liked keyboard R because of its large return key and "smooth key movement." <u>Shift key</u> size and shape and keyboard <u>on/off audibility</u> were rated last among design parameters of importance. Keyboard D, for no given reason was also rated above average, but D and K were said to have "longer space bars." (How long is not reported.) Key cap size and shape were preferred on keyboards D and R, and least preferred on W. Inspection of the photos is the only clue as to why. They may be slightly larger, more square, and perhaps more widely spaced than keyboard W. <u>Failure to quantify the characteristics</u> of various keyboards was a major limitation of this proprietary study so far as developing design criteria. In general, they found no significant performance differences in the six keyboards. Not discussed were two other variables: (1) a tendency to unintentionally hit the key for capitalization on electronic typewriters with the little finger, left hand. A tiny red key light comes on signifying capitalization, but is frequently not noticed until several words have been typed. <u>A click or tone rather than a light</u> would be superior; (2) Norman has recommended an <u>automatic</u> return feature (stating it would improve typing speed over any layout alteration). While this may be true, one should also consider whether typists want an automatic return (some often type slightly beyond the tone for right margin). Perhaps there should be a three or four letter "grace" after the tone.

CHORD KEYBOARDS

Simultaneous activation of keys offers the possibility of doubling the keying speed. Representation of the chord keyboard ma are the "Velotype" by special systems industry and the IBM Microwr . The "Velotype" is butterfly-shaped so that finger reaching is minimized and the left and right half of the keyboard are largely mirror images. The operator enters by syllable rather than by character. Multipressing certain character keys to achieve certain characters places a demand on memory, but 200 wpm is claimed after only 45 hours of practice.

The "Microwriter" is a six-key handprint keyboard with LCD readout. Appropriate simultaneous finger positioning permits the typist to form a selected character. Obviously, it is much slower (45 wpm) but offers the advantage of one-hand entry which may be of advantage in field applications requiring limited alphabetic entry and where extraordinary speed is not a requirement.

Typing at the Speed of Speech, A brochure on the Dutch-made "Velotype," a new chord keyboard for dictation stenotypists. Special Systems Industry, B.V.

This new chord keyboard makes almost magical claims for [illegible]d and ease of usage. One types words or syllables in a single strok[illegible]y chording). The typist thinks by breaking characters down into syllables which is easier they claim. The 37 keys are in a butterfly-shaped pattern, which has the advantage of the hands not moving from a fixed position; all keys are accessible by finger reach. The other feature is a layout claimed to be based on finger counts of character usage with heaviest loads assigned to the strongest fingers.

Among the claims made are: (1) types at the speed of speech (900-1000 characters per minute or three times the QWERTY); (2) outdates shorthand machines and the need to transcribe after usage; (3) easy to learn by anyone. In 45 hours a typist will be at 200 wpm and in 200 hours at 750 wpm (professional shorthand rate).

This electronic chord keyboard is shown in the following layout. I have not attempted to draw the butterfly shape:

P H I (BLANK) O H P

F T J O U I J T F

S C R E A E R C S

L R Y R L

M V W M W M H V

Shift

The layout is unfortunately not discussed. The U and A are double-size keys in the middle column. Except for O and I the left and right sides are mirror-images. The five vowels are all assigned to the forefinger (good). Since it is a chord, one may type two-vowel digraphs simultaneously. The middle 9 keys are convertible to numbers i mputer layout with the Y being the zero.

Certain characters are formed by combining two keys: T + J = D. This is poor since it requires recall of meaningless digraphs as equaling a sought character. B is "with" P, D is with T, G is with C, Q is with H. (H is also duplicate with the L.) N is with a capitalization key. This combined key feature, especially where three characters like L, M, and V are assigned to one key, is very poor design.

Again, this is a sales brochure and does not bother the reader with mundane matters such as the rationale for character placement. It does note, however, that the keys are split into three groups: the left side is for initial consonants in a syllable; the right side is for final consonants. The vowels go in between, so a single chord using three simultaneous presses would permit any consonant - vowel - consonant syllable or word.

It claims the left and right hands are used equally in typing rather than 61% left for QWERTY. However, it is questionable that the key assignments are optimized for English. The manufacturer claims it is an international keyboard for all Western Languages, meaning a standard layout. But it is questionable that the frequencies of character usage are constant across languages. For example, "J" is not a popular character in English yet it has a prime location on the Velotype keyboard. Other more popular characters like the S, T, and C are smaller finger functions and the B, M, and W did not even rate a separate key. Though the basic notion of consonant duplication and location of vowels central is a good one, the specifics of character location are controversial.

A claim that the Velotype "thinks" for the user is an exaggeration. Output is on a one-line matrix display with, at most, 40 characters. If one is typing at 900 characters per minute, a single line would erase after one twentieth of a minute or three seconds! Thus, a user would need to scan almost continuously to proof (and this is not feasible with text typing). So what good is a visual readout? The output should be stored on a page screen or (if working from print input rather than voice input) the readout should be via a voice synthesizer.

The Velotype needs to be evaluated by an independent research agency. Is it a state-of-the-art advancement over the stenotype machine or word-writing machines currently used in courtrooms? If it is as simple as claimed (and only $2,000) why not replace typewriters in offices with such a device and triple output? The butterfly-layout also needs evaluation. Does it reduce fatigue and improve speed aside from the layout issue? (Traditional shorthand machines have used the slight V pattern since 1920, but why has the typewriter never adopted the straight-wrist feature?) Could current QWERTY typists work faster with a different shaped keyboard?

Microwriter, Microwriter USA Ltd, 251 E. 61st St. NY, NY. 10021
list price: $499 includes case and recharger

This powerful one-hand six key handprint keyboard is by far the most successful of the breed of handprints. It is a complete terminal with permanent word processing and formatting software and communications abilities. It has the full range of word processing commands and features which include power wrap-around, two scrolling speeds, jumping around in text, tabs, and carriage returns. When hooked up to a screen, screen editing can be done.

Developed by Cy Endfield and backed by Hambro Life Assurance Company, a large British firm, the machine has apparently found a niche in Britain. Rodwell reports the British Government as "keen Microwriter users; apparently there's a Home Office section which uses them to produce neatly typed documents on subjects too hush-hush to be entrusted to typists." Paul Cutler, head of the company's U.S. office sees the target audience for the machine as "what we call 'thinker-writers,' usually professional people at the middle-management level. They draft reports with a pen and paper, talk into a dictaphone, or sit at computer or typewriter tapping away with two fingers and getting very frustrated. When you think about it you realize that there are several million people who fit into that category. The Microwriter could potentially be of use to them all (Freff, 1984)."

This book-sized keyboard has a frontal hump to rest the palm on and the keys are on a slope (see Figure 1). The sixth key is an extra thumb key and is used for commands. Unfortunately the keys are square instead of elongated, so large hands cannot type with the fingertips while the fingers are extended. Since the author has relatively large hands, this was a concern because it lead to cramping. Associates with small hands liked the layout and none had trouble reaching any of the keys.

Figure 1. The Microwriter

The keys, themselves, are rather sensitive and too easy to activate for the novice. Microwriter literature explains this as facilitating expert user's speed, however most reviewers mention this as a design flaw. The most unusual feature of the keys is that t[illegible] do not send code on depression, but instead upon release. This allow[illegible] r a non-simultaneous chord, the letter code sent only when all keys are released.

There is a 16-character display with 14 characters usable for character entry on the line of LCD elements. Two characters are under a yellow film and denote command characters to indicate any special mode such as upper case, numeric or menu. Each letter consists of a 5 x 7 grid of small LCD elements underlined by a blank line and a single line of 5 more elements (see Figure 2). The bottom line is where the descenders for the letters are generated. Most descenders are incomplete and practice is needed to be able to discern between some of them.

The chording scheme is the most notable feature to most writers. Mnemonics are used to good advantage (see Figure 3). Some are visual such as the "H" where you are to visualize the crossbar produced by the thumb and little finger. Others are symbolic, like the "O" which represents a bulls eye, which relates to the center of the hand, the middle finger. The third type of mnemonic is based on wordplay. The "S" is produced by the "S"ignet ring finger. Rodwell reports that it took approximately 30 minutes to learn the alphabet, 30 minutes for numbers and punctuation. Two hours per day for two weeks allowed him to build up to a reasonable speed.

The machine has three modes or registers. The default mode is letters and a few punctuation characters. The next most commonly used

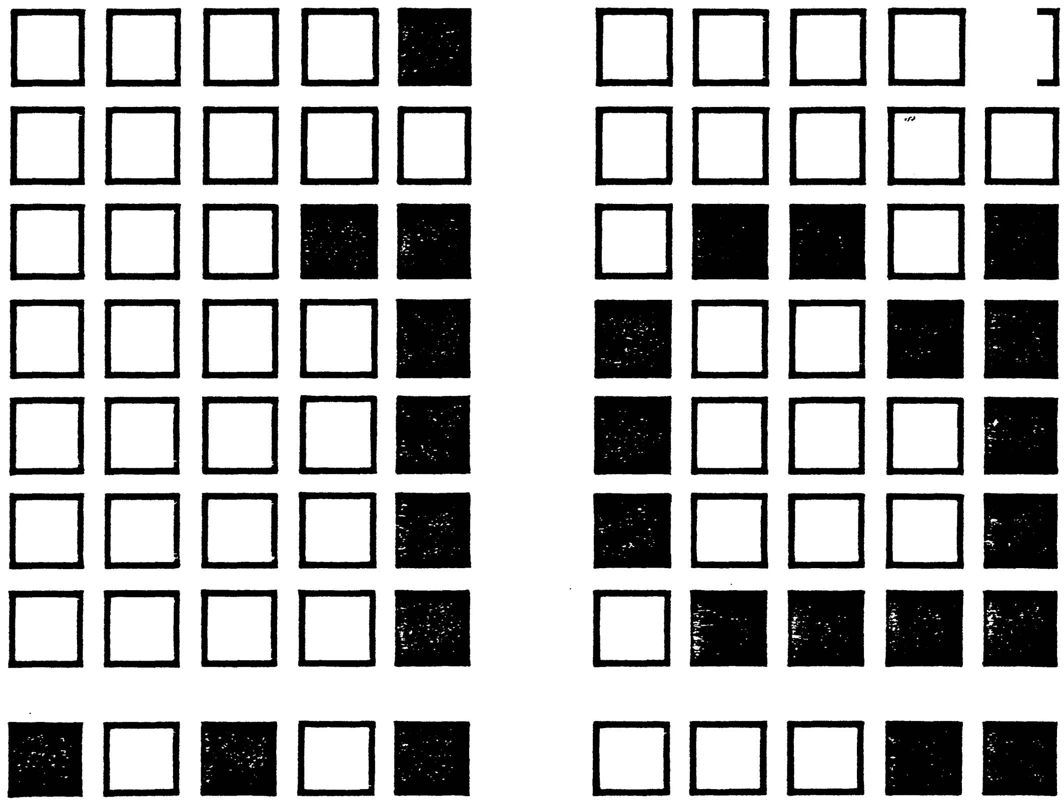

Figure 2. The Microwriter LCD Grid showing a "j" on the left and a "q" on the right.

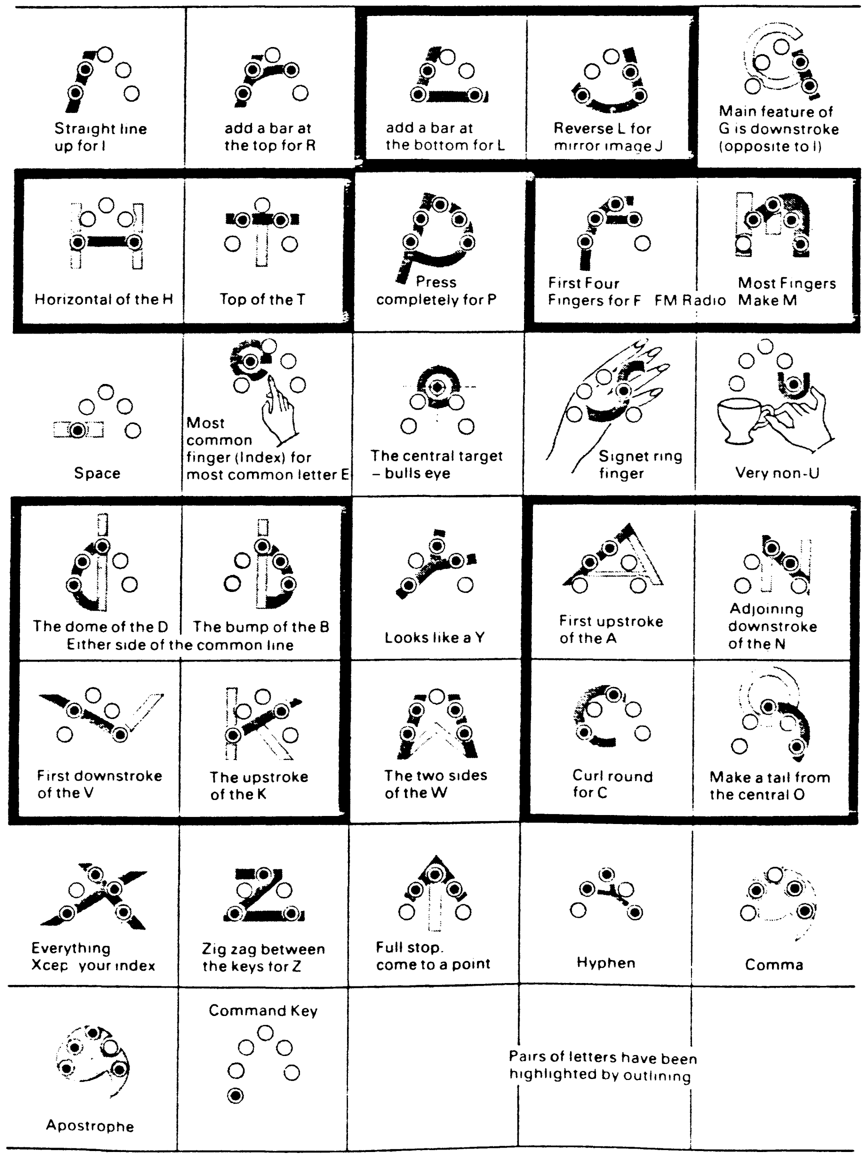

Figure 3. Alphabet Mnemonics on the Microwriter.

register is the numeric with the remainder of the punctuation and special characters such as the English pound sign, percent, dollar, etc. to get to this and the other mode which is for changing formatting commands, a command chord, which is mnemonically significant, is struck. For the numeric mode, a CNTL-N is used. This is only a regula ' code with the use of the second thumb key. To get to menu register the first chord struck is the CNTL-M, "M" for menu. To lock into the new register just hit the chord twice. This is the same logic used to produce upper case letters; by hitting just the command key once, the next letter will be upper case. By hitting it twice, the upper case is locked in until it is cleared by pressing both thumb keys at the same time.

Although the Microwriter was not designed to compete with skilled QWERTY typists, speeds of 45 characters per minute (cpm) are common, with 50 to 60 cpm being reported informally by Freff. This is most definitely faster than handwriting and eliminates the illegible scrawl problem. Further, this can be used where QWERTY fears to tread. The fingers stay on the keys so moderate vibration and bumpiness, which may be experienced on many modes of transportation, is no deterrent to efficient character entry.

Miscellaneous, but by no means unimportant, features include the ability to hook up to anything that takes a standard RS-232 communications card, and the ability to store to cassette. The power comes from batteries which are claimed to be good for up to 30 hours. Documentation is well written without becoming bogged down by too much technical jargon. Cue cards for all chords, divided by register, are provided and indispensable, especially during the first week. (See figure 3 for example of alpha register cue card.)

This machine with all its features is sure to become less of an oddity and more commonplace as reports spread. Rodwell reports that Endfield is experimenting with children to see how quickly they pick up the basics of computing using the device. The author is currently using the machine in a study comparing it to the 4 x 4 keypad for al umeric entry. Further research into a more efficient chording scheme seems superfluous at present. What should be considered is ergonomics. A better range of hand sizes needs to be accommodated, more specifically the larger hand sizes. The display, which is an off-the-shelf item could use improvement. For that to happen, however the minimum cost-effective order for custom displays is 100,000 units (Rodwell, 1980). The practicality of using this device with other special need user groups should also be investigated.

- Freff. "The Microwriter Alternative", PC Magazine, June 26, 1984, pp 160-166.
- Rodwell P. "Microwriter", Personal Computer World, (UK) V3(12), p 77-80, 1980.

TOUCH SCREENS AND PANELS

Touch screens (TSD's) are direct access devices for which research has been forthcoming only in the past 10 years. Pfauth and Priest (1981) discuss the basic principles of touch screens and the evol[illegible] of current technology. Like other pointing devices, they are excellent for modifying display elements or menu-selection. Beringer and Maxwell (1982) and Beringer and Peterson (1983) have noted that high resolution screens are within current technology, but a problem arises in stabilizing the hand and arm to permit precise movements. Both Beringer studies explore different declination angles of the screen to avoid wrist fatigue. Improved stabilization aids and possible feedback of pointing errors with touch devices are areas meriting further research and development.

Proceedings, 1981

M. Pfauth and J. Priest, Person-Computer Interfaces Using Touch Screen Devices, (Texas Instruments and University of Arkansas)

Discussion only, but interesting for the person unfamili ith TSD technology. In the mid-sixties, the touch wire system was developed. This was thin metal wires embedded in a CRT overlay. When a finger contacts the wire, this unbalances the inductance capacitance bridge. Reduced operator time compared to keyboards was noted (but not with other input devices). Disadvantages were failure to detect touches reliably and visual interference (picture obscured?) by the touch wires in the overlay.

In the early 1970's, LED-based touch sensitive technology developed at the University of Illinois for computer-aided teaching. An array of LED's matched with phototransistor detectors were located along the edges of the screen. The finger or pointing device breaks the LED beam, and touch is sensed along with X, Y coordinates. Disadvantages were limited resolution capability and a parallax problem caused by distance between the curved CRT screen and the LED beams. Also, varying ambient illumination affected the LED's. Attempts have been made to solve the parallax problem by increasing the size of the touch area targets around the periphery of the screen and avoiding use of the edges of screen where parallax is worst. Another modification lowered the LED beams to 0.2 inches or less from the CRT surface.

A third technology involves accoustical ranging techniques similar to sonar. On a glass plate overlay, ultrasonic waves are generated in orthogonal directions. Transducers along the sides of the plate pick up echoes reflected from the finger or pointing devices. X/Y coordinates are calculated by measuring time lags between emission and detection of a reflected wave. Advantage is high resolution (up to 0.5 inch). A disadvantage is a 1.5 or 2.0 s[illegible] on the glass surface which is insensitive to touches. Also, it is so sensitive that dirt, grease, or scratches may lead to false touch commands.

A fourth family of technologies is the <u>conductive membranes</u> currently popular. There are three technologies, but all rely on a thin membrane of transparent conductive material. One is called <u>membrane</u> switches; it has two transparent surfaces with an electrode grid of a conductive material layered on each surface in X/Y directions. Applying pressure shorts an electrode pair and completes a circuit.

A second, similar variation is <u>distributive</u> resistance. A third variation is <u>capacitance</u> (capacitive switches in a thin film on the back of a glass faceplate). A touch within a segmented pattern is identified whenever the capacitance is altered. These switches can only be addressed individually, not as an array. Disadvantages are (1) the required overlay reduces the light emitted from the screen; (2) the flexible plastic switches can be scratched and punctured.

<u>Research</u>

Three applications studies are mentioned. Ritchie and Turner (1975) studied the TSD's along with other graphical input devices (mechanical, light pens, data tablets). They concluded a TSD is best for "manipulating or modifying displayed data," but joystick/tablets are better for generating new graphic info (like drawing a line). Bauerschmidt and LaPorte (1979) studied shipboard applications and found the touch overlay was two-thirds faster than a trackball (faster to point to a target than use a cursor). The touch ov y also reduced visual search time and reach distance.

Bird and Stammers (1978) found several limitations such as an effort to minimize errors (training needed), slow acknowledgment of input, no controls for adjusting brightness, and TSD's should be integrated into existing systems (rather than used alone).

Conclusions

Most of TSD's uses have been in menu-selection dialogue (a low resolution task). Although high electronic resolution exists, little research has been done to see how well humans can perform high accuracy tasks. With TSD's, inputs and outputs are the same. This saves space. However, the CRT may need to be tilted to 30 degrees from horizontal to provide arm support (less fatigue, greater precision). This often introduces an overhead glare problem. Summarizing, then -- ADVANTAGES: input/output in one location, fast data entry for some tasks, less training, immediate feedback, no memorizing or eye-hand coordination, liked. DISADVANTAGES: costly, requires programming, not flexible unless a keyboard is also available, parallax affects touch locations, screen glare, fatigue in reaching, finger blocks screen.

Proceedings, 1982

D.B. Beringer and S.R. Maxwell, Use of Touch-Sensitive Human Computer Interfaces: Behavior and Design Implications.

Abstract only. This appears to be an earlier version of Beringer's research reported in the 1983 Proceedings. He was concerned about operator fatigue using a vertical display surface for pointing tasks, particularly for frequent and extended usage.

The task was similar to that reported later: detection and designation of a "break" in one of 54 circles (Landolt C targets). The CRT display was colored with an infrared touch panel mounted on the surface. Declination angles were different from 1983: 90, 67, 45, and 35 degrees to the line of sight. (Unclear if this means horizontal line of sight so that 90 degrees would be vertical. Should have reported it in absolute declination angles.)

Results

Response time and number of errors showed "no reliable effects" of declination angle. Performance overall improved over the first 9 of 25 trials per subject. Sample size was not given.

Responses were slightly lower than the target for the greater declinations. (This constant error was noted in the second study.) Shoulder and arm fatigue were reported when the display was at 90 degrees (almost vertical) and wrist fatigue when it was at 35 degrees. Apparently, reaching forward often at shoulder level was the cause of the former fatigue. The latter fatigue must be due to how the touch device is grasped, which is easily solvable.

From Proceedings, 1983.

D.B. Beringer and J.G. Peterson (Wisconsin at Madison), Touch-input Devices: Training the Device or the Operator

This is one of the few research studies on touch panels. communicating with computer-generated graphical or pictorial data, there are several options: (1) cursor movement devices such as mice, joystick, or keyboard (2) direct-access devices (pointing) such as light pens, light guns, touch panels, and graphics tablets (the latter not directly on/the display surface). These are not explained or illustrated. These touch panels, used in (2), are fine for "low-resolution tasks" but not as well established for "high-resolution tasks." High-resolution designation was previously done by slewing a cursor to a target position, but if the entry point and target are widely separated, the task is slow. High-resolution touch devices exist, (thereby replacing slewing with pointing) but they may exceed the "resolving power of the human finger" (i.e., we are too "shaky" to hit an exact point). The authors ask: what resolving power is useful? How accurately can we designate points on a display?

Another related issue is how much the screen should be tipped for touch input. Coskuntuna (1983) found operators prefer a 45-degree angle of tilt as opposed to a 20 or 30 degree tilt from vertical. But why not use a horizontal screen (90 degrees) or perhaps one at 60 or 75 degrees? The experiment was complex in that it raised another issue rather than simply how accurately can we point and what's the best tilt. It asked: should the machine be compensated for "known bias error" or should operators be trained to be more discriminating?

Eight students used a touch-panel made by Carrol Touch Technology. It had sensors with one-quarter inch spacing betw centers, but pointing accuracy could be reported to one-eighth h. They examined on the screen 54 symbols in a 6 X 9 matrix. The symbols were Landolt C rings with breaks at either 3 or 9 o'clock. Apparently, there was only one ring per screen. They touched directly the "break" after which the "field changed color to match the rings." Half of the trials were black background with white rings and half were reverse video. Four angles of declination were studied in a repeated message design.

Results

Poorly reported results begin with an ANOVA and trivial issues. Screen angle was said to have no effect, but the 90 degree angle had substantially more vertical error than did 75, 60, and 40 degree angles. No mention of reverse video effect was given. Error was greater for targets near the top of the screen than near the bottom. This was due to arm extension and possible parallax, they surmised.

Subjects were more accurate hitting the target when the break was on the right of the ring than when it was on the left. (They were right-handed.) Right-eye dominance was a possible explanation. This was interesting, but trivial.

The authors conclude there was bias error present (some error in y-axis) when there was no "extrinsic feedback." They often touched lower than intended. They decided we might teach the machine to allow for this bias or we might train subjects by giving feedback on accuracy. (Why not teach them to point slightly higher than they planned to, particularly at the top of the screen? This was not mentioned. Apparently, some did *not* have this bias and telling them they missed was deemed better.)

Conclusions

The authors appeared to be overwhelmed by the magnitude of their data and got lost in describing their statistical analyses. Some subjects profited by training; others did not. One might ask why they could not simply receive feedback on the *direction of error*, given the target is known. At the time of the report they were still analyzing "training data using extrinsic feedback," but they felt training would be the answer rather than "to make the machine more forgiving." Why? Certainly, if there is a way to make the machine accept a less accurate point, this should be done. If not, the "explicit feedback" should be of a command or deviation nature so they can make the apropriate correction. We could also require that touch points have sensors to "accept" anything within one-third inch, if necessary.

The major problem is that the authors are not design-oriented. They are researchers well grounded in statistics, but unable to grasp simple design solutions. They lost track of the key issues: (1) How accurately can the human point? (2) How does accuracy vary with tilt angle of the screen? (3) Are the errors constant or variable? (4) How can we best provide feedback so that the operator can correct the direction of error? If error is constant, then the machine could correct the bias. If it is variable, then the operator requires individualized feedback. If accuracy, due to tremor, is beyond human limits then (a) design the acceptance tolerances so they match human skills or (b) provide stabilizing aids such as wrist rests, a more horizontal screen, a finer point on the touch device, and a mo distant hold point. (They conclude that the touch point is often obscured by the fingers. But by holding the pointer 1.5 inches from the point, this problem might be solvable.)

In general, the way in which the data was reported was disappointing (glossing over tilt angle, omitting reverse video discussion, etc.) and showed a lack of understanding of the human engineering issues.

COMPARISONS OF THE LIGHT PEN, LIGHT GUN, AND VOICE WITH KEYBOARDS

Voice commands offer greater simplicity and speed of entry for many applications, but a study by Exxon Office Systems (1983) suggests that it is poor for applications such as moving a cursor to a designated position. Describing positions verbally seems to be inherently slower than simply pointing to the positions.

A study by Goodwin (1975) is a classic in illustrating the development of the light pen and light gun. The pistol-grip light gun provided a less fatiguing method of designating positions than the traditional thumb-actuated pushbutton on pens.

For a series of clerical tasks, the light pen and gun were shown to be much faster than keyboard cursor controls. Of course, this would be expected because pointing devices do not need to be concerned with the distance of cursor movement or the tedious process of movement of the cursor to a designated position.

MIL-STD-1472C still recommends the light pen for only "non-critical" situations (e.g., menu item selection) while the trackball/joystick is recommended for "precise" input functions. Pfauth and Priest (1981) also recommend the joystick for drawing lines or generating new data, while the touch screen is recommended for modifying or manipulating displayed data and other low resolution tasks. Advancements in technology may permit the user to accomplish much more with light pen, touch screens, and other pointing devices as the operator achieves better stability and feedback of error. The current recommendation to limit pens to item selection, gross position designation, and gross drawing also may be altered by improved magnification aids.

From Proceedings, 1983

J. Thomas Murray et al, Voice vs. Keyboard Control of Cursor Motion
Exxon Office Systems Company.

Abstract only. Granted that keyboards are slow for curs control, one wonders why voice was compared to keyboards rather than the mouse or joystick. They say 30% of commands involved in word processing involve cursor control, so the issue is important. Voice does not require removing the hands from the keyboard and should be faster, they reasoned.

The experimental task was set up to begin with fingers on the home row. Task time included time to move the hands to the cursor control, slew the cursor to a target embedded in a screen full of text, and reposition the hands on the QWERTY home row. Apparently, they hoped voice would be faster if the need to move the hands were omitted.

The shocking finding (to them) was that voice took twice as long to position the cursor as did using keys. They mention "cognitive confusion associating an utterance with the intended direction of cursor movement."

Voice is poor for identifying locations. It takes longer to describe how to go from point A to point B on a road map, than it does to direct a toy car along the same route. It is quicker still to simply point to where you wish to go. However, pointing devices have other technical limitations, as described in the Beringer and Peterson article (1983).

In general, the paper was useful in reminding us that voice is not a universal panacea. Although much faster than keyboards for problem solving and argumentation, it is not as efficient in the spatial domain where the task involves only designating a location remote from the initial position.

From Human Factors, 1975, 17(3), June.

N.C. Goodwin, Cursor Positioning on an Electronic Display Using Lightpen, Lightgun, or Keyboard for Three Basic Tasks. (Mitre Corp)

It is sobering to realize the research in this area was done a decade ago and the author cites a study by English et al reported in 1967 comparing the lightpen, mouse, graphic tablet, joystick, and a knee control for a cursor moving task. However, the English study had no statistical analysis.

The study reported is really a pilot study (N=6). A photo of the pen and gun are shown as well as typewriter keyboard. She meticulously explains how they work: (1) The keyboard cursor positioning keys did not permit direct (continuous?) up-down, left-right movement of the display. Instead it moved in discrete steps. It is poorly explained, but discrete steps would be slow; (2) the light pen (photoelectric cell) is activated by aiming at a character and pushing a button. The cursor moves directly to the character causing it to blink. The cursor is an underline blinking at 6-Hz rate. Pens are awkward to hold and the button causes a sore finger as designed. Hence, the pistol-like light gun was studied.

One hypothesis was that the gun would be easier to aim and activate than would a pen. The other hypothesis was that either pointing device would be faster for positioning a cursor than a keyboard. One task involved replacing in numerical order, numbers 0 to 9, with X's overtyped by the devices. Number location was random. The second task (form filling) involved moving from top to bottom of the display, called sequential cursor positioning. A third check-reading task involved finding 10 substitution errors in a paragraph and replacing each with an X. The three tasks simulated respectively: menu options, form filling, and proofreading.

Results

For arbitrary positioning (menu) the mean time for ten tasks was faster with the gun (26 s); second with the pen (32 s) and slowest with keys (135 s). For the sequential task, the pen and gun were statistically equal (21 and 25 s) while the keyboard was twice as slow (55 s). For check reading, the results were similar (65, 68, 106 s).

Conclusions

Keyboards take four to five times as long as pointing devices when the task involves moving around the display in random pattern. (Although she admits the keyboard selected was clumsier (discrete steps?) than some available.) The results were as expected because <u>cursor movement distance is irrelevant</u> for the pen and gun, whereas the keyboard involved noticing the current cursor position and pushing the correct key to move it to target position.

ABBREVIATIONS

While military standards for abbreviations have existed for many years, it was found in reviewing certain military course syllabi for specific devices, that the abbreviations being used tended)ear little or no resemblance to the word or phrase being abbreviated. Logical abbreviations or mnemonics which employ selected characters from the abbreviated word or phrase, should aid work in speed of operator learning and reduction of input errors.

A related issue is the employment of some form of alphabetic shorthand in transcribing material. Schoonard and Boies (1975) recommended "short type," a technique employing a list of abbreviations for frequently typed words. This type of approach might greatly reduce the time required for entering data into computers especially in situations when the vocabulary of words being entered was limited and highly repetitive entry was the required task.

In summary, speed of entry and error reduction can be improved by either improved data entry technology or by simplification of the required operator task.

Schoonard, J. and Boies, S. Short-Type: A Behavioral Analysis of Typing and Text Entry. Human Factors, 1975, 17(2), 203-214b

This study evaluated a typing task which incorporated an encoding operation. This technique, called "short-type," takes advanta[illegible]f word repetition to reduce the number of keystrokes required to tran[illegible]be documents. Four typists were taught a list of abbreviations for frequently occurring words. Their subsequent task was to enter documents into a computer via a standard keyboard. Each time a word from the training list was detected, the corresponding abbreviation was to be typed in its place. It was found that: (1) over 93% of the to-be-abbreviated words were detected by the typists; (2) the error rate in selecting and typing abbreviations was no greater than the error rate in typing words which were not abbreviated; and (3) the substitution process did not adversely affect the keystroke rate. It was concluded that short-type is a practical technique in improving typing performance.

Tactical Radio Communications, U.S. Army Signal School Document SSO-059-6.

This is a military course syllabus teaching techniques and principles of radio communication. It includes the area of radio voice communications (pp. 76-92) particularly the use of the phonetic alphabet. Most of the report deals with the hardware configurations. The teletypewriter is discussed (pp. 126-136), but the actual keyboard is never shown (only block diagrams).

On page 133 "prosigns" which are simply alphanumeric abbreviations for common messages were discussed. These are very poor following neither of the conventional ways of abbreviating (key consonants or truncation). For example, DE means THIS IS, IMI = SAY AGAIN; ZBK2 = I COPY YOU GARBLED. More logical abbreviations would require le ote memory for the technician. The only possible reason for such abbreviations would be enemy confusion after message interception. However, they would likely have a decoding manual. The dangers of operator error are greater; interesting, but not a helpful report in our task.

Syscon: Communications Systems Planning, Engineering, and Control. Special Text 11-154-4, Army Signal School.

This report begins with a discussion of organization of the Signal Corps, then various trouble reports and paper flow are shown via diagrams. This discussion of a complex bureaucracy is not at a level to be useful.

Certain codes are used. Again, they have arbitrarily assigned a letter (or two letters) to each function. Only by having this code list could an operator know the meanings. There are 2- and 3- letter abbreviations (using the first letter of the words) which would provide at least some clue for the experienced operator. To illustrate, "JA" is used for "high noise level." Why not use "HDB" or "HNL" instead?

CONCLUSIONS

RESEARCH TRENDS

Out of 148 articles studied in this literature review, l than 30 were informative enough to merit closer scrutiny. Data Entry Devices; Keyboard Specifications and Evaluations; Keyboard Layout; Keyboard Slope and Height; Keyboard Displacement, Resistance and Audio Feedback; Chord Keyboards; Touch Screens and Panels; Comparisons of Light Pen, Light Gun, and Voice with Keyboards; and Abbreviations are the subtopics dealt with in the literature reviewed.

One of the major trends in research is to take a close look at the QWERTY (typewriter) layout to determine if it belongs in its position of number one in use and popularity. Although the alphabetic keyboard layout has been shown on many occasions to be inferior to the QWERTY for text entry, it shows some merit for occasional one-handed entry by novice typists. Though Francas et al., (1983), support the QWERTY over the alphabetic keyboard, there are strong arguments for the alphabetic arrangement for highly technical material and when a modified design (3x3, 4x4, 5x5) makes it impossible for keys to be in QWERTY locations anyway.

Norman's article (1981), though not design oriented, explains why the alphabetic keyboard isn't easy to use; because it is not oriented in a frequency of use fashion. Function keys used frequently should not be assigned to the same finger. The Dvorak or DSK keyboard layout gets its strength from what the alphabetic keyboard lacks.

The DSK principle of consonants on the right and vowels on the left to permit rapid alternation of fingers on opposing hands could be incorporated into any single press keyboard design to speed up data entry. Use of a DSK format has netted a 10-20% increase in typing speed (Noyes, 1983), but the format has been pushed asi because of the investment required in training and conversion costs. There is one other instance where the advantages of QWERTY and DSK over alphabetic lessened - when multiple characters were programmed into a single key (reviewer's conclusion).

This multiple character programming is used for the two chord keyboards studied. Each of these keyboards is a possible alternative to the QWERTY for special use groups. The Dutch "Velotype" chord keyboard for dictation stenotypists sometimes has three characters assigned to one key, a poor design. Some characters are made by combining two keys. A DSK type of setup is used; initial consonants are set up on the left side, final consonants set up on the right, and vowels in between. Three presses will enter any consonant-vowel-consonant word. The 37 keys are arranged in a butterfly shape with all keys accessible from a fixed hand position. Also like the DSK, the heaviest load characters are ostensibly assigned to the strongest fingers. This international keyboard layout is questionable because some not popular English characters are in primary positions, e.g., "j."

The claimed advantages of the Velotype are: 3x the speed of the QWERTY, no need to transcribe after use, and that it is easy to learn. The one line matrix display is definitely a disadvantage - if typing at 900 characters per minute, the text would disappear after three seconds, making proofing impossible. The system should have a page screen.

The other chord keyboard studied, the "Microwriter," is the most successful of the handprint keyboards. Some of the reasons for its success are that it has a full range of word processing commands and features: wrap-around, scrolling, fast movement in text, tabs and returns. There is a 16 character display with 14 for entry and 2 for commands. Screen editing can be done if the keyboard is hooked up to a screen.

The Microwriter has a lot of advantages for the targeted market of mid-management and other professional people. The keyboard is book-sized with a hump on it for resting the palm, and it is battery powered, making it efficient for use on transportation. A common speed is 45 characters per minute, which is faster than handwriting, and it eliminates the problem of illegible scrawl. Mnemonics are used well visually, symbolically, and through wordplay. There are three modes or registers including numeric mode. An interesting feature is that the keys on this device send a code on release instead of depression, allowing a non-simultaneous chord. There are some problems, however. The keys are square and not elongated so that large hands can't type with fingertips while fingers are extended, and cramping results. The keys are too easy to activate; this was intended to be an advantage but is actually a design flaw.

The desire to make data entry easy for the operator can result in design flaws if carried to extremes as in the Microwriter's easy key activation mentioned in the previous paragraph. In most cases, however, the operator does benefit from these efforts, e.g., a keyboard may be cupped to take into account varying finger lengths and to provide tactile feedback if the typist strays to the wrong row (Francas et al., 1983).

In line with this desire to make data entry easy for the operator, a trend in data entry devices has begun to seek out very best entry devices for different types of tasks. For example, when voice was first explored it was viewed as a panacea for all types of data entry. In reality, voice is fast but tiring and disliked for entering digits. Also, voice commands are poor for identifying locations; it takes 2x longer using voice commands than it does with keys. However, voice commands are much faster than keyboards for problem solving and argumentation.

Knobs and levers are slower than keyboards, but touch devices are faster and easier to learn where applicable. Light guns and pens are faster for positioning a cursor than keyboards. But the mouse is faster than the light pen and less tiring for cursor positioning. The joystick and trackball are good for precise input functions.

Light pens are faster than joysticks and tracker balls for designating targets on the screen. This is backed by the 1472C, 1983 revision, which states that the light pen is mainly for item selection. Williges (1984) says, however, that if there are many selectable items in a menu - typing is faster than a light pen. The light pen is awkward to hold and the button causes a sore finger. Arbitrary positioning (menu) is faster with a gun, second the pen, slowest - keys. For sequential cursor positioning the pen and gun are statistically equal and the keyboard 2x as slow.

Touch wire displays are faster for pointing than typing, but their unreliability slows operators down. They are also faster for limited alphabetic data but not text entry (Umbers, 1983).

Aiding the input process on computers are double action keys, i.e., light pressure backlights a function on the screen and h er pressure executes that function. Backlighting can also be used to indicate the proper sequence of key depression to perform a particular task, locking out those keys that are not backlit.

Although the MIL-STD-1472C, 1981 revision is more specific than the 1983, the 1983 revision offers common sense guidelines on ease of use and system response, e.g., validation of data entry before a new transaction begins. Though the 1981 revision gives an option for numeric entry and alphabetic - a separate keyboard to the right with numbers or no separation between alpha and numbers, the 1983 revision states that the keyboard should have a numeric keypad if there is a lot of numeric input. Shift keys should not be used for variable function keys. The configuration of a system should be standardized if it has more than one keyboard.

Williges (1984) design guidelines say when to use a particular device, but there are some contradictions in different sources. A clear and concise summary or table showing when to use different devices is needed. The designs that are recommended are for inferior systems like light pen and joystick, rather than for those systems they recommend, e.g., trackball (faster than special function keys).

MIL-STD-1472C based a decision on earlier research on keyboard slope and height, and adopted a 15-25 degree range for tilt. Most low profile keyboards are <15 degrees.

Suther and McTyre (1982) found that a 5 degree slope was uncomfortable and a 25 degree was disliked and uncomfortable. 10-18 degrees for a fixed slope was best; 10-25 for adjustable slope. The author theorizes that stature and hand length are related to this issue. Men therefore, may prefer a less steep keyboard.

Miller and Suther (1981) found that the shorter the person, the greater the preferred keyboard angle. The preferred angle was 18 degrees, with a 14 degree minimum, and a 25 degree maximum. Miller recommends adjustable slopes. Home row preferred height was 77mm. Data supported Cakir's recommendation of minimal thickness of keyboard, because most tables are 27 inches without a keyboard and the ideal height from the floor is 27.8 inches.

Emmons and Hirsch (1982) recommend home row thickness not >30mm. Concerned in the study with the height of the keyboard relative to wrist and forearms, the slope and therefore, height varied for testing. Many variables affect performance; some were: contour of board, and key size and shape. What causes fatigue is more complex than simple tilt angle (height/angle combination). Like Suther, Emmons found that the 5 degree slope was least liked and most tiring.

Burke, Muto and Gutemann (1984) found that performance favored heights of 38 and 45mm over 30mm height. There was no performance difference between 5, 10, 15, and 25 degree tilt, but 10-15 degree was preferred. Xerox kept an 11 degree tilt throughout the study and varied the height of the home row, even though MIL-STD-1472C's permissible range is 15-25 degrees.

Feedback to the operator that a key has been pressed is a factor in whether a keyboard is acceptable to the operator. Bruner and Richardson (1984) found that though initial auditory feedback was important, there was no clear result for an electronic click. One noiseless elastomer and one with auditory feedback were both preferred. (Results don't apply to occasional entry systems.) However, in another study by Monty and Snyder (1983), typing was faster with the electronic click on than off; experienced typists were faster with the click on, but made almost twice as many errors.

There is greater wrist fatigue on the keyboard with the least feedback; it was also least preferred. Too little resistance led to errors. This is undoubtedly one of the reasons that MIL-STD-1472C requires a certain amount of resistance and displacement unmet by the membrane keyboard. In Cohen's study (1982), non-touch typists performed the same on membrane and full-travel keyboard; for touch typists there was still some advantage for conventional. Elastomer action of keys led to faster typing.

Other findings by Monty and Snyder (1983) were that a large return key, L-shaped, was liked. The return key should be oversized and in standard typewriter location. An automatic return was suggested; but consideration must be given to whether typists want it, since they often type past the margin. It is easy to unintentionally hit the CAPS key on an electronic typewriter with the little finger, left hand. The light which comes on should be a click or tone.

Touch screens and panels are, like other pointing devices, excellent for modifying display elements or making menu selections.

High resolution screens are within current technology, but stabilizing the hand and arm for precise movements is a problem.

Advantages of touch screen devices: Input/Output are at one location, not much training is required, there is immediate feedback for the operator, and they are liked. Disadvantages: they are expensive, require programming, are not flexible unless a keyboard is available, screen glare, finger blocks screen, change in position from which viewed affects touch locations.

Declination angle had little effect on the number of errors and response time. For greater declinations, touches were slightly lower than target. Shoulder and arm fatigue were expressed if the display was at 90 degrees, wrist fatigue at 35 degrees.

Another way to make data entry easier for operators is to simplify or standardize the information itself. For example, abbreviations used in military courses bear no resemblance to the words abbreviated. Abbreviations used in tactical radio communications are not conventional, requiring rote memory and increasing likelihood of operator error. The same holds true of SYSCON.

Logical abbreviations or mnemonics should speed operator learning and reduce input errors. Schoonard found that "short-type" or the use of a list of abbreviations for frequently typed words to be a practical technique to improve typing performance and to reduce data entry time.

RESEARCH VOIDS

The available literature on keyboard design leaves many questions unanswered. For example, Alden's article (1970) never answers the question, "How small can keys be without having a negative impact on data entry?"

Research has been almost non-existent in the area of numeric function keys. Even the basic mathematical functions have not been standardized for calculators, much less for keyboards. Goodman et al. (1983), from his study supported a 3x3 layout for a public access terminal (7 function keys).

The combination of the standard height of keyboard tables (27" without keyboard) and the ideal height of the keyboard from the floor (27.8 inches), should be pursued. How to get the thin keyboard and the preferred 18 degree slope simultaneously was not addressed by Miller (1981) and should be.

The results are unclear for the best type and amount of feedback. Can visual and auditory feedback replace tactile? Domes and embossing aid in finger placement, and tone seems to reduce error, but the effect may not be the same as a kinesthetic one (Roe, Muto, and Blake, 1984).

The Velotype chord keyboard needs rating by an independent research agency to evaluate butterfly layout. If it does reduce fatigue, and improve speed, would the QWERTY benefit from a different shape? A need exists to further confirm or refute the claim that the keyboard layout is international.

Ergonomics research is needed on the Microwriter: Can it be adapted for a range of hand sizes and the display be improved? A study should be done on the feasibility of use by other special need groups.

A study of the proper angles of touch screens and panels to prevent wrist fatigue is needed, and the possibility of arm supports should be considered. Research is also needed into possible feedback for pointing errors. Instead of advocating training on touching correctly like Beringer and Peterson (1983), make the machine more forgiving by programming it to accept a touch within 1/3 of an inch.

All key issues must be addressed from a design standpoint. How accurately can humans point? How does accuracy vary with tilt angle of screen? Are errors constant or variable? If constant the machine should correct them, if variable, give feedback to help the operator correct them. If accuracy is beyond human limits due to tremor, design acceptance tolerances to match human skill or provide stabilizing aids (e.g., wrist rests), a more horizontal screen, a finer point on the touch device, or a more distant hold point. More understanding of human engineering issues is essential if useful information is to come from future studies.

APPENDIX A

ANNOTATED BIBLIOGRAPHY

A1-KEYBOARD CHARACTERISTICS, CURRENT TECHNOLOGY/FEATURES

1. Anonymous. Alphanumeric Keyboards Survey. System Int., 1981, 9, 23-25.

Describes various types of alphanumeric keyboards availa[illegible] and discusses the advantages and disadvantages of them. The ergon[illegible] aspects of the various keyboards are briefly discussed, as are [illegible]ssible applications for the various types.

2. Anonymous. Terminals Price War Continues as New Features Abound. Data Communication, 1983, 12, 76-81.

A price war has broken out in the display terminal sector, resulting in cheaper and cheaper alphanumeric display terminals possessing more and more advanced features. The article presents a user survey of some 91 'dumb' and 'smart' terminals (but excluding 'user-programmable' devices) from 33 manufacturers. Based on 797 responses representing 122063 installed units. The survey includes measures of overall performance, ease of operation, display clarity, keyboard feel and usability, hardware reliability, and maintenance service and technical support.

3. Eikelberger, R.J. Selecting the Right Keyboard. Machine Design, 1981, 53, 68-74.

There can be vast differences in the performance of keyboards that seem outwardly identical. Even minor variations in mechanical and electronic make-up can have a large impact on costs. The author looks at the various types of keyboards, and considers their advantages and disadvantages.

4. Harding, B. Keyboards. New Electronics, 1982, 15, 33-47.

Discusses current keyboard technology and the options available to the potential user. Ergonomic factors with regard to key and color grouping and membrane pads are described. Electronic systems, including the use of microcomputers, are also discussed.

5. Hackmeister, D. Focus on Keyboards: The Real Challenge is 'Interfacing' the Computer User to the Right One. Electronic Design, 1979, 27, 169-172.

As computer users grow in diversity, interface keyboards are growing in capability, economy and performance to accommodate all of them. Most OEM keyboards (alphanumeric) and keypads (numeric only) are custom designs, produced on a sole-source basis. The designer should select a keyboard technology whose longevity matches that of the host system, and then bring in the keyboard manufacturer to design for utility and lowest cost.

6. Hogan, G. and Beatie, R. A Question of Quality...and Compatibility. PC User, 1983, 46-47.

There are a number of differences between the IBM personal computer's keyboard and those of its nearest competitors. The important features to look for are ease of use, noisiness, and key positions. The advantages and disadvantages of the IBM PC are examined in detail.

7. Morris, H.M. Pushbutton Keyboards Let Men 'Talk' to Controls. Control Engineering, 1981, 28, 85-88.
The most common man-machine interface is still the pushbutton. Whether alone or configured into a keyboard this tried-and-true technology is experiencing a market growth due, primarily, to ever-increasing proliferation of microprocessor-based instrume and computer peripherals. Regardless of the sophistication of the instrument, an operator must still use a keyboard to program instructions or engineering parameters into these sophisticated devices. The author explores the variety of keyboard styles available to the control and instrumentation design engineer.

8. National Technical Information Service. Computer Keyboards; Design, Selection, and Evaluation. 1975-September, 1983. Springfield, VA: Author, 1983.
This bibliography contains citations concerning computer keyboard design, selection, and evaluation. Keyboard and display interfaces of the terminals, operator interface and customized design, and operation reliability are discussed. Keyboard styles, key configuration, and keyboard erase control are included. Keyboard facilities and costs are considered.

9. Simms, J. Keyboards: Vital Features. Modern Office & Data Management, 1982, 21, 28-30.
The first point of evaluation of the keyboard of a word processing (WP) workstation is whether it is separate from the rest of the terminal or is an integral part, the former being preferable due to the many ergonomic advantages it offers. Since it is a 3-dimensional object, its physical size must be taken into consideration to ensure that it fits conveniently into its projected surroundings. The QWERTY keyboard is the world standard, despite its disadvantages, but some systems permit the use of other keyboards. Some systems offer special features, such as a separate numeric pad for the input of numbers, and the facility for quickly moving the cursor to specific points. Another point of argument over keyboards concerns the relative merits of having specific function keys or relying on mnemonics. Few systems have enough function keys to be able to achieve every objective with a function key, but the new soft-key approach constitutes one solution to the problem. Factors that can be reviewed in relation to specific keys include: 1. Some systems permit all keys to be repeat keys. 2. Some have a "cap lock" key, enabling the user to type in caps yet still have access to numbers on the top row of the keyboard. 3. The position of the keys in relation to each other must be convenient.

10. Tiddens, M.E. Keyboards continue evolving. Digital Design, 1981, 11, 48-50.
Keyboards are undergoing major changes due to cost pressures, modularity trends and ergonomic considerations. Designs remain custom and unique to every terminal and computer product, but certain functional characteristics have become common to most applications. Keyboard technologies and designs are reviewed.

A2-ERGONOMICS/HUMAN FACTORS CONSIDERATIONS IN KEYBOARD DESIGN

1. Alderman, I.N., Ehrenreich, S.L., and Bindewald, R. Recent ARI Research on the Data Entry Process in Battlefield Automated Systems. Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences, Report No. ARI-RR-1270, September, 1980.

This paper reviews ARI research designed to improve the entry process. The first and second sections of the paper describe data entry process in general and in the context of a specific battlefield automated system, the Tactical Operating System (TOS). Because it was used as an exemplar of the data entry process, TOS played an important role in the development of improved data entry procedures. The third section of the paper reviews the findings and conclusions of the many ARI research projects concerned with data entry. Among the areas covered in ARI's research program are: how to format and display data entry information; what safeguards can be developed to reduce the number of operator errors made and/or accepted by the system; what kinds of operator job aids can be developed to improve performance; how to improve operator training; how to make the system's message codes easier to use and more memorable; how to improve the design of keyboards. The fourth section of the paper reports on efforts to analyze the cause of operator error. This section also discusses the development of a simulation of the data entry process. The simulation is intended to facilitate system design by permitting the inexpensive evaluation of alternate data entry procedures. The fifth section presents a general discussion of the problems that have been encountered by the ARI research program. Also included here is a discussion on how this program might be improved in the future. The final section of the paper summarizes the operational implications of ARI's research result. (Author)

2. Andreiev, N. Trends in Pushbuttons and Keyboards. *Control Engineering*, 1974, *21*, 84-87.

The author examines the human engineering aspect and its effects on the design of pushbutton switches and keyboards.

3. Bailey, R.W. Human Performance Engineering. Looking Through the User's Eyes. *Computerworld*, 1983, *17*, 1-6.

Gives an introduction to visual perception as it relates to human performance engineering, for example in CRT or keyboard design. The importance of schema, or format, is emphasized.

4. Cakir, A., Hart, D.J., and Stewart, T.F.M. *Visual Display Terminals*. New York: John Wiley & Sons, 1980.

This book summarizes the most recent ergonomics knowledge (at time of printing) relevant to the design and selection of VDT's and VDT workplaces. This knowledge has been derived from a large number of experiments and field studies conducted by the present authors and many others in recent years. Included is a discussion of the ergonomics of keyboards.

5. Coombes, K. (Ed.) Proceedings of the Ergonomics Society's Conference 1983, London: Taylor and Francis, 1983.

The following topics were dealt with: Introducing ergonomics into the design of commercial computer systems, human factors in expert systems, data input via keyboard, characterizing task performance, trial videotex keyboard system, ergonomic aspects of menu-based dialogues for man-computer interaction.

6. DeCallies, R.N. and Potter, N.R. Development of Human Engi ing Standards for Multifunction Keyboard Design. Proceedings o the IEEE International Conference on Cybernetics and Society, 1976, 434-438.

The necessary engineering design for multifunction keyboards must consider the capabilities and limitations of design options against preselected values for performance. This paper reports on the assessment of the adequacy of existing military and civilian standards and on a proposed standard for hardware keyboard design which was written.

7. Deininger, R.L. Human Factors Engineering Studies of the Design and Use of Pushbutton Telephone Sets. The Bell System Technical Journal, 1960, 39, 995-1012.

From the user's point of view, what are the desirable characteristics of pushbuttons for use in 500 type telephone sets? The studies reported bear on this question and also on questions of how people process information when keying telephone numbers. Four categories of design features were studied: key arrangement, force-displacement characteristics, button-top design and central office factors. The results indicate that considerable latitude exists for key set design in terms of user performance; however, the preference judgements are more selective. The studies also showed that the manner in which the person acquired and keyed the telephone number influenced performance appreciably.

8. Dinan, J. Designer-Think 'User' When You Firm Up That Interface Device. EDN, 1976, 21, 77-81.

Discusses user-oriented computer room equipment design points concerning operator-machine contact affecting speed and quality of throughput. The author considers noise, room layout, keyboard design and the need for standardization, safety aspects, and operator comfort.

9. Fletcher, J.H. Designing Keyboards for the User. Paper presented at the International Conference on Man/Machine Systems, Manchester, England, July, 1982.

Keyboards and their smaller relations, keypads, are currently the most common interface between humans and computer like systems. They may be simple or complex, user friendly or user unfriendly. This paper lists and reviews principles of keyboard design that may be implemented to increase the user friendliness of complex keyboards. The relat values of these principles is still the subject of current research a hile it may not be possible to incorporate all of them into any one ...ign, marked deviation from them should be avoided wherever possible.

10. Gilb, T. and Weinberg, G. Humanizing Data Entry by Default. Datamation, 1976, 22, 73-76.

Data entry operators are still used as eye/finger machines. Little changes to improve their lot can lead to big improvements in efficiency. Defaults alone can cut keystrokes by half.

11. Gladman, R. Human Factors in the Design of Visual Display Units. In Visual Display Units and their Application, Ed. Grover, D. Guildford, Surrey, England: IPC Science and Technology Press, 1976.

The specification and size of characters on the screen must be considered in relation to inter-line spacing to optimize the display for the operator. The type of cursor is important, as is the mode of indicating significant data. The keyboard has evolved to the point where electronic methods are used to optimize the keying action to be light but positive. Rollover capability is necessary to minimize error rates and various keyboard designs are mentioned. The dimensions of the work station have been extensively investigated to ensure adequate space and comfort for the operator.

12. Harris, R.H. Curved Keyboard. IBM Technical Disclosure Bulletin, 1979, 20, 2784-2785.

A flat, slanted keyboard having buttons of identical shape and identical keytop orientation may cause operator discomfort because of the lack of any curved or dishing effect produced along the various plans of the keytops. A curved keyboard intended to alleviate this problem is disclosed.

13. Hewin, L. and Saylor, D. The Man-Machine Interface (2) HASCI Comes Through. Desktop Computer, 1983, 3, 16-20.

Issues and answers column discusses the concepts of integrated software and hardware modification to meet human needs. The HASCI standards (Human Applications Standard Computer Interface) are described for keyboards and monitors.

14. Kaplan, A. Ergonomics of Keyboarding. Modern Office Procedures, 1976, 21, 30-32.

The keyboard in man/machine language is considered the interface between the operator and the equipment. The positioning of the operator at the keyboard and the keyboard workstation layout are essential for good systems operations. The best arrangement of the keyboard workstation requires several things - 1. All read-outs, surfaces, and holders for work material should be placed directly in the line of vision, 2. Keyboard units should be placed on a side run-off perpendicular to the desk, and placed at a height permitting operating with the elbows down, 3. Lighting should be placed overhead, slightly toward the operator, 4. All contact surfaces, either for manipulative work or visual work, should be placed on a radius sweep of human body motion of 120 degrees, 5. Traffic patterns around workstations should avoid movement behind the backs of the operators. This moveme an adversely affect the working rhythm.

15. Kinkead, R.D. and Gonzalez, B.K. Human Factors Design Recommendations for Touch-operated Keyboards. St. Paul, MN: Honeywell, Inc., S&RC Research, March, 1969.

A series of four experiments was conducted to determine the best experimental design for keyboard performance studies, the optimal levels of key force and displacement to minimize adverse transfer effects from standard typewriters, and the importance of tactile feedback in the keystroke. It was found that typists used to electric typewriters do best if force and displacement are held within certain limits; 0.9 to 5.3 ounces, and 0.05 to 0.25 inches, at the full travel of the keys. An advantage was found for keyboards which had no snap action or override point during key travel. No difference in performance between stepped or sloped keyboards was noted. The characteristics of the Micro Switch product line of keyboards fall well within these limits.

Recommendations for further experimental and in-use evaluations of keyboards are made, and the effects of recent research and keyboard design and standardization activities are discussed.

16. Knapp, J.M. The Ergonomic Millennium. Computer Graphics World, 1983, 6, 86-88, 92-93.

The first attempts at office automation met with resistance, perhaps because the early relation of man to computer was antagonistic. Ergonomic research is only now beginning to change the interactive office. Numerous studies have yielded practical answers to questions concerning operator well-being. Distinct man-machine interfaces are required for each variety of user. A poorly designed manual, screen array, or menu can be just as damaging to the mind as a badly angled keyboard to the wrist. The reward and redirection concepts of programmed learning, extensive prompting, and conversation-like interchange are ergonomic concepts that help to promote creativity and may spark genius.

17. Koffler, R. The Hards and Softs of Ergonomics. The Independent Guide to IBM Personal Computers, 1982, 1, 225-230.

Defines and explains ergonomics, human factors engineering. Says that ergonomics involves both hardware and software. Notes that many ergonomically designed computer displays are available but properly designed keyboards are rare.

18. Liebmann, W.K. Data Processing Ergonomics and Meeting User Requirements. Neue Technology, 1981, 23, 55-60.

The need for human factors engineering of computer terminals is noted, with special reference to data displays and keyboards. Good focusing, adjustable intensity as well as adequate character size on cathode ray displays are specified; it is suggested that characters should not subtend less than 18 minutes of arc which would mean a linear dimension of 26 mm. Reference is made to DIN proposal 66234. The difference between 5x7 and 7x9 dot matrix representation is discussed and flicker problems are examined. Keyboards with built-in feel are reviewed, key layouts are compared and reference is made to the Japanese Kanji key layout. Means for reducing acoustic noise from printers are described, and an IBM supermarket work station type 3874 is contrasted with a cashpoint station.

19. McCann, C. Graphic Display Interaction. Part I. Literatur_ review. Ontario: Defense and Civil Institute of Environmental Medicine Downsview, Report No. DCIEM-TR-78X4, January, 1978.

This paper presents a critical review of the ergonomic literature on devices for entry and manipulation of data on a computer graphic display system. A general review is made of the extensive research effort devoted to studies of keyboard design and operation, and to studies of devices for target acquisition and tracking. The main body of the paper reviews the more recent body of published work on devices for man-computer interaction. Conclusions are presented on the nature and limitations of the existing body of human factors data on graphic display interaction devices. (Author)

20. Mehta, N., Smith, K.C., and Holmes, F.E. Feature Extraction as a Tool for Computer Input. _Proceedings of ICASSP 82_, 1982, 818-820.

This paper describes a versatile human-machine interface designed to achieve an important balance between human factors and flexibility. It incorporates attributes of keypads, tablets and 'mice' and possesses freedom of keyshape, size and function. The system uses a TV camera focused on a 'keyboard' area to generate electrical signals in response to optical inputs. Additional optical and electronic feature extraction result in an input device capable of processing discrete and continuous input simultaneously.

21. Oatway, S. Fitting Machines to Users Boosts Productivity of Both. _CIPS Review_, 1984, _8_, 8-10.

The benefits of ergonomics include greater office efficiency. In any work situation it is important to develop a harmonious relationship between man and machine in order to minimize error and maximize accuracy and output. A person's comfort and performance depend on how well physical facilities fit. Keyboard layout, functions, and key design are vital to user productivity and acceptance. A successful workplace depends not only on ensuring that the equipment is ergonomically designed, but also integrating it so that it functions satisfactorily together with the user. Chairs which provide proper back support, a desk positioned to provide both knee clearance and a good working position for hands and arms all comprise part of the solution.

22. Ominsky, M. Human Factors in the Development of a Family of Plant Data Communication Terminals. _IBM Systems Journal_, 1981, _20_, 216-236.

Developing a set of terminals for users who had no computer experience and whose normal jobs could not be subject to interference involved human factors. Most of the design work focused on the keyboard and display interfaces of the terminals. Studies were made, alternative designs were considered, and tests were performed to ensure that the equipment was easy to use and provided acceptable speed and accuracy.

23. Ormond, T. Latest Keyboard Improvements Stress Ergonomic Considerations. EDN, 1983, 28, 106-166.

Human engineering permeates today's keyboard industry as manufacturers strive to offer products that maximize workstati productivity and minimize operator fatigue. Nurtured by the g ng emphasis on ergonomics, the low-profile keyboard is one of the electronics industry's fast growing product areas. However, while 'low profile' seems to be the catch phrase of the 1980s, human factors engineering has not concentrated solely on profile; it has also addressed encoding schemes and keyboard-layout problems.

24. Primrose, B. Anatomy of an I/WP System: Part III-The Keyboard. Modern Office Procedures, 1983, 28, 130.

Even though it is essential to system operation, the keyboard is the component most often neglected, abused, and overlooked by both information/word processing (I/WP) system users and manufacturers. The basic elements of the keyboard are the standard alphanumeric keys and a group of control and/or function keys used for actions such as implementing text editing. The keyboard usually has a keypad that is used to control the movements of the cursor on the display. A calculator-style numeric keypad is also used on some keyboards. There are a number of text input/edit features controlled at the keyboard, including : 1. file sort/select, 2. line spacing, 3. text underlining, and 4. column move/delete. In spite of claims that they are user-friendly, most keyboards require a dedicated training and practice program before a comfortable level of operation is reached, however, today's highly competitive marketplace does put more emphasis on ergonomic design of the keyboard. The intelligent consideration and selection of the system's keyboard will greatly influence and enhance the user's chances for quality input/output.

25. Swaine, M. Fashions in Micro Hardware: Add-in CPU's, Smaller Drives, Screens. Infoworld, 1982, 4, 39.

Discusses how the CPU used in microcomputers is becoming selectable by the user, keyboards are being detached, ergonomics are becoming important, graphics capabilities are increasing, and also discusses portable computers and flat screen displays.

26. Taylor, R.M. and Berman, J.V.F. Aircraft Keyboard Ergonomics: A Review. Display Technology and Application, 1983, 4, 97-104.

The increasing use of complex digital avionics systems has resulted in the aircraft pilot making ever greater use of keyboards. The designer has comparatively little coherent information or guidance to help him select the optimal physical and functional characteristics of the keyboard, but current technology gives him a very wide choice. Much of the literature available in the early 1980s relates to studies based on static ground environments and, although there is some evidence derived from studies of aircraft, the majority of the ergonomics data relevant to keyboard design is not easily generalized to the airborn environment. A review of the current military standards underlines this as they are brief and they are not always rigidly adhered to in practice. The factors which are likely to affect keying performance are discussed and the state of ergonomics knowledge in the area reviewed.

27. Taylor, R.M. and Berman, J.V.F. Human Factors in Aircraft Keyboard Design: Standards, Issues and Further Evidence Relating to Gloves and Key Characteristics. AGARD Conference Proceedings, 1982, 1-17.

Keyboard factors affecting data entry performance includ yboard positioning and layout, key size, actuation force, pre- and post-actuation travel, visual and tactile feedback, key separation and barriers. Other factors include the effects of aircrew gloves on manipulative ability, tactility and hand/finger dimensions, operator comfort, fatigue and aircraft vibration, the level of skill of the operator, the cognitive and physical components of the data entry task and the interference between keyboard data entry and other tasks performed concurrently in the cockpit. The 1982 status of human factors knowledge in these areas is reviewed and the results of experiments conducted at the RAF Institute of Aviation medicine are discussed in relation to keyboard standardization agreements and aircrew training.

28. Thomson-Smith, N. How Comfort Can Be as Vital as the Computer. Computer Management, 1983, 30, 26-27.

Ergonomics, the relationship between the worker and his work, is playing an increasingly important role in the design of computer-related equipment. According to the office furniture manufacturers and various reports, most office workers will soon be using VDUs, and electronic filing systems, computer output microfilm, and computer-aided retrieval will be widespread. As a result, filing products and the furniture that goes with them must adapt to suit the office of the future. An environment must be created which avoids the worker suffering from drowsiness, lack of concentration or back problems. The article looks in particular at chair design, VDUs and keyboards, and gives suggestion for creating a good working environment for the automated office.

29. Woodson, W.E. and Coburn, C. Human Engineering Design Criteria for Modern Control/Display Components and Standard Parts. San Diego, CA: Man Factors, Inc., Report No. MFI-80-101(R), May, 1980.

Review and analysis of control-display requirements in MIL-STD-1472B for the purpose of updating to reflect contemporary hardware component use in military system, equipment and component products. In addition to detailed modifications, general recommendations are made for future Standard revision. (Author)

30. Zipp, P., Haider, E., Halpern, N., and Rohmert, W. Keyboard Design Through Physiological Strain Measurements. Applied Ergonomics, 1983, 14, 117-22.

The physiologically tolerable range of positions for the joints of the upper extremities have been investigated for typing tasks by recording the myoelectric activities of the involved muscles. For long-term typing tasks a split keyboard is recommended allocating a key field to each hand. The fields should be rotated against each other in the horizontal plane and inclined laterally.

A3-KEY LAYOUT, FUNCTION KEYS

1. Calhoun, G.L., Herron, E.L., Reising, J.M., and Bateman, R.P. Evaluation of Factors Unique to Multifunction Control/Display Devices. Westlake Village, CA: Bunker-Ramo Corp., Report No. AFWAL-TR-80-3131, November, 1980.

Aircraft which utilize computers will require the use of ti- function displays and keyboards (MFK). Eight arrangements of ats which present flight control, navigation, and status informati ere examined. All were found usable but arrangements in which attitude information was placed above navigation information and those utilizing electro-optical devices rather than conventional flight instruments were slightly better. Two types of MFK logic were also examined. MFK operation was more efficient with Tailored Logic (frequently used functions presented) than with Branching Logic (functions presented by systems). (Author)

2. Collins, D.E. and Turner, J.F. Multipurpose Keyboard System. Washington, D.C.: Department of the Air Force, Report No. PAT-APPL-563004, March, 1975.

The patent relates to a system for varying the function of a keyboard using a plurality of status keys to select a function. The status keys form a binary which is decoded in a first word decoder forming a single word which is fed to a plurality of binary decoders, one each associated with one of the information keys on the keyboard for controlling the readout thereof. The information keys are also switches that activate a word encoder for producing a final output. A comparator gate can be interposed between the word encoder and the selection switches of the information keys, the gate being enabled by the first word decoder. The decoded word originating from the status keys also feeds a segment decoder which activates segments surrounding selected information key elements.

3. Conway, D.L. Digital Xseconds Typewriter Keyboard. IBM Technical Disclosure Bulletin, 1976, 18, 4187-4190.

Described is a revision of the keyboard layout for electric typewriters which could result in much less fatigue and considerably greater speed for the typist. The revision is based on well-known industrial engineering concepts concerning human factors engineering and motion economy.

4. Emmons, W.H., Every, R.J., and Hirsch, R.S. Placement of Function Keys for Increased Productivity. IBM Technical Disclosure Bulletin, 1980, 22, 5084.

This keyboard design affords a potential increase in productivity by using the standard QWERTY graphics key placement, and relocating function key placement on the basis of frequency of usage and dexterity data.

5. Gopher, D. and Koenig, W. Hands Coordination in Data Entry with a Two-Hand Chord Typewriter. Champaign, IL: Illinois University at Urbana-Champaign, Report No. CPL-83-3, June, 1983.

This paper describes the results of an experiment conducted to investigate the process of acquisition and operation of a data entry skill based upon a newly designed two-hand chord keyboard. This keyboard represents an effort to identify effective alternatives to the existing typewriter. It consists of two separate 5-key panels (one for each hand), and characters on each panel are entered by typing chords composed of one to five fingers. Each panel is capable of producing the full dictionary of characters, and hence can be considered to [illegible]n independent typewriter. Three important questions raised by t[illegible] design are the best coding principle represents identical letters on the left and right panels, the duration of the initial acquisition period, rate of progress, and final levels of performance of this system, the nature of coordination between hands in simultaneous chord production. The paper reviews the results of an experiment conducted to examine these questions. (Author)

6. Grimes, J.D. A Knowledge Oriented View of User Interfaces. Proceedings of the Twelfth Hawaii International Conference on System Sciences, 1979, 158-163.

The knowledge oriented view of user interfaces focuses on the way people acquire the knowledge necessary to use computer based functions. The knowledge of cognitive view can be divided into learning styles, memory and retrieval processes, learning effectiveness and thought processes. These are defined and related to three typical techniques: keyboard commands, menus, and function keys. Two kinds of text editors are briefly discussed. A particular menu driven user interface is presented as an example of a successful interface. This interface is related to several aspects of the cognitive view. The conclusion is that menus are an underutilized, useful and human oriented user interface for many applications.

7. Hirsch, R.S. Procedures of the Human Factors Center at San Jose. IBM Systems Journal, 1981, 20, 123-171.

Research undertaken at the IBM Human Factors Center (San Jose, California) explores the interface of people and machines to the end of optimizing machine design. Experiments comply with rigid control procedures to assure valid observations and to maximize the reliability of conclusions that may be drawn. In a typical investigation, researchers compared the standard typewriter keyboard design to an alternative design in which the letters are arranged in alphabetic sequence. Non-typists were trained on both machines, and the results after training were examined. Subjects introduced to the standard keyboard not only type faster in their initial test but also are able to increase their typing speed more rapidly with training. Other areas of investigation at the IBM Human Factors Center involve video displays, audio feedback for typists, and Japanese language keyboards.

8. Namiki, I., Siratori, Y., Sugiyam, K., and Kitayama, T. Piezoelectric Tablet Kanji Input Equipment. Trans. Inst. of Electronic and Communication Engineering, 1981, E64, 557.

Kanji input equipment, located in the man-machine interface in the Japanese information processing system, is designed in various input forms for input operation methods and input character number. Tablet format kanji input equipment has kanji symbols arranged on a board face.

Piezoelectric tablet kanji input equipment, utilizing piezoelectric elements on a piezoelectric keyboard, enables simple equipment construction and a simple input pen using pressure only. Piezoelectric tablet kanji input equipment design conditions were obtained. Trial manufacture confirmed operation stability.

9. National Research Council. The Multiple Position Letter Sorting Machine. An Evaluation of Visual, Auditory, and Human Fact Problems. Washington, D.C.: Author, 1979.
This report reviews and comments upon studies proposed b U.S. Postal Service task force concerned with reducing operator error rates and improving job satisfaction with the Multiple Position Letter Sorting Machine (MPLSM). The major recommendation of the report is that the Postal Service Study the feasibility and cost-benefit effectiveness of: (1) changing MPLSM operation from machine pacing to operator pacing; (2) providing an error key to enable operators to correct mistakes they themselves detect; (3) providing on-line feedback on personal performance to operator; and (4) rewarding operators who achieve low error rates. The importance of establishing an adequate system for measuring baseline error rates is emphasized. The report also considers the structure of the work environment, including visual and auditory factors, and explores the possibility of complete automation of the sorting system. (Author)

10. Robinson, J.R. Selective Shift Lock. IBM Technical Disclosure Bulletin, 1981, 24, 3576.
A selective typewriter shift lock key is described which affects only the alphabetic keys and helps prevent some typing errors.

11. Rochester, N., Bequaert, F.C., and Sharp, E.M. The Chord Keyboard. Computer, 1978, 11, 57-63.
A keyboard prototype offers one-handed operation, small size, low cost of manufacture, and permits the touch typing of large alphabets.

12. Rutkowski, C. An Introduction to the Human Applications Standard Computer Interface. I. Theory and principles. Byte, 1982, 7, 291-310.
Discusses the development of ideas behind the human applications standard computer interface (HASCI), a keyboard design that divides into a series of menus linking the user (as pattern recognizer) to the computer (a symbol manipulator).

13. Svigals, J. Interactive Complex Transaction Keyboard and Display. IBM Technical Disclosure Bulletin, 1981, 24, 1224-1226.
Describes a multipurpose keyboard and display, having a regularized format to reduce operator confusion.

1. Gentner, D.R. Evidence Against a Central Control Model of Timing in Typing. San Diego, CA: University of California, Center for Human Information Processing, Report No. CHIP-108, December, 1981.

Terzuolo and Viviani, in widely cited research, propose a central control model of timing in typing, in which keystroke times ar generated in parallel from centrally stored, word-specific tim patterns. Differences in overall time to type a given word are attributed to a multiplicative rate parameter, constant for a given typing of the word, but varying from one typing to another. Three major lines of evidence are cited for this model: (a) keystroke times expand or contract proportionally when words are typed slower or faster; (b) in a word; (c) the times to type a given digraph exhibit word-specific differences. My analyses show that (a) keystroke times do not expand proportionally; (b) the apparent constancy of variances is an artifact of the method that Terzuolo and Viviani used to transform the keystroke times; (c) the effects of surrounding character context are sufficient to explain differences in digraph latencies and these effects across word boundaries, showing that they are not word-specific. (Author)

2. Gentner, D.R., Grudin, J., and Conway, E. Finger Movements in Transcription Typing. San Diego, CA: University of California, Center for Human Information Processing, Report No. 8001, May, 1980.

High speed film and key press latencies of a skilled typist show that finger movements usually overlap in time. The starting time of these movements is highly variable, even when comparing identical sentences. Often movements toward keys were initiated out of the order in which the letters were eventually typed. The results conflict with current models of rapid, well-learned motor movements. (Author)

3. Gentner, D.R. Skilled Finger Movements in Typing. San Diego, Ca: University of California, Center for Human Information Processing, Report No. CHIP-104, July, 1981.

Six skilled typists were studied while they transcribed English text. The typists showed stable patterns of performance, but with significant individual differences among the typists. Inter-keypress latencies for 2-finger digraphs (typed by two fingers on the same hand) were particularly variable among typists. Two typists showed large differences in 2-finger digraph latencies, but similar overall typing speeds. Finger movement trajectories, determined from analysis of videotapes of these typists, indicated that the differences in 2-finger digraph latencies correspond to differences in the independence of within-hand finger movements. A high-speed film of one typist showed that finger movements of this typist almost always overlapped. The starting times of movements were six times as variable as the ending times, suggesting that it is the completion rather than the initiation of the movements that is controlled in skilled typing. These studies demonstrate the importance of considering individual differences in constructing a theory of skilled human performance, even in a highly automatized task such as transcription typing.

4. Gentner, D.R., Grudin, J., Larochelle, S., Norman, D.A., and Rumelhart, D.E. Studies of Typing from the LNR Typing Research group. San Diego, CA: University of California, Center for Human Information Processing, Report No. CHIP-111, September, 1982.

The report consists of five chapters. Chapter 1 is a glossary of terms and a classification of typing errors intended to be used as a standard nomenclature for future work. Chapter 2 is an overvi f studies of typing and a brief review of the computer simulati del of skilled typing. Chapter 3 compares skilled and novice perform in discontinuous typing. Chapter 4 discusses keystroke timing in transcription typing, and Chapter 5 discusses error patterns in skilled and novice transcription typing. In general, the studies use a variety of methods, including computer simulation, stop-frame video analysis, studies of interkeystroke interval distributions, and analysis or error patterns. Subjects ranged from novice typists (taking a high school typing class) to expert and super typists: typing speeds studied ranged from 12 wpm to 112 wpm. The studies help explore the influence of motor schemas and preplanning in the learning and performance of highly skilled motor activities, examine the row of overlapping, parallel motor activity, analyze the significant differences in typing styles, even among typists of equivalent ability, and lead us towards better understanding of the cognitive control systems for complex motor tasks.

5. Pollard, D., and Cooper, M.B. The Effect of Feedback on Keying Performance. Applied Ergonomics, 1979, 10, 194-200.

The introduction of new telephone signalling systems and new technologies for telephone keypads has stimulated interest in the effect of providing electronic feedback on keying performance. An experiment using a conventional keypad is reported which shows that electronic auditory feedback had no significant effect on keying speed, accuracy or subject's opinion. A further series of experiments investigating the best type of feedback to improve performance with 'touch' keypads is then described. It was found that an electronic tone presented through the telephone earpiece was the best feedback. Finally, performance with two types of touch keyphones incorporating the optimum form of feedback was compared with performance using a conventional keyphone. It was found that accuracy was significantly greater with the conventional keyphone, although performance with the touch keypads could be improved by electronically removing some of the very short spurious signalling times produced by them.

A5-KEYPADS

1. Brannon, C. Atari CX85 Numerical Keypad. Computer Journal Prog. Comput., 1983, 5, 112.
The Atari CX85 numerical keypad is an add-on, ten-key number pad (adding-machine style) with seven additional function keys. Its primary use is to make it easier to type in numbers. This add on unit reviewed.

2. Litterick, I.A.N., Tadrous, G., and Seegoolam, S. The Development of a Single Handed Keypad. Paper presented at the International Conference on Man/Machine Systems, Manchester, England, July, 1982.
The design of the keypad follows from four primary objectives:
1. It should be small sized (target was paperback book size or smaller).
2. It should be readily usable by the unskilled.
3. It should be usable fluently and accurately by skilled users (the target was speeds as good as those users would get on a full-sized QWERTY-but it should be noted that the keypad is not aimed at the professional typist).
4. It should be versatile (it should offer at least the character set of a normal data entry keyboard). At first sight most of these objectives conflict. The design process has been used to reconcile these conflicts.

A6-REVIEW OF QWERTY KEYBOARDS

1. Litterick, I. QWERTYUIOP-Dinosaur in a Computer Age. <u>New Sci.</u>, 1981, <u>89</u>, 66-68.

Every aspect of the computer save one has been designed or redesigned over the past 20 years to match changing technology and people's wants. The part of information technology that has e ɘd is, ironically, that which ordinary people are most likely to use-keyboard, the device people use to 'talk' to computers. The Q Y keyboard is discussed, along with past and present attempts to ımprove the layout and design of typewriter of computer keyboards. Some ergonomic factors are considered, as are new developments such as chord keyboards and single-handed keyboards.

A7-ALTERNATIVES TO KEYBOARDS - GENERAL

1. Anonymous. Data Entry, Intelligent Terminals and OCR. Computer Decisions, 1979, 9, 47-48.
Excerpts are presented from a report offering guidelines on selection and use of data entry devices.

2. Bentley, T.L. and Meyer, G.N. Design and Evaluation of a T Editing Console. 1976 SID International Symposium, 1976, 66-67.
The design described in this paper was developed at Xerox Corporation's Palo Alto Research Center to explore alternatives to their present combination of keyboard, SRI Mouse and CRT display. Numerous concepts were considered before the final design of pointing device and keyboard was developed and evaluated. Although designed as an integrated system, the pointing device and keyboard can be examined separately. The author offers a brief description of the console then focuses on the design and evaluation of the cursor positioning system.

3. Beringer, D.B. The Design and Evaluation of Complex Systems: Application to a Man Machine Interface for Aerial Navigation. Navigation, 1980, 27, 200-206.
Systematic and economic design and evaluation strategies were applied to a computer generated 4-D aerial navigation system. During the evaluation each of 24 experienced instrument pilots received training in a plato-based digital flight simulator using either a keyboard entry/static map, keyboard entry/dynamic map, or touch entry/dynamic map system. Tasks performed during the execution of an area navigation course included continuous flight control, navigation data updating, digital data entry, and amended course plotting. Digital data entry training time was comparable for all three systems but the touch-map proved superior for the plotting tasks, greatly reducing training and task execution times while virtually eliminating errors. Subsequent performance evaluation showed that the touch-map reduced flight path tracking error, increased processing rates on a digit-cancelling secondary task, and increased the accuracy of manual plotting operations. It was concluded that a touch entry system could significantly reduce cockpit workload across a wide range of operational environments.

4. Biermann, A., Rodman, R., Ballard, B., Betancourt, T., and Bilbro, G. Interactive Natural Language Problem Solving: A Pragmatic Approach. Presented at the Conference on Applied Natural Language Processing, Santa Monica, California, February, 1983.
A class of natural language processors is described which allow a user to display objects of interest on a computer terminal and manipulate them via typed or spoken English sentences. This paper concerns itself with the implementation of the voice input facility using an automatic speech recognizer, and the touch input facility using a touch sensitive screen. To overcome the high error rates of the speech recognizer under conditions of actual problem solving in natural language, error correction software has been designed and is described here. Also described are problems involving the resolution of voice

input with touch input, and the identification of the intended referents of touch input. To measure system performance we have considered two classes of factors: the various conditions of testing, and the level and quality of training of the system user.

5. Keeler, R. Keyboards Adapt to New Technological Challenges. Electronic Packaging and Production, 1983, 23, 44-48.

Discusses keyboards which represent a fast-changing indu . Driven by such market forces as cost savings, a concern for hu factors engineering, reliability and the demand for low-profil d tactile sensation they are changing in capability, appearance and pricing structure. Key Tronic is offering the ability to custom design a low-profile intelligent keyboard which can translate data entered not only from keystrokes, but also from a voice input device, optical character reader, or an optical 'mouse'-a handheld device used to move a CRT display cursor faster than is possible with the cursor key.

6. Lasden, M. Keeping Pace in Data Entry. Computer Decisions, 1982, 14, 90-96, 101-102, 106-110.

Innovations in data entry include distribution of the data entry function to user departments, optical character readers, and voice entry systems. But there are still many centralized data entry shops with productivity problems which must be solved. Studies continue, seeking ways to increase productivity while reducing stress, which was found by the National Institute for Occupational Safety and Health to be greater for data entry personnel than in any other industry, including air traffic control. Several ideas have been introduced. These include additional breaks, as frequent as 15 minutes per hour, ergonomics (fitting the work environment to the people), sound management principles to reduce absenteeism, quality circles, flexible work weeks, and the use of outside service bureaus.

7. Lusa, J.M. Data Entry: Going to the Source. Infosystems, 1979, 26, 52-56.

Data entry has changed considerably since the days of the gigantic keypunching operations. Data entry systems are now being placed in user departments. This has eliminated the step of transcribing the data from input documents and has led to fewer errors. Distributed processing has brought another major change to data entry with the capability to do more processing at the point of entry. The 96-column and the 80-column keypunch and key-to-tape units are destined for extinction, while the keyboard-to-disk and terminals are expected to make large gains. Other growing methods of source data entry are optical character readers (OCR), voice entry, and voice response systems. Audio response terminals are very economical, but voice terminals must interface with a voice or audio system.

8. Newell, G. New Directions in Applications. In D. Meade (Ed.) Microprocessor Systems. State of the Art Report, Oxford, England: Pergamon Infotech, 1983.

The input/output facilities and types of processing required by microcomputer users, particularly in some of the newer kinds of application, are discussed in the paper. The weaknesses and strengths of keyboards, light pens and digitizers are considered; particular reference is made to the digitizer system used in the main credit betting office of William Hill, the bookmaker. The user interface is examined in the context of the 'total environment' required for usable applications systems, and the 'automatic desk' project undertaken at Queen Mary College, London, is also considered. Finally, future developments which may benefit the end user are assessed.

9. Parker, R. Input/Output Technology. Computer Design, 1982, 157-180.

Some subjects covered in this general review are sensors transducers, optical sensing, keyboards and their ergonomics, touch-sensitive CRT screens, digitizer tablets, speech recognition and synthesis for voice input and output, and printers, CRT screens and flat-panel displays, and graphics in CAD/CAM.

10. Romans, G. Color Programs without Keyboard. In Wescon/82 Conference Record, 1982, 1270.

Expands perception of the man-machine environment beyond that of the alphanumeric keyboard and white or green text on a CRT. There are other ways for the computer-shy application user to 'program' an application. Many of the graphics input techniques are undergoing rapid development and understanding, and other technologies, such as voice input/output are becoming more usable. Supplying computer applications with a friendly, easy-to-learn, easy-to-remember, easy-to-understand user interface will make them less intimidating to users awed and frightened by the mystique of programming.

A8-VOICE TECHNOLOGY/ENTRY, SPEECH RECOGNITION, COMPARISON TO KEYBOARDS

1. Anonymous. Human Voice Replaces Conventional Input Terminals to Instruct Computer Operations. <u>Production</u>, 1983, <u>92</u>, 29, 31.

During a recent interview, Christopher R. Seelbach, president, Verbex Division, Exxon Enterprises (Bedford, Massachusetts), e[illegible]ined the Verbex Model 3000 voice data entry system. The Model 3000 [illegible]esents a family of continuous speech voice data entry products that a[illegible]s users to orally input data to a computer. Seelbach believes voice data entry will become one of the major breakthroughs of the 1980s. The Model 3000 system eliminates most: 1. keypunching, 2. writing, and 3. other manual record keeping procedures. The system is reliable and can be programmed to ask questions. It is also user friendly and may be interfaced with existing computer systems. The system has a feedback feature to act as a prompter and is not adversely affected by extraneous noise.

2. Anonymous. Intelligent Terminal Activated by Users Speaking in English. <u>Computerworld</u>, 1978, <u>12</u>, 37-39.

A computer that understands English and may be addressed by telephone or microphone has been invented by Interstate Electronics. The computer can talk back to clarify figures which enhance its accuracy. The system uses 4 channels or stations and understands 900 words. Manual data entry is eliminated. A flexible control program allows users to write their own applications software. The terminal is composed of feedback station, intelligent controller, control interface, and executive software. Up to 4 user input stations can be accommodated at one time. The voice terminal uses acoustic pattern classifiers that make a digital code according to what it said to it. Word boundary detectors identify the beginning and end of utterances. Recognition accuracy is over 99%, and the terminal sells for $18,750.

3. Anonymous. Voice Technology Efforts May Replace Keyboarding. <u>NTIS Tech Note</u>, 1982.

This citation summarizes a one-page announcement of technology available for utilization. Development of systems that respond to an operator's vocal commands is an undertaking of the Naval Air Development Center (NADC), Warminster, PA. The Navy is now addressing the problem of developing a methodology for specifying voice-controlled functions in airborne systems and for living in a world of voice-controlled avionics. Experiments indicate that entry of data and mode selection are two to three times faster than by keyboard.

4. Connolly, D.W. Voice Data Entry in Air Traffic Control. Atlantic City, NJ: National Aviation Facilities Experimental Center, Report No. FAA-NA-79-20, August, 1979.

Two major experiments and a number of subsidiary pilot studies were conducted to assess the potential operational utility of state-of-the-art word recognition technology in air traffic control applications. Experiment I, employing 12 operators or 'talkers,' secured baseline data representing the inherent 'best case' recognition accuracy of the system. Three of the subvocabularies of an operational data entry language were tested exhaustively to a total of over 46,000 spoken words. On the average, across all speakers and all three subvocabularies, only 1 percent of the words spoken were erroneously recognized. Subsequently 'tuning' of the recognition algorithm reduced the error rate to less than 0.4 percent. Experiment II compared the quality and efficiency of the voice system versus the existing keyboard method of entering complete operational messages.

5. Edwards, T.V., Ferris, D.D., Nester, K.L., and Bozek, R.E. Data Entry for C2 Problems. Rome, NY: Pattern Analysis and Recognition Corp., Report No. PAR-81-15, June, 1981.

The objective of this effort was to investigate techniques integrating voice data entry, using automatic speech recognition equipment and other automatic data entry equipment, such as keyboards and dynamic character pens, etc. The research program focused on methods of combining those automatic data entry aids to provide high data throughput, low system error rates, and in particular, natural and efficient man-machine interaction. (Author)

6. Melnicoff, R.W. Getting Behind the Modern Man-Machine Interface: A Look at Speech Technology. Telephony, 1984, 20, 128-137.

The next major breakthrough in the computer revolution will involve communicating with a computer through voice input/output (I/O). Speech technology is comprised of 2 basic elements: 1. speech recognition, in which a computer accepts and understands verbal inputs using speaker dependent recognition (SDR) or speaker independent recognition (SIR), and 2. voice output, in which the computer 'talks' using digital speech compression encoded from a human source. Speech compression is divided into 2 categories: 1. voice response (VR), and 2. voice store and forward (VSF). Speech recognition and voice output are useful in environments in which a user's hands or eyes cannot be tied to the computer, such as in inventory procedures and laboratory applications. Voice I/O offers benefits where time factors are critical. Other applications of speech technology include: 1. remote processing, 2. remote data interfacing, 3. voice mail messaging and security, and 4. using speaker verification. A glossary of speech technology terminology is provided.

7. Mountford, S.J., and North, R.A. Voice Entry for Reducing Pilot Workload. Proceedings of the Human Factors Society, 24th Annual Meeting, 1980, 185-189.

An experiment was conducted to assess the potential improvement in operator performance when data entry is performed by voice input over keyboard input. In a workload condition simulating manual/visual time sharing of two tasks (tracking and radio channel changing) performance on both tasks are significantly improved when operators switched to voice input for the data entry task. Results are discussed in light of the potential of voice recognition systems for the future fighter cockpit.

8. O'Neil, E.F. Voice entry: Terminals You Can Talk To. Data Communications, 1982, 12, 133-141.

It is now feasible to incorporate voice-entry technology into today's networks and terminals. Voice recognition is already well established for business, medical, and industrial applications. Automobile insurers are interested in computerized car-repair estimates by voice input. Inspectors at General Electric's range manufacturing plant in Columbia, Maryland, dictate observed defects into lightweight microphones. Advantages of voice-to-computer communications include: 1. increased productivity, 2. complete interactivity, and 3. humanizing of computer input. Limitations of voice recognition exist, such as the necessity to train the terminal to recognize the speech characteristics of the person speaking. The voice recognizer builds up a memor words from a user based on several initial repetitions of the word. n the user speaks a word, the voice recognizer compares it with the codes stored in memory. New nonprofessional users will emerge in the 1980s and 1990s as a result of voice recognition and other advances in human engineering.

9. Szuprowicz, B.O. Aggressive Jockeying Begins in Voice Tech Race. Computerworld, 1983, 17, 120.

Companies are fighting for shares in the emerging market for voice recognition, voice mail, and other voice response systems, such as voice-activated typewriters and word processors now in development. Humanizing the man-machine interface is the major objective of voice technology in office and factory environments. Significant productivity improvements and abatement of stress may result when operators can give verbal commands to machines. The most sophisticated and difficult of all voice technology applications is voice recognition equipment that transforms speech input into digital format for processing by peripheral office equipment and computers. Training by the individual speaker is necessary for speaker-dependent systems, while speaker-independent systems generally can handle only a small set of single-word commands. Voice mail appears to be the most explosive of all voice technology markets now appearing.

10. Welch, J.R., and Shamsi, E. Advanced Image Exploitation Aids. Delran, NJ: Threshold Technology, Inc., Report No. RADC-TR-80-74, March, 1980.

This report describes the configuration and testing of a large vocabulary voice recognition system which could be used for image interpretation and intelligence report generation involving the creation of descriptive statements with unpredictable content and variable format. Recently, Threshold Technology developed an innovation in voice input technology which combines keyboard input with automatic voice recognition to provide accurate and rapid entry of a large vocabulary of words with no requirements for structuring the data entry process. This innovation, referred to as Talk & Type, is a system in which the user types the first letter of each word to be entered while he speaks the word into a word recognition device. The typed letter then activates only those vocabulary words which start with that letter, thereby greatly reducing the size of the working vocabulary and greatly increasing recognition accuracy and speed. (Author)

11. Welch, J.F. Automatic Data Entry Analysis. Delran, NJ: Threshold Technology, Inc., Report No. RADC-TR-77-306, September, 1977.

Speed and accuracy have been compared for isolated-word voice recognition, keyboard, and graphical menu data entry systems. One entry task involved simple copying of numeric and alphanumeric data strings. A second was a simulation of complex flight data entry scenario. The factors evaluated included voice response feedback and prompting, hand occupation during data entry, and subject experience. Keyboard provided the fastest and most accurate entry of numeric data strings and the fastest entry of alphanumeric strings by subjects with keyboard experience in the simple scenario, but was slow relative to voice and graphical menu for entry of words by inexperienced subjects in the complex scenario. Voice entry provided the lowest error rate for entry of alphanumeric data strings in the simple scenario primarily use of its greater immunity to reading errors. In the complex scenar voice was faster than keyboard for inexperienced subjects, and had a similar operational error rate, but had a substantially higher error rate before correction. Graphical menu ranked between keyboard and voice in most of the simple scenario measures, except that it was least accurate with alphanumeric data, and had the lowest entry speed for long strings.

12. Yuschik, M. Speech for Control of VLSI Graphics. IEEE International Conference on Computer-Aided Design. Digest of Technical Papers, 1983, 16-18.

The author discusses a combination of speech with graphics to enhance the efficiency of the man-machine interface for VLSI design. The designer may control the graphics by the cursor, keyboard, or speech input. The entire system is structured in an expert system framework, composed of four subexperts: A speech recognizer, a parser, a planner, and a graphics command generator. The control structure, modules and partitioning of the auditory and visual information are discussed.

A9-TOUCH-SENSITIVE SCREENS/PANELS

1. Beaton, R.J., Schulze, L.J.H., Snyder, H.L., and Winner, L. Touch Entry Devices and Human Performance. 1. Quantifying the Display Quality. 1983 SID International Symposium. Digest of Technical Papers, 1983, 224, 162-163.

   In recent years, touch entry devices (TEDS) have become lar alternatives to conventional keyboards for certain types of in ctive tasks with computer-based information systems. These devices lly consist of a transparent panel, housing a matrix of touch sensitive switches, which is placed directly over a display screen. In a series of experiments, the authors examined the effects of TEDS on display quality as well as the concurrent effects on operator performance. This paper reports a photometric evaluation designed to quantify the display quality parameters for five commercially available TED technologies.

2. Gartner, K.P. and Holzhausen, K.P. Human Engineering Evaluation of a Cockpit Display/input Device using a Touch Sensitive Screen. AGARD Conference Proceedings, No. 240, 1978, 7, 1-13.

   Describes a cockpit touch input/output system which in effect integrates and combines several control and display functions of several airborne systems into one space which can be located in the primary control and display areas of the cockpit. This integration is accomplished by the use of touch sensitive virtual switching arrays on a CRT driven by sophisticated computer software. Various technical approaches to the touch sensitive aspect of this system are described. The touch input control device (TICD) and its possible application to airborne systems are discussed in some detail in terms of its advantages and reliability requirements. Several unique ergonomic problems associated with these new devices are identified. A case history application for selected airborne systems involving use of menu-select hierarchies of virtual keyboards is presented.

3. Janes, C.C. and Brodzik, P.A. Eliminate the Keyboard with Touch-sensitive CRT Screens. Second Annual Phoenix Conference on Computers and Communications. 1983 Conference Proceedings, 1983, 575-579.

   Kitt Peak National Observatory (KPNO) is experimenting with the use of touch technology as a method for human interaction with the computer in process control. The authors describe an application in which a touch sensitive terminal is used for a large telescope control, discuss the design considerations, and review the strengths and weaknesses of the technology.

4. Miller, T.J. Operator-process Interface Becoming More Flexible, Easy-to-use. Control Engineering, 1983, 30, 109-110.

   Recent years have seen rapid development of microprocessor- based means for human control of machines. The ubiquitous CRT interface has been refined and added to in a variety of useful ways and other more portable devices are destined for wide use in remote data entry and field engineering. The goal is, of course, increased productivity, both in terms of increased throughput and saved man-hours (and man-effort). A brief, process-control oriented look at recent improvements is taken.

These include developments in touch sensitive screens, 'function screens,' programmable keyboard overlays and CRT terminals.

5. Shaw, L.C. Why Touch Sensing? Datamation, 1980, 26, 138-141.
Many computer applications require a man-machine interface that uses a simple, natural communication technique. Touch sensitive input devices eliminate the need for light pens, wands, cursor controls, and joysticks and take advantage of the natural instinct to point nger at what is wanted. Typical interactive applications use a que n and answer dialogue between the computer and the operator. Touch itive input devices allow the operator to touch the displayed item that answers the question. Unlike a conventional operator's console with many buttons and keys, touch sensing would only display choices that pertain to the question to be answered. Pictures can also be displayed that allow an operator to specify choices without knowing technical jargon about the data being displayed. Several technologies are available for touch sensors. Infrared light and photo detectors have been used on terminals for computer assisted instruction. Acoustic surface waves on a transparent surface can be modified by the presence of a finger. Another system uses transparent terminal overlay with a varying voltage signal indicating the point of the screen that was touched.

6. Thornburg, D.D. The Computer as a Bandwidth Diode-The Challenge and Promise of Low-cost Alternatives to the Keyboard. Digest of Papers Spring Compcon 83, 1983, 172-174.
Most personal computers are capable of conveying information in a far richer form than they can receive it. One can say that the computer has become a bandwidth diode, with the keyboard being the principal limiter of input bandwidth. Numerous mechanical alternatives to the keyboard, such as joysticks, light pens, etc., have come into common use but none of these devices has the flexibility of a graphics tablet. In the past, graphics tablets have been expensive. The characteristics and potential impact of a recently developed low-cost graphics tablet designed for the consumer.

7. Usher, D.M. Comparison of a Touch-sensitive VDU and Computer-aided Keypad for Plant Control. Display Technology and Applications, 1983, 4, 157-161.
The technology of touch screens is discussed with emphasis on the development of appropriate software and human factors. A touch screen is compared with an intelligent keypad in an experiment in which CEGB personnel controlled a simulated plant. Users preferred the touch screen in normal conditions and even more for emergency working. Also, a statistically significant improvement in plant controllability is recorded when the touch screen is used in place of the keypad. Touch screens are seen to possess many advantages over conventional man-machine interfaces. Their use is shown to be appropriate in applications such as alarm analysis, data and mimic selection and interactive graphics as well as for controlling a plant.

8. Venhuizen, J.R. Real-time Interactive Simulation: Using Touch Panels, Graphics Tablets, and Video-terminal Keyboards. Idaho Falls, ID: EG and G Idaho, Inc., Report No. EGG-M-26282, July, 1983.

A Simulation Laboratory utilizing only digital computers for interactive computing must rely on CRT based graphics devices for output devices, and keyboards, graphics tablets, and touch panels, etc., for input devices. The devices all work well, with the combination of a CRT with a touch panel mounted on it as the most flexible combination of input/output devices for interactive simulation.

A10-MEMBRANE KEYBOARDS

1. Anonymous. Effective Membrane Switches Need More than Good Looks. EDN, 1980, 25, 147-149.

Thin, flat and lightweight, membrane switches actuate with a light touch and fine use in virtually every pushbutton or keyboard application except high-speed data entry. They appear easy to fabricate: coat the back of a label with a flexible metal conductor and stretc is imprinted membrane aaross a spacer and a PC-board substrate. their actual manufacture is more complex, and when specifying membrane switches, it pays to know enough about them to be able to evaluate a unit on the basis of several criteria. The author presents and discusses these criteria.

2. Anonymous. Membrane Technology Applied to New Keyboard. Canadian Datasystems, 1981, 13, 48.

Discusses three Honeywell micro switch keyboards which use membrane technology. The capacitive membranes allow a signal to be emitted when struck by a conventional key.

3. Ford, D. Membrane keyboards: The Tests Will Tell. Circuits Manufacturing, 1983, 23, 62-65.

Discusses membrane keyboard design and testing. Static tests include keyboard switch life, spacer bar force and wobble, shift lock key force and force travel characteristics. Dynamic tests include impact, contact bounce, shock and vibration. Environmental tests include storage temperature, actuation force vs. temperature, humidity, operation at reduced and increased atmospheric pressure, salt fog and temperature cycling. Other tests include abuse (flammability, contamination), static discharge and EM/RFI shielding.

4. Jesson, J.E. Smart Keyboards help Eliminate Entry Errors. Computer Design, 1982, 21, 137-142.

The workings of full-travel membrane keyboard switches are outlined and their development from micromotion touch panel membrane switches is mentioned. The role of intelligent keyboards in detecting operator errors during data entry is discussed. Using a microprocessor to scan the keyboard matrix in search of phantom keys eliminates errors without slowing down the burst rate of entries.

5. Kelly, W.P. Minimizing the Cost of Membrane Keyboards. Machine Design, 1982, 54, 75-77.

An important feature of membrane keyboards is the low cost of materials and processes used in their construction. But some membrane manufacturing techniques are more expensive than others, with the differences depending mainly upon the complexity required in conductor patterns. The author looks at these manufacturing techniques, and the various tolerances involved.

6. Kunita, M. Membrane Keyboards seen as Switches of the Future.

Input keyboard of microcomputer-applied electronic machines, the membrane keyboard switch is a most attractive keyboard switch: with multi-color printing, it can offer a free and colorful surface design;

it is excellent in waterproof, dustproof, oil resistance, and other environmental properties; and, with a thin-type design it can save on space.

7. Levi, P. Membrane Keyboards. Electronic Industries, 1982, 25-26.
Membrane keyboards offer an important alternative to mechanical keyboards, which are liable to give rise to faults. The two existing types of membrane are described, these are either metallic or ucting elastomer. The general principles of construction of these ar described. A table is given of comparisons between plastic key ds and traditional ones. One advantage of membrane keyboards is reduced costs for reasonable quantities. Gives some details of electrical and physical characteristics.

8. Loeb, K.M.C. Human Factors and Behavioral Science: Membrane Keyboards and Human Performance. Bell System Technical Journal, 1983, 62, 1733-1749.
This paper describes systematic human factors research in which typing performance using a membrane keyboard and using a conventional, full-travel keyboard were compared for subjects representing different levels of typing proficiency. The results indicate that for non-touch typists there was little difference in performance between keyboards. For touch typists, performance with the conventional keyboard was initially much better than with the membrane keyboard. Rapid learning resulted in improvement in typing performance with the membrane keyboard-both within an experimental session and across sessions-such that the advantage of the conventional keyboard over the membrane one for touch typists was reduced substantially, although not completely.

9. Nash, J.C. and Nash, M.M. Sinclair ZX81 (review). Interface Age, 1982, 7, 92-97.
The sinclair ZX81 is a small, inexpensive, comparatively powerful calculating engine. Its speed, numerical precision and function set make it a good tool for trying out numerical algorithms. Flexible string handling also allows it to be used to test certain non-numeric programs, but lack of tape storage facilities for data is a hindrance. Despite very small size, its power demand and need for a television and a cassette recorder mean it is not a truly portable computer. The confining keyboard will annoy some users-especially those who touch-type.

10. Neale, A. Membrane Switch Technology in Touch Panel and Keyboard Applications. New Electron, 1983, 16, 47-48.
States that the marriage of graphic overlays and membrane switch techniques has brought a fundamental change in design approach to many control panel and keyboard applications and these are discussed. Visually attractive and cost effective, membrane touch panel designs proliferate. Ergonomic enhancements have been developed, such as tactile feedback and embossment for key 'homing.' Usually contact switches are employed, but for high throughput keyboard applications, a sealed, capacitance membrane switch matrix combined with full travel actuators provides the necessary ergonomic and electronic performance.

11. Oder, E. and Cross, H. Realize a Touch Sensitive ASCII Keyboard. Micro-Systems, 1980, 77-82.

The principles of a touch sensitive keyboard are outlined and the complete system for producing ASCII characters is described. Strobe, repeat and break signals and audio output are also generated.

12. Ohr, S. Membrane-based Keyboard Keeps Life Up, Cost Down. Electronic Design, 1980, 28, 211.

Describes the full travel membrane (FTM) keyboard from O Technology, which consists of a series of spring-loaded keycap unted on a flat membrane switch plate. The keycap springs provide 0.160-in. of travel, communicating strong tactile feedback to the operator. The keyboards are well-suited to computer terminals, word-processing machines, or point-of sale terminals.

13. Tebbutt, D. Sinclair ZX80. Personal Computer World, 1980, 3 55-57.

Sinclair has produced a simple to use, hand held, personal computer. It can be connected to a television set and a cassette recorder. The keyboard is a waterproof, chemical proof, completely sealed unit stuck on to the main PCB. The keys are in standard QWERTY layout although somewhat compressed compared to, say, the office IBM. The machine is controlled by an NEC 780-1 processor chip, ...a copy of the Z80. This CPU, running at 3.25 MHZ, does all the work for the ZX80, including driving the TV and the cassette recorder. The basic interpreter, operating system, character set and editor are all held in a 4K BYTE ROM. The screen is not memory mapped; it's treated like a serial file-like a printer in fact-which means that fast moving graphics are out of the question.

14. Williams, P.R. Touch Sensitive Keyboard. Practical Electronics, 1978, 14, 921.

The circuit described was designed to provide a synthesizer keyboard with an additional control voltage output, whose magnitude is proportional to the velocity at which a key is struck. This voltage can, for example, be used to control the maximum amplitude which a note attains during the attack time to give the keyboard a piano-like feel, in that it is sensitive to how 'strongly' the music is played.

A11-COMPARISON OF KEY SWITCHES

1. Anonymous. Alphanumeric Keyboards Survey. Systems International, 1981, 9, 23-25.

The alpha-numeric keyboard is still the fundamental item of human interface in computing systems. This will be true until the speech-operated input is a reality. The data tablet, which ac s handprinted information, is not likely to accomplish the same l of versatility, particularly in terms of error correction and spe A keyboard is an ergonomic arrangement of on/off push switches which control 'parcels' of encoded command functions or other data, but the major problems the keyboard designer has to confront remain the conventional problems of contact resistance, contact life, and contact bounce. The problems of contact resistance and contact bounce became apparent upon realization of the drastic effect of failed keying or contact bounce on the efficiency of the system. The traditional manner of handling the contact resistance problem is to use different switching techniques, which may include reed switching, capacitive switching or solid-state switching. The most modern development in key switching is the capacitive kind, where metallized mylar discs form the operating section of the plunger, acting purely as a capacitor switch.

2. Anonymous. Threshold Capacitive Key. IBM Technical Disclosure Bulletin, 1971, 13, 3301-3302.

Describes a threshold key arrangement for capacitively making electrical contact between two conductors. The force versus displacement characteristics of the key arrangement is shown. The characteristics approximate the 'feel' of a keyboard of a selectric typewriter, thus meeting the human factors requirement of tactile feedback. To approximate this 'feel' the force-displacement characteristic of a key arrangement must exhibit a firm switching action in the middle range of key travel while providing the components of first, a pretravel, and then, a positive threshold and negative impedance (toggle action) and finally, a post travel. In addition, practical key arrangements must also have provision for restoring the key to its original position. The key arrangement meets these requirements by employing a pair of springs, and a magnet. The springs and magnet act to impart the required forces upon the key and its corresponding key stem.

3. Burkitt, A. Keyboards. Electronic Engineering, 1976, 48, 81-83.

Reviews keyboard systems and touch-control switches which give a clean and reliable action. The author covers reed switches, conductive silicone elastomeric contacts, contactless magnetic switches, hall effect switches and piezoelectric switches.

4. Carey, M. Membrane Switches. New Electronics, 1979, 12, 94-95.

Describes the membrane switch which is a flat, thin, and lightweight sealed panel with integral graphics. It requires only a light touch to operate and is mounted, and interconnected with others, within the membrane. Its life expectancy exceeds ten million operations. With the exception of high-speed data entry, the membrane switch can be used in virtually any push-button or keyboard application.

5. Dance, M. Keyboards, Keyswitches, and Interface Devices. Electron. Ind., 1978, 4, 33, 35, 37-41.
The growth of professional keyboard application ensures the further development of keyswitches. The article reviews charges that could occur and types of keyswitches on the market together with the main manufacturer and approximate costs for each type.

6. Dellaert, E., Keprda, J. and Koller, S. Keyboard Key Switc STB11. Siemens Components, 1981, 16, 166-171.
The series of keyboard key switches described take into unt state-of-the-art human engineering for optimum design of a man/machine interface in addition to operability. As a result of a close cooperation in system and component development, this series of keyboard key switch offers a wealth of aspects relative to production for the rational configuration of keyboard and keypads.

7. Embrey, D.M. Keyboards - The Man/Machine Interface. New Electronics, 1981, 14, 54, 56, 60.
Describes designs than can be roughly divided into three groups: touch sensitive switches which require no mechanical movement to activate the contact but rely on a change of electrical resistance or capacitance brought about by placing a finger on the button; ultra-short travel, non-tactile keyboards having moderately low contact resistances when the contacts are made; short travel keyboards having a tactile feel and having a low or medium contact resistance when the contacts are made. Each group has both advantages and limitations.

8. Frostick, K.H. and Lowe, J. More Stringent Environments Demand New Technologies. Electron, 1977, 38, 69.
Keyboards use is increasing at a rate commonly estimated to be greater than 30 per cent per annum. Man's need to communicate with machines creates an increasing number of applications involving keyed data. This article examines the requirements of various professional markets and indicates that choice of switching technology will become more critical. Capacitance type keyswitches, and possibly non-mechanical touch types, will gain wider usage.

9. Glazer, S. Keyboards Become the Latest Computer Peripheral. Mini-Micro Systems, 1984, 17, 97-102.
Many keyboards now come from the factory in their own cases, contain their own printed-circuit boards, and can immediately be plugged into a monitor. Because the keyboard is virtually the only part of a computer that is not shrinking in size, it is the logical place to put a voice-recognition device, an optical character reader, or an interface for a mouse. Some keyboard manufacturers are selling directly to system integrators and end users. Key Tronic Corp., the leading independent U.S. manufacturer of keyboards, has gained new original equipment manufacturer (OEM) contracts by developing products for end users. According to Venture Development Corp., a research organization, capacitance keyboards will remain the industry leader for the next 5 years. Membrane and conductive-rubber technologies are threatening the supremacy of capacitance switching, but these technologies have such problems as unreliability and unacceptable feel.

10. Lawry, D.K. Push-Button Switches. Electronic Equipment News, 1975, 16, 37-39.

The rapid increase in the use of the electronic calculator has brought forth the most dramatic development in the push-button switch and the push-button keyboard. Aspects of the design of the reed push button are considered. Low cost systems for pocket calculators are also discussed.

11. Ormond, T. Membrane, Conductive-elastomer Technologies Vi r Domininance in Low-end Keyboards. EDN, 1982, 27, 61-66.

Two technologies-full-travel membrane and conductive elastomer - are increasingly challenging the traditional dominance of gold-contact mechanical-switch keyboards in low-cost alphanumeric applications. The technologies provide several advantages compared with mechanical techniques, but also prevent some problems. The former and the latter are both explained. Some available products are then described.

12. Pensinger, M. The Changing Needs for Keyswitches. Electron, 1978, 33.

Examines the historic development of switches required by the expansion of the man machine interface market.

13. Sharpe, C. Keyboard Switching. Design Engineering, 1982, 85-99.

Looks at the data entry keyboard switching options which are available to the product designer and how to evaluate them.

14. Stockburger, D.W. and Penn, A. For the Thick-Skinned Computerist. Kilobaud Microcomput., 1982, 6, 100-101.

This quick, relatively bounce-free switch responds directly to human touch and has no moving parts. It can be used in any situation where direct human input to the computer is desired, such as applications for the handicapped, musical instruments, and industrial control. The switch is called a skin-to-printed wiring (S2PW) switch, and compares the voltage of a completed circuit through the fingertip with a given standard voltage. If the voltage through the circuit is greater, then the finger is present. If not, then the finger has been lifted.

15. Sugino, H. Actual Conditions and Points of Data Input Keyboard Systems. Office Equipment & Products, 1984, 13, 58-61.

The 3 types of keyboard construction for personal computers are: 1. ergonomics, 2. hand-held, and 3. pocket computer. Each corresponds to a type of personal computer. The most popular switch and the one best suited to high-speed keying is the mechanical switch. Other useful switches include: 1. the capacitive switch, 2. the membrane switch, and 3. the conductive rubber switch. The capacitive switch, designed before the mechanical switch was completely reliable, has a long life but requires that measures be taken for noise. The membrane switch is best suited for an application of a switch matrix. Key touch is the most important of the factors that determine operability of the keyboard. A future direction for keyboard design is unification of keyboards and software as seen in the European personal computer market.