TELIDON

TELIDON BEHAVIOURAL RESEARCH 4

Data entry in videotex: Keypad design and page number format

Behavioural Research and Evaluation

Department of Communications

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DATA ENTRY IN VIDEOTEX: KEYPAD DESIGN AND PAGE NUMBER FORMAT

January, 1982

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TELIDON BEHAVIOURAL RESEARCH 4
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DATA ENTRY IN VIDEOTEX: KEYPAD DESIGN AND PAGE NUMBER FORMAT

Preface

This is the fourth in a series of reports prepared by the Behavioural Research and Evaluation Division of the Department of Communications. The reports are provided to assist in the design of videotex systems that reflect the abilities and limitations of the user. This report presents recommendations concerning some aspects of the design of data entry on videotex.

At present, videotex users retrieve information either by numeric selection from displayed lists of alternatives or by entry of page numbers directly. The device typically used to direct retrieval is a small keypad that permits the entry of numeric and other data. The two papers in this report address user issues arising from the design of the keypad and from the format in which videotex page numbers are presented.

The first paper is "Human Factors and Telidon Keypads: A New Design and An Examination of the Current Models" by Paul Hearty. He argues that the design of manual data-entry devices for videotex should take account of three classes of user characteristics: the size and mobility of the hand, perceptual-motor abilities, and cognitive processing facilities. Citing evidence relevant to these considerations, he makes specific recommendations for the design of Telidon keypads. He then provides designs for both a basic Telidon keypad and an alphabetic extension. Finally, he examines current Telidon keypads critically and makes suggestions for improvement.

The second paper is "The Problem of User Errors Caused by Long Videotex Page Numbers" by Eric Lee. He notes first that, when accessing pages directly, users will find it difficult to recall and enter the long page numbers inevitable with commercial-sized databases. In reviewing the empirical literature, he notes that people spontaneously segment long number strings into shorter sub-groups during recall and that performance in a variety of tasks is facilitated when long digit strings are presented in a manner consistent with such "natural groupings". He concludes that, at presentation, videotex page numbers should be divided into sub-groups of three (or perhaps four) digits by the insertion of blank spaces.

In summary, the two papers address some of the human factors issues that should be considered in the design of videotex data-entry systems. While humans are adaptable and can learn to use devices and systems that are not designed optimally, it is likely that design of videotex systems will be a deciding factor in which are most popular. Careful design based on knowledge of human limitations and capabilities can enhance the ease and pleasure with which users address their videotex systems.

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January, 1982

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HUMAN FACTORS AND TELIDON KEYPADS: A NEW DESIGN AND AN EXAMINATION OF THE CURRENT MODELS

Paul J. Hearty

1982

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Human Factors and Telidon Keypads: A New Design and An Examination of the Current Models

Paul J. Hearty
Department of Communications

Summary

The present paper briefly surveys human-factors literature relevant to the design of hand-held keypads and makes specific recommendations for design. The recommendations are then implemented in a new keypad that provides the basic operations necessary for Telidon. Techniques for permitting alphabetic input are discussed and an optional alphabetic extension that is viable from the human-factors viewpoint is given. Finally, each of the current Telidon keypads is examined in terms of the design recommendations extracted from the human-factors literature.

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INTRODUCTION

Telidon user terminals from four Canadian manufacturers are now available to the public. Each provides a unique data-entry device (keypad). In part, the differences among keypads reflect differences in the manufacturers' conceptions of user needs. The Norpak (Mark 3) and Bell (Vista) keypads provide a set of basic operations and a numeric cluster to permit the retrieval of information by numeric selection from lists of alternatives or by directly addressing particular pages of the database. The Microtel and Electrohome units provide the basic operations and numerics but, in addition, permit the entry of alphabetic characters.

Recently, there has been growing concern with human-factors aspects of Telidon keypads (e.g., Muter, 1980). Briefly, the human-factors position judges a device by the extent that it accommodates the limitations and promotes the convenience of its user. The present paper first examines relevant human-factors literature and makes specific recommendations for keypad design. It then provides a design for a hand-held, nonalphabetic keypad that satisfies these human-factors requirements; it also presents an acceptable extension that permits alphabetic input. Finally, each of the current Telidon keypads is examined briefly in human-factors terms.

HUMAN-FACTORS RECOMMENDATIONS

Because Telidon is a new application, there is little directly pertinent evidence to guide keypad design. There is, however, a body of empirical data from comparable applications that can be drawn upon. In addition, normative data concerning the dimensions and mobility of the human hand are both relevant and available.

At least three classes of human-factors considerations confront the designer of a data-entry device. The three concern limitations arising from the anthropometric, perceptual-motor, and cognitive characteristics of the user. Keypads that do not accommodate such limitations will yield either or both of lower data-entry rates and increased data-entry errors. Moreover, such devices will likely encourage disenchantment, or even avoidance, in the user. It is critical, then, that Telidon keypads conform to human-factors principles of design.

Anthropometric Concerns

Because keypads are, at least in principle, hand-held devices, they must be designed with reference to anthropometric data for the human hand. The task for the designer, then, is to ensure that the unit can be held, and used, comfortably by all but those with the smallest hands. For such purposes, it is standard procedure to design with reference to measurements representing the fifth percentile of the adult population (i.e., the values below which only five percent of adult individuals fall).

Axis-of-Grip

While operating the keypad, the user might hold the unit with one hand and use the other hand to activate keys. Alternatively, the user might use a single hand both to hold the unit and to activate its keys. In either case, however, the dimensions of the hand restrict the size of an acceptable keypad.

Many types of grip are feasible for two-handed operation. However, if the unit is sufficiently small, the user typically will place his thumb along one side of the keypad and the tips of his forefinger and middle finger against the opposite side. If this grip is to be maintained comfortably for long periods, the unit's axis-of-grip (usually its width) should not exceed the distance between the base of the user's thumb and the joint closest to the tip of the forefinger (or the middle finger) when the hand is relaxed. Extrapolation from data reported by Garrett (1971) provides relaxed-hand distances for fifth-percentile adults of 2.72 and 2.69 inches (6.91 and 6.83 cm) for the forefinger and the middle finger, respectively. Thus, the data support a maximum axis-of-grip for two-handed use of about 2.70 inches (6.86 cm).

During one-handed operation, the user should rest the unit upon his fingers and move his thumb about the key-face to select keys. If the grip is to be both secure and comfortable for long periods, the unit's axis-of-grip should not exceed the distance between the muscular pad at the base of the thumb and the joint closest to the tip of the forefinger (or the middle finger) in the relaxed hand. Furthermore, if the thumb is to be free to move over the key-face, the unit's thickness should not exceed the size of the largest gap between the thumb and the forefinger when the thumb is moved towards the palm but held parallel to the fingers. Extrapolation from data presented by Garrett (1971) reveals that, for fifth-percentile adults, the unit's axis-of-grip should not exceed 2.35 inches (5.97 cm) when either the forefinger or the middle finger is used to grip the unit and the unit's thickness should not surpass 0.75 inches (1.91 cm).

The difference between the maximum axis-of-grip recommended for one-handed operation (2.35 inches) and that recommended for two-handed use (2.70 inches) is small. Given that both recommendations are based upon approximations, it seems reasonable to suggest 2.50 inches (6.35 cm) as an acceptable compromise.

Accessibility

Although both one-handed and two-handed modes of operation suggest similar values in axis-of-grip, they differ considerably otherwise. In particular, with two-handed operation, all keys are accessible while, with one-handed operation, the keys accessible are those within the range of movement of the thumb. Fogel (1963, p. 478) indicates that the thumb can move a maximum of 125° within the plane of the hand, describing a maximum angle of 45° with the forefinger in movements toward the palm and a maximum of 80° in movements away from the palm. Thus, if users grip the keypad with its centre of gravity centered upon the body of the hand, the keys accessed most easily in one-handed operation will be those at and above the centre of gravity but within about 2.0 inches (5.08 cm) of the base of the thumb [Garrett, 1971, gives thumb lengths of fifth-percentile males and females as 1.99 and 1.84 inches (5.05 and 4.67 cm), respectively].

In summary, anthropometric considerations indicate that keypads should not exceed 2.50 inches (6.35 cm) in axis-of-grip. Moreover, in one-handed usage or, as is more likely in practice, combined one-handed and two-handed operation, it would be convenient if the keys that will be used most frequently were at or above the unit's centre of gravity and within about two inches of the edge of the unit.

Perceptual-Motor Concerns

The precision and ease of visually guided manipulations of the keys of a data-entry device are necessarily limited by the perceptual-motor abilities of the user. Consider, for a moment, the task facing a relatively inexperienced user. Given that a particular key must be pressed and that the user knows the label but not the location of the key, he must search the key-face for the label, locate the key to which it refers, and press only that key. The search and location components of the task are, of course, perceptual activities while the finger movements associated with pressing the key are motor activities that are guided perceptually.

An appropriately designed keypad will minimize the difficulty of each component of the task. The next three sub-sections of the paper will present some basic guidelines for facilitating perceptual-motor activities in keypad usage.

The Search Process

It is clear, even obvious, that the search process will be facilitated if the key labels are large, have sufficient contrast with their background, and are easily discriminated from one another. The questions for the designer, then, are how large must labels be and how can one provide sufficient contrast and discriminability.

Size. Under good viewing conditions, the accuracy and speed of form identification improve as the largest dimension of the form is increased to subtend a visual angle of approximately 18 minutes of arc (Steedman & Baker, 1960). Thus, for a standard viewing distance of 28 inches (about 71 cm), the largest dimension of a form used as a label should extend at least 0.15 inches (0.38 cm).

With good illumination, letters only 0.10 inches (0.25 cm) high can be discriminated accurately at the standard viewing distance; with very low levels of illumination, however, letter heights of 0.20 inches (0.51 cm) could be necessary (Grether & Baker, 1972, p. 107). Thus, a letter height in labels of 0.10 to 0.15 inches (0.25 to 0.38 cm) should be sufficient for accurate discrimination in all but the worst of circumstances. In addition, for maximum discriminability, the ratio of the width of a letter to its height should be approximately 3:5 and the widths of the line segments composing a letter should be 1/6 to 1/8 of their heights (Grether & Baker, 1972, p. 107).

Contrast. Although data concerning the contrast a label should bear with its background are scanty, Grether and Baker (1972, p. 109) suggest that, unless dark-adaptation is required, labels should be black on white matte backgrounds. Of course, coloured labels and backgrounds can be used, but the labels must contrast highly, both in hue and in reflectance, with their backgrounds. The latter, two-difference technique is necessary to aid users with deficient colour vision and to ensure sufficient contrast under widely ranging conditions of illumination.

Discriminability. Selection of a label set whose members are easily discriminated requires consideration first of the operations the labels must represent. Clearly, the best labels for alphabetic and numeric keys are the letters and numbers themselves. Once the alphabetic and numeric keys have been removed from consideration, of course, the remaining single-keystroke operations require discriminable labels. However, as will be seen presently, the number of labels required for these operations influences the selection of an encoding basis in labelling.

There are numerous bases from which a label set can be produced. Those used most commonly include colour, geometric shape, pictorial representation, and the short word.

If keys are labelled by surface colour, only nine easily discriminated labels can be derived and discriminability is affected by room illumination (Grether & Baker, 1972, p. 69). Thus, as the sole basis of a labelling scheme, surface colour is of limited utility (Chapanis & Kinkade, 1972, p. 352).

Geometric forms can be used in two ways. The set of labels may include a number of forms (e.g., circle, triangle, etc.) or it can use one form that is varied parametrically (e.g., from circle to narrow ellipse). Recommended set sizes for such methods are five (Grether & Baker, 1972, p. 69) and five to eight (Muller et al., 1955) elements, respectively.

Pictorial representations can provide large label sets. Unfortunately, they typically require concrete referents and large symbols to be effective; the latter requisite is particularly unfortunate given the size constraints of keypads.

When possible, short words are clearly the best alternative. They permit large, discriminable label sets for a relatively small cost in space [e.g., four letters of the size recommended previously can be placed in an area of 0.15 by 0.50 inches (0.38 X 1.27 cm)].

The Location Process

Once the user has found the label that represents the operation he wishes to select, he must locate the key to which it refers. Clearly, if the labels have been applied directly to the keys, there is no uncertainty about which key to press. If, however, the labels have been placed between the rows of keys, uncertainty in the location process increases to a maximum as the positions of the labels approach the midpoints of the spaces between rows.

To illustrate the point, consider the case in which the labels have been placed between the rows of keys and above the keys to which they refer. If the label sought is in the highest row of labels, the user will experience little uncertainty in determining the key to which it refers; only one key will be above or below the label. If, however, the label is in any other row, it will fall between two keys and, unless the label is clearly nearer the appropriate key, the user will be uncertain of which key the label represents. Unfortunately, the removal of such uncertainty requires relatively large spaces between rows of keys; labels 0.15 inches (0.38 cm) high, for example, might be applied to the lower third of a 0.60 inch (1.52 cm) space between rows.

In summary, labels should be applied directly to the keys themselves. Otherwise, the limited space available in the keypad may be insufficient to permit adequate localization of the keys to which labels refer.

The Keypress

When the user has determined the key he will press, he engages in a visually guided finger movement that, hopefully, culminates in activation of that key. The difficulty of this activity reflects at least three factors: 1) the dimensions of the keys and of the spaces between keys; 2) the spatial arrangement of keys as it relates to the demands of the task; and 3) the physical characteristics of the keys themselves.

Dimensions. For speed and ease in the operation of controls, the precision required should be minimized (Damon et al., 1963, p. 263). In practical terms, this means that both the keys and the spaces between keys should be relatively large.

Although empirical evidence concerning optimum key sizes and spacings is scanty, recommendations abound. For example, Damon et al. (1963, pp. 267,313) suggest that push-buttons should have at least 0.50 inch (1.27 cm) diameters and that, when presses do not form a simple path spatially (e.g., in telephones and keypads), the space between the edges of adjacent buttons should be at least 0.50 inches (1.27 cm). Unfortunately, the situation is not as clear as the Damon et al. conclusion suggests. Dreyfuss (1959) has argued that keys have a maximum width of 0.50 inches (1.27 cm) and a maximum length of 0.44 inches (1.12 cm). And Deininger (1960) has found good keying speeds and low error rates with telephone keys separated by as little as 0.25 inches (0.64 cm). Thus, although the suggestions are somewhat contradictory, rectangular keys 0.50 inches in width and smaller in length with edge-to-edge spaces of at least 0.25 inches seem acceptable.

Arrangement. In operating the Telidon keypad, it is inevitable that the user will press some keys more frequently than others. For example, because Telidon requires a terminator to most commands (the SEND key), this key will be used most frequently. It is critical to the convenience of the user that the keys used most frequently occupy the positions in the keypad that are accessed most easily. Moreover, because the application provides operations that will disrupt the orderly progress of the session if engaged mistakenly (e.g., ABORT OPERATION), it is important that the keys activating such functions are not contiguous with those used most frequently. The latter is necessary to reduce the incidence of serious error as the keys that are used most frequently are also most likely, in the long run, to encounter perceptual-motor error; if disruptive keys are adjacent, they are likely to be activated mistakenly. Finally, because the terminator must follow most commands, it would be convenient if its key were near those that will be used most frequently with it (i.e., the most frequent, terminated operations).

Physical Aspects. The sizes of keys and of the spaces between keys are important considerations in keypad design. However, other physical characteristics of the keys should affect ease and performance in keypad usage. Such characteristics include the force and displacement required to activate the key as well as the extent that the key protrudes above the surface of the keypad.

Clearly, ease and speed of operation will be affected adversely if excessive force or displacement is required. However, the force and displacement necessary should be sufficient to prevent accidental activation. Numerous estimates of optimal forces and displacements have been advanced. Dreyfuss (1959) has recommended forces of 4.1 to 11.0 ounces (116-312 gm) and a displacement of 0.19 inches (0.48 cm). Deininger (1960) found no difference in performance with forces between 3.5 and 14.1 ounces (99 and 400 gm) or displacements between 0.03 and 0.19 inches (0.08 and 0.48 cm), but noted that users preferred the keys requiring lighter touches. In contrast, Kinkead and Gonzalez (1969) found superior keying rates with relatively low levels of force and displacement; they recommended forces between 0.9 and 5.3 ounces (26 and 150 gm) and displacements between 0.05 and 0.25 inches (0.13 and 0.64 cm). Thus, although the recommendations are somewhat contradictory, a key resistance of about six ounces (170 gm) and a key displacement of about 0.13 inches (0.32 cm) seem reasonable.

Although it is obvious that keys should protrude above the surface of the keypad by at least the displacement required for activation, there are apparently no data to indicate the optimal protrusion. McCormick (1970, p. 617), however, recommends a protrusion of at least 0.13 inches (0.32 cm). Thus, a protrusion equivalent to an acceptable displacement of 0.13 inches would seem appropriate.

An additional consideration deserves mention. Leonard and Newman (1965) have suggested that the presence of sensory feedback from the keypress is critical in the refinement of a keying skill. The travel and resistance of the key and the visual echo on the Telidon monitor would, of course, provide considerable feedback to the user. It may, however, be useful to supplement the feedback with a kinesthethic "snap-action" and an audible click on key activation. Consistent with the suggestion, West (1967) has noted an increase in dependence upon kinesthetic feedback as operators progress to intermediate levels of keying efficiency.

Multiple Keypresses. Occasionally, the user will inadvertently press two or more keys simultaneously. Such multiple presses could arise if the user rested his hand upon the keys or if he were sufficiently inaccurate in a keypress attempt to strike more than one key. Although the likelihood of the former is reduced by sufficient key resistance and that of the latter by appropriate spacing of keys, the problem would be alleviated further if simultaneous key presses were ignored by either the keypad or the device receiving its signals.

What, then, if the inadvertent multiple keypresses were not precisely simultaneous? One would still wish the spurious input to be suppressed but, to accomplish this, one would require a minimum delay between keystrokes before accepting their output.

With such a procedure, the question to the designer is obvious -- how long should the enforced delay be? One wishes to suppress spurious multiple keypresses but not to reject genuine speeded keystrokes. In this context, some early work on the maximum rate at which people can tap a key is illuminating. Miles (1937) reported that subjects can achieve rates upwards of one tap per 71.4 msec. Other sources, however, indicate that rates are somewhat slower. Dvorak et al. (1936) noted a maximum rate of one tap per 232 msec and Smith (1967) pointed out that infrequent users may achieve rates of only one tap per 667 msec. Thus, it appears that enforced delays as short as 50 to 70 msec will not induce the loss of genuine entries. They may, however, reduce errors resulting from inadvertent multiple keystrokes.

It should be noted that the present procedure differs in aim from the interlock/rollover systems used in many applications. Such systems typically preserve keystrokes entered at rates higher than the servicing device can accommodate (see Alden et al., 1972; Davis, 1973). In contrast, the present scheme eliminates inputs at rates higher than the user is likely to produce validly.

Cognitive Concerns

The operator's impressive ability to acquire and retain new information can lead to a cavalier attitude toward the complexity of the processing demands in keyset operation. However, it is critical to the convenience of the user that operation of the keypad is made as simple as possible.

Labels

Because of space constraints, some manufacturers of keysets use single symbols as labels for keys. For keys corresponding to letters or numerals, the single alphabetic or numeric character is clearly the most appropriate. For keys with other referents, however, it is often difficult to derive a symbol that is associated explicitly with the referent. Thus, arbitrary symbols are often used with the implicit assumption that the symbol-referent associations can be learned readily.

The use of arbitrary symbols in keypad labelling has serious consequences, particularly if the keypad is intended for occasional usage. Specifically, it imposes upon the inexperienced user demands in addition to those already presented in learning the syntax of the interaction and the facilities of the system. Thus, if possible, the use of arbitrary symbols as labels should be avoided; instead, the designer should use either symbols explicitly associated with the referent or appropriate short words.

A related problem arises when symbols with explicit associates are used improperly. For example, symbols with spatial referents (e.g., "→" to the right or forward) should refer only to operations that, in the user's conceptualization of the system, result in a compatible change in location. Moreover, there is evidence to suggest that even the direction of the motor activity in responding should be compatible with any spatial associations of a label (see, for example, Fitts & Seeger, 1953). Thus, the use of symbols with explicit associations requires careful consideration of compatibility between symbol and referent and even, in some cases, between finger movement and referent.

Chording

Given the space constraints inevitable in keypads, one may be tempted to reduce the number of keys necessary by permitting either a number of keys pressed simultaneously or, in Telidon, a series of keys pressed before the terminator to define the operation performed. Here, I refer to the case in which the set of keystrokes defines a function that none of the keystrokes suggests individually rather than that in which a modifier is added to an operation. The simultaneous-keystroke procedure is called chording and even its proponents (e.g., Seibel, 1972, pp. 320, 328) admit that it requires considerable training, particularly in learning the "vocabulary" of the coding scheme. Because the latter, sequential scheme is effectively a variant of chording, it is inevitable that it, too, will suffer the need for considerable learning.

To illustrate the problem with the sequential procedure, consider the task confronting the user. To use the sequential facilities properly, he must know first that the operation he desires cannot be specified with a single keystroke and, thus, that a search of the labels on the keypad will not be fruitful. Next, he must recall in order or retrieve from an external source the sequence of keystrokes necessary to select the operation. Finally, he must press the series of keys in proper order, attending to the labels for the selection of keys but ignoring their normal referents. Thus, the sequential procedure is cumbersome and demanding, should not be used if possible, and, if used, should never be required for critical or urgent operations.

Strategic Search

In the earlier treatment of the search process, nothing was said of the role of strategy in search. Yet, it is clear that the experienced user does not search the entire keypad for the label (and key) he desires. Instead, he recalls the approximate location of the key and searches that area for his target. Even the inexperienced or occasional user, however, can use such a strategy successfully if the keys of the keypad are grouped functionally (e.g., numerics together, operations together, etc.)

The search process should be facilitated further if, within groups, keys are arranged in a manner that even the new user expects. For example, Lutz and Chapanis (1955) have demonstrated that, when asked to arrange the digits 0 to 9 within the spaces of a blank 3 X 3 matrix that has an additional outlying position, people tend overwhelmingly to place low numbers at the top and to place the zero in the outlying position. One might suspect, then, that performance with this "expected" arrangement would be superior to that with other configurations. Consistent with the suggestion, Conrad and Hull (1968) found greater speed and accuracy in keying with the "expected" arrangement than with one having high numbers at the top of the matrix. Thus, the search process will be facilitated if keys are grouped by function and if expected arrangements are used within groups.

IMPLEMENTING THE RECOMMENDATIONS

In the preceding section, relevant human-factors literature was reviewed briefly and used to make recommendations concerning keypad design. Some of these recommendations are summarized in Table 1. I will present next a keypad design that satisfies these requirements. The new design does not permit alphabetic input, but an acceptable alphabetic extension will be provided also.

The Nonalphabetic Device

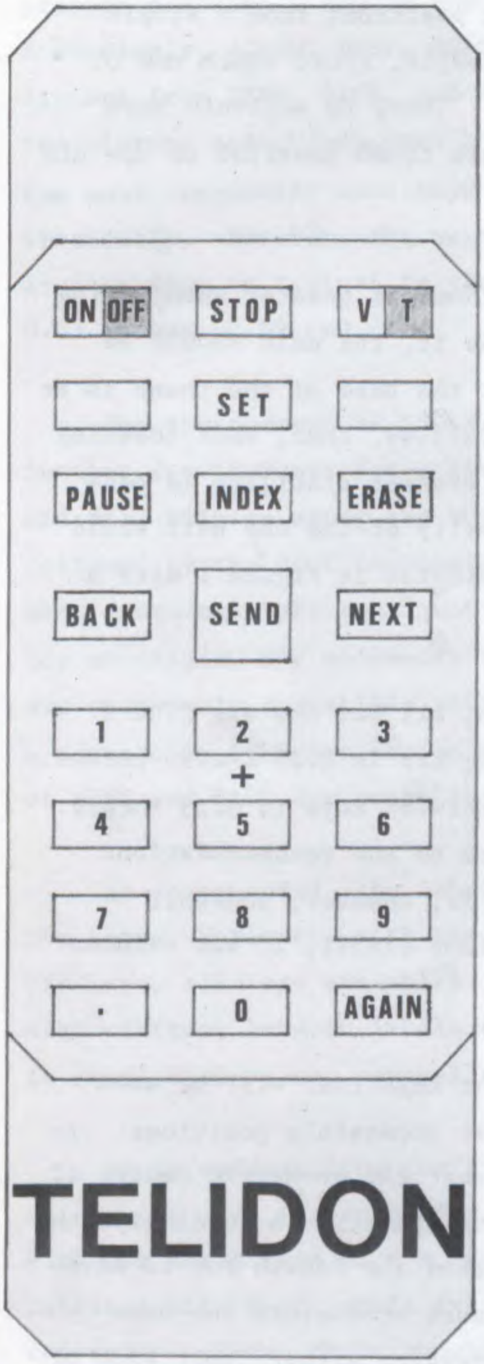
A top view of the proposed keypad is illustrated in Figure 1 together with brief explanations of non-obvious labels. The key-face is shown approximately in actual size.

The keypad is 2.50 inches (6.35 cm) wide. Thus, its width conforms to anthropometric recommendations for the maximum axis-of-grip in both one-handed and two-handed operation. Note, as well, that keys are restricted to three columns and that no key centre is more than 2.00 inches (5.08 cm) from an edge of the unit. Thus, in one-handed operation, no key will be beyond reach from an edge of the unit by any

Table 1

Some Human-Factors Recommendations for Telidon Keypads

Consideration		Recommendation
Keys:		
	width	0.50 inches (1.27 cm), approx.
	length	0.44 inches (1.12 cm), approx.
	edge-to-edge space	0.25 inches (0.64 cm), minimum
	resistance	6.00 ounces (170 gm), approx.
	displacement	0.13 inches (0.32 cm), approx.
	protrusion	0.13 inches (0.32 cm), approx.
Labels:		
	largest dimension - forms	0.15 inches (0.38 cm), minimum
	- letters	0.10-0.15 inches (0.25-0.38 cm)
	placement	on keys
	contrast	black on white
	maximum number - colours	9
	- shapes	5 to 8
	- words	indefinite
The Unit:		
	axis-of-grip	2.50 inches (6.35 cm), maximum
	thickness	0.75 inches (1.91 cm), maximum
	numeric arrangement	standard keyphone
	feedback	snap-action and click
	sequential chording	not recommended
	key-lockout period	50 - 70 msec



LABELS

ON/OFF - Telidon on or off; off terminates session

STOP - clear screen, abort current operation

V/T - select videotex or teletext

SET - followed by other key(s), specifies operations

PAUSE - halt display until SEND is pressed

INDEX - return to immediately superordinate choice page; if pressed twice, return to first choice page

ERASE - delete previous character -- SEND excepted

BACK - return to page viewed most recently

SEND - execute operation

NEXT - advance to next page

AGAIN - transmit present page again; used following a transmission error

Figure 1. An illustration of the nonalphabetic keypad.

but those with the shortest of thumbs. Of course, not all keys can be touched by the thumb from a single resting position; from a single position, fifth percentile females, for example, could touch one or more keys in only seven of the eight rows. Thus, to activate keys beyond reach, the user must either shift his thumb position or use his other hand.

Because the angular mobility of the thumb is greater when moving away from the palm than when moving towards it, the unit should be held during one-handed operation such that the base of the thumb is at or below the centre of the key-face. It follows, then, that lowering the unit's centre of gravity will promote greater stability in one-handed operation. Thus, the centre of gravity of the new unit would be between the "2" and "5" keys; it is indicated in Figure 1 with a "+".

Of the 24 keys in the proposed design, all but one are 0.50 X 0.25 inches (1.25 X 0.64 cm); the remaining key is 0.50 X 0.50 inches. The minimum horizontal or vertical space between keys is 0.25 inches. Thus, the width and spacing of keys conform to the recommendations made previously. The length of most keys is, however, somewhat smaller than the maximum proposed by Dreyfuss (1959); it was reduced to permit greater spaces between keys.

It was recommended previously that the keys that will be used most frequently should be assigned the most accessible positions. In one-handed operation, such positions are near the geometric centre of the key-face and above the unit's centre of gravity. Accordingly, the SEND, BACK, and NEXT operations were assigned the fourth row of keys. Note, as well, that these keys were made more accessible for one-handed or for two-handed operation by increasing either their size or the vertical space between them and their neighbours.

Keys that can disrupt the orderly progress of the session if pressed mistakenly should not be adjacent to those used frequently. Accordingly, AGAIN, STOP, ON/OFF, and V/T are at least two rows distant from SEND, BACK, and NEXT. Although PAUSE, INDEX, and ERASE can disrupt also, they have been placed in a row adjacent to that of the most frequently used keys as they too are likely to be used frequently. However, the vertical spacing between these two rows is greater than is typical in the keypad; center-to-centre distance is 0.63 inches (1.59 cm).

The arrangement of INDEX, BACK, SEND, and NEXT satisfies two further requirements for a good keypad. First, because INDEX, BACK, and NEXT will be among the most frequently used keys and each must be followed by the SEND terminator, the keys that will be used together most frequently are contiguous spatially. Second, assuming the SEND key as origin, the movements required to select BACK, NEXT, and INDEX are reasonably compatible with their referents (conceptually, INDEX is a retreat to a higher choice point; the forward and backward referents of NEXT and BACK are compatible with right and left, respectively).

As recommended, the labels are black and are placed directly upon the keys. Moreover, with the exceptions of the two-toned V/T and ON/OFF keys, all keys are white. Thus, the search process is aided by high contrast between labels and backgrounds and the location process is simplified by the removal of ambiguity in label-key correspondence.

As is evident from the figure, at least five letters of approximately the size recommended can be placed on the surface of a key. With the exceptions of the numeric, ".", and "V/T" keys, all have been labelled with short words explicitly associated with their operational referents. Thus, there should be little difficulty in learning the basic vocabulary of the unit and, consequently, operation by new or occasional users should be facilitated.

It should be noted, however, that the English labelling scheme is something of an optimal case; it is difficult to find semantically equivalent French words that are equally short. With keys 0.50 inches (1.27 cm) wide, only six letters can be placed conveniently on a key. Thus, if short, but acceptable, French words cannot be found, longer words must be either printed with smaller letters or abbreviated. Each option produces undesirable results; smaller letters will be more difficult to discriminate and abbreviations may be more difficult to learn. Of the two options, I recommend abbreviation, provided unique abbreviations are possible.

The numeric keys are arranged in a 3 X 3 matrix with the low numbers at the top and the zero centred below the third row. This arrangement enjoys two advantages. First, data from Lutz and Chapanis (1955) and Conrad and Hull (1968) suggest that it will conform to users' expectations and will yield good keying performance. Second, the arrangement matches that used in the conventional push-button telephone and, thus, will be familiar to many users. Consequently, even inexperienced users will benefit from prior expectations and/or experience during the search process.

The keypad would also implement the enforced keystroke interval recommended previously and follow the suggestions for the displacement, resistance, and protrusion of keys. Feedback would be augmented with a kinesthetic snap-action accompanied by an audible click. Consistent with anthropometric data, the gripping area of the keypad would not be more than 0.75 inches (1.91 cm) thick. Finally, to enhance the visibility of labels when the unit rests upon a horizontal surface, the key-face would be tilted towards the user by about 10°.

In closing, note that none of the urgent or frequently used Telidon operations requires sequential chording in the new keypad. Moreover, the single-keystroke facilities of the keypad can be expanded; two keys are left unassigned. Finally, operations that are neither urgent nor frequently used can be selected using the SET key followed by one or more keypresses.

An Alphabetic Extension

Efficient use of some of the facilities that will be offered by Telidon (e.g., "messaging") requires direct entry of alphabetic characters. Clearly, the keypad presented in the preceding section of the paper does not permit such input. The question, then, is how can alphabetic capabilities be offered in a manner compatible with human-factors recommendations.

For those using the alphabetic facilities extensively, an alphanumeric keyboard is clearly most appropriate; the keyboard offers all the alphabetic, numeric, and punctuational characters required and its layout will be familiar to typists of even modest experience. The Telidon operations could be provided by a separate keypad or by an operations cluster integrated with the keyboard. One could, for example, insert the entire keypad shown in Figure 1 in the same way that the numeric and cursor-control cluster is applied to many keyboards.

Those who will use alphabetic facilities infrequently may be unwilling to accept the cost and bulk of a full-sized keyboard. For such users, one might consider instead a single keypad that offers both the basic Telidon operations and the alphanumeric and punctuational characters required. Unfortunately, such a keypad would likely violate some of the human-factors recommendations presented previously. To illustrate the point, consider the problem of adding 35 to 40 extra characters to the keypad shown in Figure 1; either the size of the unit would have to be increased considerably or the sizes of keys and of spaces between keys would have to be decreased. Another undesirable, but likely, consequence of adding operations would be increased use of the sequential chording procedure.

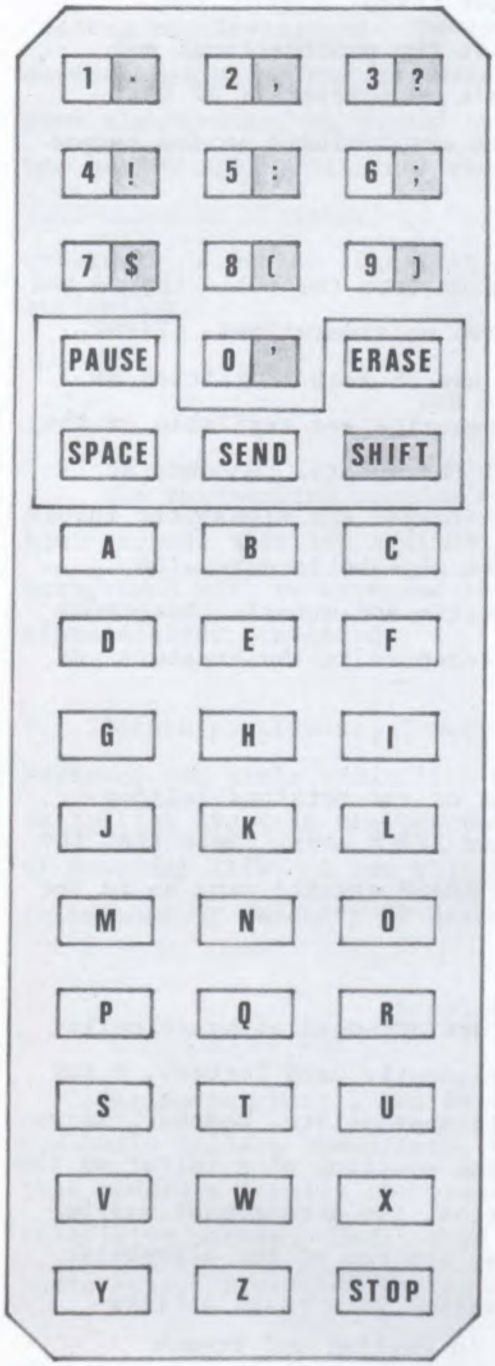
Perhaps the best way of producing an integrated, alphabetic Telidon keypad would be to miniaturize the augmented keyboard previously described while following the human-factors recommendations for key sizes and spacings. Clearly, such a unit would be intended primarily for table-top use; if the letters were arranged in the normal, QWERTY fashion and the keys of the basic keypad in Figure 1 were arranged with the Telidon operations cluster beside the numeric cluster, the unit would be at least 13.0 by 2.5 inches (33.0 x 6.4 cm).

Alternatively, one could offer the alphabetic capability in a separate, and optional, hand-held unit. Thus, those users not interested in the alphabetic facilities need not be penalized unneccessarily by the cost and bulk of a full unit and those who will use the alphabetics occasionally need not purchase a unit that is not easily held.

An acceptable hand-held extension that permits direct entry of alphabetic and punctuational input is presented in Figure 2 (Note that the extension is the same size as the basic keypad). Clearly, the unit was designed according to the same principles that guided the design of the basic keypad shown in Figure 1. Consequently, the features the two keypads share will not be dealt with again. Instead, some of the special features of the extension will be examined briefly.

Note, first, that some of the Telidon operations in the basic keypad are repeated in the extension; these operations are those I consider most likely to be needed in using the alphabetic facilities. The PAUSE, ERASE, and STOP keys function as in the basic keypad, but SEND corresponds more closely to the return key of a keyboard.

The keys are arranged in three clusters. The numeric and punctuational cluster takes the standard keyphone format and the punctuational characters are selected by pressing SHIFT followed by the appropriate key. The latter information is reflected in the identical backgrounds of the punctuational and SHIFT labels.



LABELS

PAUSE - halt display until SEND is pressed

ERASE - delete previous character -- SEND excepted

SPACE - insert one blank space

SEND - accept line of text or execute operation

SHIFT - next entry in upper case; used for capitals and punctuation

STOP - clear screen, abort current operation

Figure 2. A viable alphabetic extension to the basic keypad in Figure 1. Note that the unit is the same size as the basic keypad.

The punctuational characters were selected for their prominence in normal English usage. Data from Thurlow (1980) support the selection. He asked keyboard users to list the punctuational and other symbols they felt should be available on keyboards; of the eleven symbols listed most frequently, ten are included in the keypad extension.

Note that the numerics are available on both the basic keypad and the extension. The repetition reflects two considerations. First, numerics will be important for efficient use of such facilities as messaging and it is convenient that the numerics are available on the same unit as alphabetic and punctuational characters. Second, at present, Telidon decoders may treat basic-keypad and alphabetic inputs differently. Inclusion of numerics in the alphabetic extension ensures that a message composed of alphabetic and numeric characters will remain integrated regardless of differences in the treatment of basic-keypad and alphabetic inputs.

The operations cluster includes most of the retained Telidon functions and, in addition, the SHIFT, and SPACE keys. Note that the spatial relations among PAUSE, SEND, and ERASE are the same as in the basic keypad.

In the alphabetic cluster, letters are arranged alphabetically and the STOP key is adjacent to two infrequently used letters, X and Z. Whether the alphabetic arrangement is appropriate, however, is an empirical question. If users estimate the position of a letter on the keypad from its ordinal alphabetic position, the arrangement may be satisfactory; if, however, users begin at the top of the alphabetic cluster and search downward, it may be useful to arrange letters according to their relative frequencies in English and French combined. Specifically, the most frequent letters (e.g., E) would appear at the top of the alphabetic cluster and the least frequent would be placed at the bottom. Thus, for most letter searches, less than half of the alphabetic cluster would be searched before locating the letter required.

In summary, there are several ways in which alphabetic capabilities can be provided for the user without seriously violating human-factors considerations. However, the user should be permitted to decide whether or not he wants such facilities. Given that he does want alphabetics, he should select an alphabetic device according to his needs. If he will use the alphabetic facilities extensively, a full-sized or miniaturized keyboard would seem most appropriate; otherwise, a device like that illustrated in Figure 2 may be sufficient.

THE CURRENT KEYPADS

The forthcoming section of the paper deals very briefly with the four keypads that are available currently for Telidon systems. In turn, each will be examined in light of the human-factors recommendations already presented.

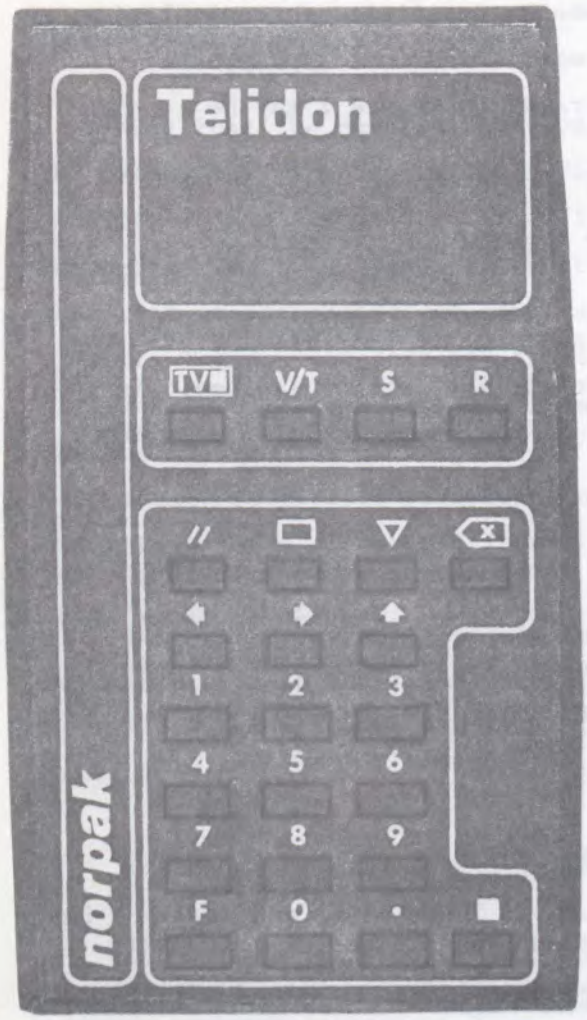
Before continuing, I must point out that the keypads to be reviewed are early production models and, hence, should be viewed only as initial steps in the process of making Telidon a comfortable part of everyday life. I see this paper as an aid to the continued refinement by industry of data-entry devices and procedures.

Nonalphabetic Devices

The Norpak Mark 3 and Bell Vista keypads provide the user with the basic Telidon operations, with the numerics, and with functions that moderate locally the presentation of information on the television screen. Thus, they correspond closely in purpose with the basic keypad presented in Figure 1.

Norpak Mark 3

The key-face of the Norpak keypad is presented in Figure 3. The unit is approximately 3.13 inches (7.94 cm) wide, providing an axis-of-grip larger than was recommended previously for one-handed or for two-handed operation. Moreover, the average thickness of the unit (1.17 in, 2.96 cm) exceeds that recommended for one-handed usage.



LABELS

TV□	- Telidon on/off
V/T	- videotex or teletext
S, R	- unused keys
//	- transmit page again
▨	- abort operation, clear screen
▽	- halt display until is pressed
⌫	- delete entry
⇦	- previous page
⇨	- next page
⇧	- previous choice page; if pressed twice, first choice page
F	- followed by other key(s), specifies operations
□	- execute

Figure 3. A reproduction of the Norpak Mark 3 keypad.

As is clear from the figure, there are two sizes of keys; all are approximately 0.16 inches (0.40 cm) long but their widths are either 0.28 or 0.34 inches (0.71 or 0.87 cm). Thus, the keys are smaller than previously suggested. The minimum spaces between keys, both vertically (0.22 in, 0.56 cm) and horizontally (0.16 in, 0.40 cm) are also smaller than the human-factors literature suggests.

Contrary to earlier recommendations, the labels are placed between the rows of keys approximately at the midpoint of the space between rows, promoting considerable uncertainty about the keys to which more central labels refer. The labels are, however, distinct; they contrast highly with their background and their sizes (letters - 0.12 inches, 0.30 cm; forms - 0.13 to 0.28 inches, 0.32 to 0.71 cm) conform well with previous suggestions.

The reader will recognize one of the symbols used in the Norpak keypad, V/T, as similar to one used in the keypad illustrated in Figure 1. I should point out that my V/T label was taken from the Norpak label; I could find no superior label for the VIDEOTEX/TELETEXT selector. The remaining operation labels in the Norpak keypad, however, are somewhat obscure and require, unnecessarily, learning by the user. The SEND operation, for example, is represented by a white square in the lower right-hand corner of the unit; inexperienced users sometimes complain that it is confusable with the outline rectangle representing the ABORT OPERATION function.

Finally, it should be noted that, although the numeric keys are arranged in the keyphone configuration recommended, the operation keys are scattered about the key-face. The SEND key is placed in the lower right corner of the unit rendering it difficult to access during one-handed operation despite the fact that it will be used most frequently. Similarly, the BACK (←) and NEXT (→) keys, which also will be used frequently, are adjacent to disruptive keys, ABORT OPERATION and REPEAT PAGE, rather than the SEND key which must follow them. Further, note that the SEND, NEXT,and BACK keys are among the smallest in the keypad despite their imminent heavy usage.

Bell Vista

An illustration of the Vista keypad is presented in Figure 4. As the figure shows, the unit is about 2.75 inches (6.99 cm) wide; the axis-of-grip thus conforms roughly to earlier anthropometric recommendations. However, the keys are approximately 0.28 inches (0.71 cm) wide by 0.19 inches (0.48 cm) long, smaller than was recommended previously. The space between rows of keys (0.38 in, 0.95 cm) exceeds the minimum suggested, but that between keys horizontally (0.19 in, 0.48 cm) is somewhat smaller than the human-factors literature endorses.

Previously, it was suggested that labels should be applied directly to the keys unless the space between rows of keys is sufficient to permit clear associations between labels and keys. In the Vista keypad, the latter option has been used successfully. The labels, however, are somewhat smaller than I would recommend. The letters, in lower case, and the numerals are a maximum of 0.09 inches (0.22 cm) high; their heights could be increased to at least 0.13 inches (0.32 cm) without adversely affecting label-key associations.

Consistent with human-factors recommendations, the operation labels in the Vista keypad are short words that refer explicitly to the operations they represent. Thus, use of the unit by new or inexperienced users should be facilitated.

The arrangement of numeric keys follows that used in the standard keyphone and, thus, matches users' expectations and prior experience. The arrangement of operation keys, however, leaves something to be desired. For example, the PAUSE key is in the lowest row of keys. This location is unfortunate for two reasons. First, there is an element of urgency in selection of the PAUSE operation and it would be convenient if PAUSE were closer to the page selection and SEND keys. Second, the PAUSE key is dangerously near the VISTA/TV (sign-off) key. The latter problem is critical because activation of VISTA/TV will terminate the session immediately and misses of the PAUSE key are relatively likely as it will be used hastily and fairly often.

LABELS

send - execute operation

next - next page

back - previous page

delete - erase previous character

retrace - repeat in reverse order last ten pages viewed

origin - restore service directory to screen

repeat - display page again

page # - display page number

function- followed by other key(s), specifies operations

vista/tv- sign-on/sign-off

pause - halt display until pressed again

zoom - expands top or bottom half of page

help - requests user instructions

Figure 4. A reproduction of the Bell Vista keypad.

The arrangement of the RETRACE (repeat in reverse order last 10 pages viewed), BACK, and NEXT operations is less than optimal. An arrangement more compatible with their spatial referents would be, from left to right: RETRACE, BACK, and NEXT. In addition, it should be noted that, with the present arrangement, users with small hands may find it difficult to select RETRACE, BACK, NEXT, and SEND during one-handed usage with the left hand.

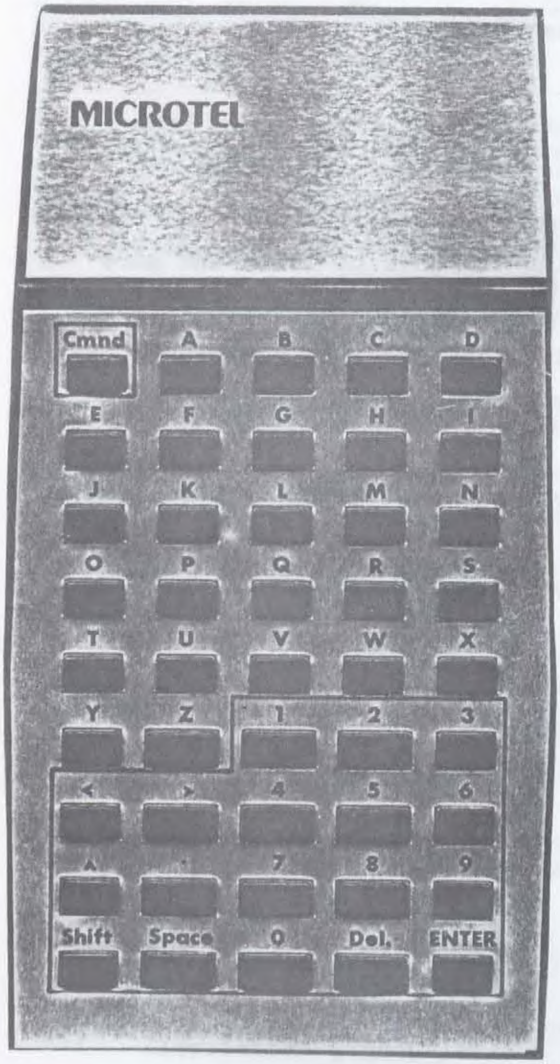
In closing, three additional problems should be mentioned. First, there is no key that returns the user directly to the immediately superordinate choice page unless that page is either the one viewed most recently or the service directory. Second, the Vista guide indicates that the visual feedback on the Telidon monitor does not match the labels of the operation keys. To avoid confusing the inexperienced user, it is critical that visual feedback matches key labels. And, finally, the unit is somewhat thicker (1.19 in, 3.02 cm) than is recommended for one-handed operation.

Alphabetic Devices

In addition to the basic Telidon operations and the numerics, the Microtel and Electrohome keypads permit the entry of alphabetic characters. Because they provide both the basic and the alphabetic facilities in a single device, they face the difficult task of reconciling human-factors considerations for hand-held input devices with the need for more keys. As will be seen presently, the two manufacturers approached the problem differently.

Microtel

The key-face of the Microtel unit is illustrated in Figure 5. The maximum width of the keypad is 3.19 inches (8.10 cm), providing an axis-of-grip larger than that recommended previously. In addition, the average thickness of the unit (1.17 in, 2.96 cm) exceeds that recommended for one-handed operation.



LABELS

Cmnd	- followed by other key(s), specifies operations
<	- previous page
>	- next page
^	- preceding choice page
Shift	- next entry shifted
Space	- insert one space
Del.	- erase entry
ENTER	- execute

Figure 5. A reproduction of the Microtel keypad.

As is clear in the figure, the keys are approximately 0.17 inches (0.44 cm) long and either 0.28 or 0.38 inches (0.71 or 0.95 cm) wide. Thus, the keys are smaller than was suggested previously. In addition, the spaces between keys, both horizontally (0.13 and 0.19 in, 0.32 and 0.48 cm) and vertically (0.20 in, 0.52 cm), fall short of the recommended minimum of 0.25 inches (0.64 cm).

In contrast with previous suggestions, the labels have been placed between the rows of keys at, or near, the midpoint of the inter-row space. Thus, the inexperienced user will likely encounter considerable uncertainty in determining the keys to which the more central labels refer. Moreover, although the labels are sharply defined and contrast highly with their light metallic background, they are smaller (0.06 in, 0.16 cm) than recommended previously.

The operation labels are a mixture of short words, abbreviations, and forms. The words should provide little difficulty for the inexperienced user; they refer explicitly to the operations they represent. The same is true, to a lesser extent, of the abbreviations. Unfortunately, the same is not true of the forms; for example, in the alphanumeric context of the keypad, the NEXT (>) and BACK (<) symbols might suggest "greater than" and "less than" to many users.

The reader will have noticed that many of the operations offered in the nonalphabetic keypads are not evident in the Microtel unit. This absence reflects frequent use of sequential chording in the specification of operations. Recall from the discussion of cognitive concerns that sequential chording is a particularly undesirable option; learning the complicated vocabulary of a chorded unit places considerable demands upon the new user, and maintaining the vocabulary taxes the occasional user.

In the Microtel unit, sequential chording is required to select several of the Telidon operations, virtually all punctuational characters, and a number of local commands (e.g., lock to upper or lower case). It is particularly unfortunate that the PAUSE operation is among those requiring chording; to pause, the user must press SHIFT, then SPACE. Thus, an operation inevitably associated with haste requires two keystrokes for activation.

It is clear that efficient use of the keypad requires extensive learning. In an attempt to alleviate the problem, the manufacturers have summarized some chording sequences on the back of the unit. It should be noted, however, that this summary reduces, but does not remove, the problem.

As the figure shows, there are two functional clusters in the keypad. The numeric keys are arranged in a variant of the standard keyphone layout; the zero is displaced to the left of its normal position. The latter may present some difficulty to users who are highly familiar with keyphones as the DELETE operation occupies the location at which they will expect the zero. The letters are arranged alphabetically, permitting the user to estimate the position of a letter in the keypad from its ordinal position in the alphabet.

The Telidon operations that can be selected with a single keystroke have been placed in the lowest three rows of the unit, adjacent to the numeric keys. Note that the SEND, BACK, and INDEX keys (ENTER, $<$, and $\wedge$, respectively) are among the smallest in the keypad. Moreover, as with the NEXT ($>$) key, the horizontal spaces between these keys and their neighbours are among the smallest in the keypad. The resulting difficulty in selecting these keys is unfortunate as they, and in particular the ENTER key, will be used heavily during normal operation. Finally, the ENTER key is in the bottom right corner of the unit, adjacent to the DELETE key. Thus, it is not only separated from the keys it will follow most frequently ($>$ and $<$), it is also adjacent to a potentially disruptive key.

Electrohome

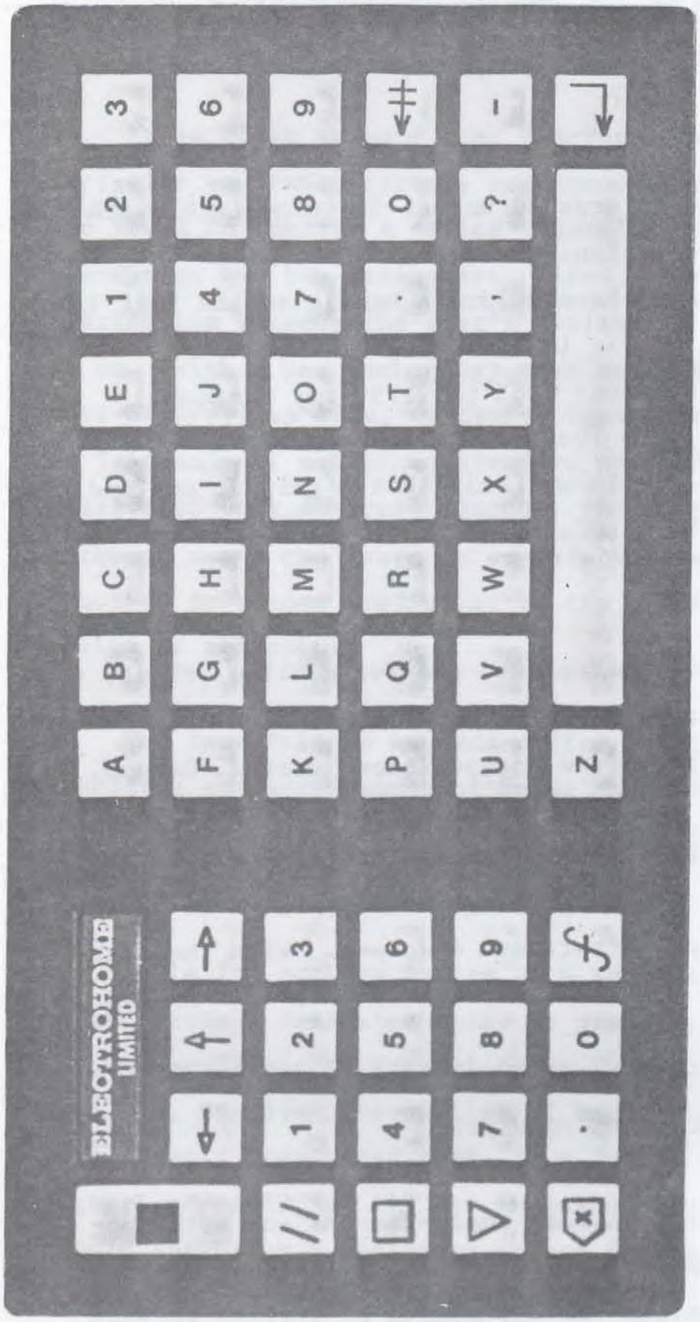
The key-face of the Electrohome keypad is illustrated in Figure 6. The key-face is 2.88 inches (7.30 cm) long and 6.38 inches (16.19 cm) wide; the unit itself is 4.13 inches (10.48 cm) long and 9.13 inches (23.18 cm) wide.

All but two of the keys are square with 0.38 inches (0.95 cm) to a side. The exceptions are the SEND and SPACE keys. The SEND key is 0.88 inches (2.22 cm) long and 0.38 inches (0.95 cm) wide; the SPACE bar is 0.38 inches (0.95 cm) long and 2.88 inches (7.30 cm) wide. The lengths of the keys (SEND excepted) conform roughly with the recommended 0.44 inches (1.12 cm). Unfortunately, the widths of the keys (SPACE excepted) fall short of the suggested 0.50 inches (1.27 cm). The space between keys (0.13 in, 0.32 cm) is also less than the human-factors literature suggests. The reduced widths of the keys and the sub-optimal spacing between keys may create problems if keying is less than completely accurate.

Consistent with previous suggestions, the labels have been applied directly to the keys and they contrast well with the white surfaces of the keys (labels for numeric and operations keys are black; those for the remaining keys are brown). Thus, the search process is aided by high contrast between labels and backgrounds and the location process is facilitated by the removal of ambiguity in label-key correspondence.

The letters and digits used as labels are 0.09 inches (0.24 cm) high, somewhat smaller than recommended. However, the sizes of the forms used as labels conform well with suggestions from the human-factors literature (minimum height or width is 0.19 inches, 0.48 cm).

The keys are arranged in two clusters that are separated by a space 0.63 inches (1.59 cm) wide. Basic operations and numerics are at the left and alphabetic, numeric, punctuational, and "carriage control" keys are at the right.



LABELS

■ - execute operation

⇽ - previous page

⇡ - previous choice page

⇾ - next page

// - transmit page again

□ - clear screen; abort

▽ - halt display temporarily

⌫ - delete entry

𝑓 - followed by other key(s), specifies operations

⇷ - backspace

↵ - return

Figure 6. A reproduction of the Electrohome keypad.

The letter keys are arranged alphabetically from left to right and from top to bottom. Thus, users can estimate the position of a letter on the keypad from its ordinal position in the alphabet. Both numeric groupings follow the standard keyphone arrangement, one that is familiar for many users.

Clearly, the unit cannot be grasped across its nine-inch width; equally, it cannot be held conveniently across its four-inch length. For hand-held use, the designers have molded a handle to the left size of the keypad. Although the handle is sufficiently thin for a comfortable grip (minimum thickness: 0.63 in, 1.59 cm; maximum thickness: 1.00 in, 2.54 cm), its location is not appropriate for left-handed users. Moreover, it is unlikely that a grip at one end of the unit will be sufficient both to support and to stabilize the unit during keying.

In closing, several additional points deserve mention. First, the presence of two numeric clusters (one for basic operations and one for alphanumeric data entry) will confuse inexperienced users. Second, few punctuational characters are offered; more could be added with the technique used for the alphabetic keypad extension (Figure 2). And, finally, the displacement of the keys is considerably less (0.03 in, 0.08 cm) than the human-factors literature endorses. With the high resistance of the keys, this will make accurate and speeded keying difficult for the user.

CONCLUDING COMMENTS

Initially, the paper surveyed some human-factors and anthropometric literature relevant to the design of hand-held input devices and made specific recommendations for the design of Telidon keypads (see Table 1). These recommendations were implemented in proposals for a basic Telidon keypad (Figure 1) and for an optional extension that permits alphabetic input (Figure 2). Finally, four Telidon keypads that are available currently were examined critically in light of the design recommendations adapted from the literature.

Some may think that I have been too critical in evaluating the current keypads. However, the purpose of the paper is to point out potential difficulties in keypads and to provide specific guidelines so that these problems can be corrected.

It is often assumed that discrepancies between keypad characteristics and human-factors recommendations are unimportant as users can learn to operate a device regardless of its design. This assumption has two drawbacks. First, it does not acknowledge a distinction between the user's ability to adapt and his willingness to do so. With a new technology that we hope will become an integral part of everyday life, we cannot ignore this distinction; interaction in Telidon must not be compromised excessively by weaknesses in the designs of user devices. Second, the attitude ignores the fact that, although users can learn to operate virtually any device, the time required to become proficient in its use is affected greatly by the design of the unit.

The four Telidon keypads differ considerably in size, in the labelling and arrangement of keys, and even in the facilities they offer. Thus, users will find it difficult to alternate between units.

A similar problem exists with the British Prestel system. A recent article indicates that, at present, there are ten different keypads available to Prestel users [Viewdata and TV User, 1979, Vol. 1(4), pp. 24-25]. The problem of incompatibility for the user is sufficiently pronounced that, in a survey of user issues in Prestel, Sutherland (1980, p. 41) has suggested that the British Post Office should establish a mandatory keypad design.

In closing, I hope that the recommendations and designs presented in the paper will prove useful to designers of keypads for Telidon. And, once again, I would like to stress that the convenience of the user, especially the new user, must guide the development of man-machine systems.

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THE PROBLEM OF USER ERRORS CAUSED BY LONG VIDEOTEX PAGE NUMBERS

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THE PROBLEM OF USER ERRORS
CAUSED BY LONG VIDEOTEX PAGE NUMBERS

Abstract

All videotex information retrieval methods except keywords require the use of page numbers for the identification, storage, and retrieval of information. For direct page requests in tree retrieval systems, on-line directories, and paper directories, users must key in long page numbers on a keypad or keyboard to retrieve information of interest. As videotex databases increase in size, the number of digits in the page numbers will increase correspondingly. The problem for the videotex user is that, as the page numbers get longer and longer, the probability of entering a page number incorrectly increases. To the user such errors can be time consuming, costly, and frustrating. The purpose of the present report was to explore the nature and seriousness of the problem of long page numbers for videotex users. This problem was examined in the light of the available literature. Since no empirical studies on videotex page numbering could be found, the present literature review was confined to an examination of very similar problems such as long telephone numbers. Analysis of this literature suggested that long page numbers could potentially be a serious problem for videotex users, particularly as the number of digits in a page number exceeds seven or eight. However, the literature also suggested that the number of user errors could be reduced by as much as 50% or even more by grouping digits in triplets within each page number and separating the groups within a page number by blank spaces. On the basis of the evidence presented in this report, several recommendations are made:

1. Digits in all videotex page numbers should be grouped in triplets. (Although grouping by 3s was best overall, grouping by 4s was frequently almost as good.)

2. Groups of digits should be separated by a blank space.

These recommendations apply to the printing of videotex page numbers in paper directories and indexes (similar to the "yellow pages"), to the display of page numbers in on-line directories and indexes, to the display of page numbers on the index and document pages in the tree structure, as well as to the echo of the user's page request on the display screen.

INTRODUCTION

A new two-way communications technology called videotex has been developed within the last five or six years. One of the primary functions of any videotex system such as Telidon, Prestel, or Antiope is to provide access to a wide range of information stored in computer databases to anyone owning an ordinary TV set and a videotex terminal. There are many different ways for users to retrieve information on videotex systems - hierarchically organized tree structures (i.e., multiple-choice menu pages), paper directories, on-line directories, and keywords. Currently, all videotex systems provide tree structures for retrieving information. Eventually most videotex services will likely provide either on-line or paper directories if only because they provide an alternative method to the ubiquitous tree for retrieving information. At present, Prestel provides the user with a paper directory (similar to the yellow pages or to a dictionary) in addition to the tree. A videotex user can retrieve any information of interest using a numeric keypad (which resembles a simple hand calculator). Any given page of information can be retrieved directly by keying on the keypad the "page" number given in the directory.

All retrieval methods with the possible exception of keywords require the use of page numbers for the identification, storage, and retrieval of information. As videotex databases increase in size, the number of digits in the page numbers will necessarily increase as well. Commercial sized databases could have anywhere from 10-20 levels in the tree, or correspondingly, 10-20 digits in a page number. Similarly, databases based entirely on directories for retrieval (that is, without the use of a tree structure) will, of necessity, require page numbers of approximately the same magnitude as the number of levels in the trees, 10-20 digits.

The problem for the videotex user is that, as the page numbers get longer and longer, the probability of entering the page number incorrectly on the keypad or the keyboard increases. Although it only takes a few seconds to read a number from a directory and then key it in, most people cannot remember even 6 or 7 digits correctly much less 15 to 25 for this brief duration of time. Often the user will be completely unaware of the error. This is a very common problem in long telephone numbers where people often invert the order of a pair of digits without realizing it. Two possible consequences of an incorrectly keyed number are that the user may be charged for accessing the page (either directly for the page of information itself or for connect time and telephone charges), and the user will waste some of his own time since he must reenter the page number to retrieve the correct page. Even if the user detects that an error has been made before transmitting the number, time will be wasted in reentering the page number. In either case the user is likely to experience frustration whenever an error occurs.

It is important to note that the problem of long videotex page numbers does not really exist when users retrieve information by making a series of selections on successive index pages using the tree structure. A tree structure enables the user to retrieve information without ever having to key in a number with more than one digit. Information stored on pages with long videotex page numbers can be retrieved by a succession of single digit entries. In such a case there is very little likelihood that a user would enter an incorrect digit, and the consequences of such an action would probably not be too serious. Direct entry of long page numbers is a much more difficult task.

The purpose of the present report is to explore the nature and potential seriousness of the problem of long page numbers for users of videotex information retrieval systems. This problem is examined and its magnitude estimated in the light of the available literature. Only a single study was found in the literature that discussed the problem of user errors caused by long videotex numbers. Although Sutherland (1980) reported that "users make a great many mistakes in keying long page numbers", no empirical data was presented to support this contention. Since no empirical studies on videotex page numbering could be found, the present literature review was confined to an examination of very similar problems such as that encountered with the dialling of long telephone numbers. On the basis of this analysis, recommendations are made for information providers and database software developers on the grouping of digits in videotex page numbers.

ANALYSIS OF THE LITERATURE

Natural Grouping

The subjective grouping of digits in long numbers was first noted in the early work on memory span. The memory span for digits is the highest number of consecutively correct digits that a person can remember 50% of the time. Several early investigators (Miller, 1922; Jones, 1925; Easby-Grave, 1924) reported the subjective grouping of digits by subjects whose task was to remember a long number, usually presented aurally with pauses of equal length between each digit. Grouping occurred not in the original presentation of the long numbers but in the subjects' recall. Oberly (1928) speculated that such grouping might be a strategy employed by subjects to increase their ability to remember the long numbers. In a memory-span experiment, Oberly presented sequences of digits aurally and required his subjects to write the numbers down and then to indicate any "grouping of digits by means of brackets or spaces". The median memory span for those numbers which subjects reported no attempt at grouping was 4.09 digits which was less than half the median memory span of 8.70 for all numbers, grouped and ungrouped. Thus grouping appeared to enhance significantly the ability to recall long numbers. The introspective comments of the subjects indicated that all of them attempted to group the digits within a number to facilitate recall. From Oberly's account of their introspective comments, the most frequently used groupings were 3's and 4's, although groups of 2's and 5's were also used at times by some subjects. Martin and Fernberger (1929) found that, over 4 months of testing, memory span improved markedly only after each of the two subjects attempted grouping the digits. The improvement was "based on the development of more efficient methods of grouping". The two subjects gradually increased the size of group employed until they were grouping in 5's. Grouping successfully by 5's only occurred after months of practice. Overall, memory span was improved by almost 40% in one case and 50% in the other by grouping.

When individuals memorize, repeat, or copy long sequences of items, they show a marked predisposition for breaking the sequences into smaller groups. Spontaneous grouping of this kind is called "natural" grouping. In natural grouping the individual imposes structure on an unbroken sequence of items by organizing the items into groups. Presumably such imposed groupings enable the individual to better accomplish task objectives such as remembering the sequence more accurately.

Several investigators have observed this phenomenon of "natural grouping" for long sequences of digits (Conrad & Hille, 1957; Crannell & Parrish, 1957). In a systematic investigation of the effect of the natural grouping of digits, Thorpe & Rowland (1965) found that unbroken sequences of 8, 9, and 10 digits presented on cards were spontaneously broken up into a very small number of different patterns by people when giving verbal reports. In fact, for over 98% of the numbers presented, some form of spontaneous grouping was employed. The three most frequently employed patterns for 7 digit numbers were 3-3-1 (31%), 3-4 (25%) and 3-2-2 (19%), while for 8 and 9 digit numbers the most frequent natural groupings were 3-3-2 (68%) and 3-3-3 (88%), respectively.

These results show that, rather than some specific type of grouping such as subdividing a given number into two equal-sized groups being preferred, it is a specific subgroup size which appears to be most natural. The most natural subgroup size is three digits. Subgroups of size 1, 2, and 4 are employed much less frequently. People seem to reduce each sequence to a set of groups of size three plus a subgroup for the remainder of the digits (for example, 3-3-1, 3-3-2, 3-3-3).

The most natural or frequently occurring patterns employed by the subjects in the Thorpe et al. experiment were also the best remembered. People made significantly fewer errors in reporting the long numbers when they employed a natural (that is, the most frequently employed type of grouping), rather than an unnatural, grouping.

In contrast to the Thorpe and Rowland (1965) investigation of natural grouping, Schoeffler (1967) investigated the phenomenon of grouping by studying the number of digits that an individual would attempt to remember between glances at long telephone numbers. Subjects in his experiment were presented with 7, 10 and 17-digit telephone numbers to dial. All digits were printed in a continuous string with no separators between any of the digits. His subjects were not allowed to view the long number and dial simultaneously. Thus, they had to view the number, dial some of the digits from memory, then look at the number again, and so on. Grouping was defined by points at which a person referred again to the display. Thus the first group was the set of digits dialled before referring to the displayed number again. The second group was the set of digits between the second and third referrals, and so on. The 7-digit numbers were most often all grouped together (over 55%). Patterns of 3-4, 4-3 and 5-2 were used for about 10% of the 7-digit numbers. For 10-digit numbers the pattern 6-4 was most frequent (50%) followed by 5-5 (about 20%) and 7-3 (about 15%). For 17-digit numbers, the most common grouping pattern was 6-6-5 (45%). For both 10 and 17-digit numbers the most preferred group size by far was six. The virtual absence of groups of size 6 for 7-digit numbers probably represents the avoidance of groups of size 1. Groupings of size 3 to 8 did not differ markedly in the average "look up time" per digit. Groupings of size 1 or 2 or over 8 were much longer and, therefore, much less efficient. In a similar study, Deininger (1960) reported that approximately half of his subjects preferred when dialling to break 7-digit phone numbers into 2 or more groups by referring back to the printed number more than once.

Schoeffler's (1967) and Thorpe and Rowland's (1965) results suggest that people employ two different grouping operations when working with long numbers. The work of Thorpe and Rowland shows that people prefer to break longer numbers up into natural groups of size 3, presumably to facilitate memory and rehearsal. Schoeffler's results indicate that people prefer to store groups of size 6 in memory before dialling. Although these two studies do not provide the pertinent information, it is probable that people prefer to break long numbers up, first, into subgroups of size 3 to facilitate remembering them and then remembering two groups of size 3 long enough to dial the 6 digits. The results of these two studies provide strong support for breaking videotex page numbers into groups of digits. They are not conclusive, however, for the real issue is whether pregrouping digits in long videotex page numbers can reduce the frequency of user errors. Several studies addressing this issue will be discussed next.

The Effect of Pregrouping On Recall

Wickelgren (1964, 1967) investigated the effects on short-term memory of different methods of grouping digits in long numbers. He hypothesized that different methods of grouping have different effects on memory (and, therefore, on the number of errors committed) because different grouping methods induce people to use different rehearsal strategies that produce differential performances on the tasks performed in studies such as those by Severin et al. (1963) and Konz et al. (1968).

Rehearsal in small groups can make it easier to remember long numbers long enough to dial the number correctly, or to write it down, or to enter it on a keyboard. In the first experiment (Wickelgren, 1964), subjects were instructed to rehearse the digits in each number presented in groups having exactly 1, 2, 3, 4, or 5 digits (insofar as each long number could be subdivided into the requisite size subgroups). The numbers varied in length from 6 to 10 digits and were presented to subjects using a tape recorder. The task for each subject was simply to write down the single number just heard.

Most pertinent to the present investigation is his analysis of errors of "ordered recall". The subject's report of a sequence was correct if and only if all digits in the sequence were recalled in the correct order. By this criterion rehearsing in 3's was optimal, but rehearsing in 4's was almost as good. The error rate for each condition was approximately 42% for 1's, 46% for 2's, 33% for 3's 34% for 4's and 41% for 5's. These results provide additional support for the proposition that the optimal method for grouping digits is in groups of size three.

Wickelgren (1967) improved upon his first experiment (Wickelgren, 1964) by obtaining an independent estimate of the optimum method of grouping for long numbers of three different lengths: 8, 9 and 10 digits. The results were highly similar to the first experiment in that grouping, or rehearsing, in 3's was optimal for numbers of length 8, 9 or 10. Grouping in 3's was superior to all other methods including 4's except for numbers with 10 digits in which case there was no difference between 3's and 4's. This second experiment provides additional support for the superiority of triplets as the method of grouping. "Furthermore, there appears to be no significance for memory performance of the greater "naturalness" of dividing a list of eight items into two groups of four or of dividing a list of 10 items into two groups of five." However, these experiments leave open the possibility that dividing up numbers with 10 digits or more is optimized with groups of size four. The data provided by Wickelgren in his second experiment (1967, see his original Figure 1) show that grouping in 4's improved as the number of digits in the number increased from 8 to 10.

Martin, Morton, and Ottley (1977) report several experiments on short digit strings. In one experiment three patterns of 3-digit numbers were presented to subjects: a group of 3 (for example, 912), a space between either the first and second digit or between the second and third digit (for example, 96 4 and 8 31), a hyphen between either the first and second or the second and third digits (for example, 96-4 and 8-31). The 3-digit numbers were presented on the screen one at a time. After each presentation subjects were required to recall each 3-digit string by writing it down and leaving out separators (space or hyphen). Response time was significantly faster for the no-separator (3) condition. Although the no-separator condition also had the fewest errors, the differences between conditions were not significant. Thus, the Martin et al. experiment provides further support for the present thesis that the optimal size for grouping digits in long numbers is triplets.

Although most investigators have manipulated the size of grouping by inserting spaces between groups of digits in a horizontal sequence of digits, Mayzner and Gabriel (1963) varied grouping size by varying the number of digits per line. They employed six different organizations of 12-digit numbers in their experiment: 12 digits in a column, 6 lines of 2 digits each in a column, 4 lines with 3 digits each, 3 lines with 4 digits each, 2 lines with 6 digits each, and 1 line of 12 consecutive digits. The type of grouping had a significant effect on the number of digits recalled correctly in their proper positions. Performance was best for the two groups of 6 digits each. It is not clear from their article, however, whether 2 groups of 6 digits was significantly better than 3 groups of 4 digits each. Mackworth (1962) reported similar results. Retention improved as the number of digits displayed simultaneously increased.

Pollack, Johnson, and Knaff (1959) reported an experiment on the effect of grouping digits in auditory presentations of long numbers. The size of grouping was varied from 1 (no grouping) to 6 digits; for example, a grouping of size 3 was read as: 542 (pause) 219 (pause) 862. At the end of the presentation of all digits in a number, subjects were asked to recall the number from memory. Groupings of size 4 had the highest digit spans (digit span is the highest number of consecutively presented digits that a subject can remember correctly). Grouping in 4's was significantly better than all other methods of grouping except in 3's. Although the auditory presentation situation is quite different from the type of situation most likely to occur with videotex page numbers (namely visual presentation of numbers), Pollack's results support the general superiority of grouping in 3's or 4's.

Long Telephone Numbers

The problem of telephone numbers is very similar to the problem encountered in videotex page numbering. When using a telephone directory, people must remember the telephone number long enough to dial it correctly on the telephone set. Telephone numbers are as long as most videotex page numbers are today, although videotex numbers will probably increase in length in the near future. Local telephone numbers in North America are 7 digits long while international long distance numbers can require the dialling of up to 12 digits on the public network (CCITT) and up to 13 digits on the Canadian federal government network.

The task of remembering a telephone number long enough to dial it correctly is quite similar to the the task of remembering a videotex page number long enough to enter it correctly on either a keypad or a keyboard. Therefore, investigations of long telephone numbers are quite pertinent to the present problem of long videotex page numbers.

Remembering even short telephone number long enough to dial them correctly is a difficult task for most people. Conrad (1958) found that even experienced telephone operators made mistakes on an average of 46% of 8-digit phone numbers when the numbers were played to the operator on a tape recorder. Adding the constant prefix digit 0 to the 8-digit numbers resulted in an average error rate of over 60% (the standard prefix 0 was often used in Britain for trunk lines).

In a summary of reseach on telecommunication, Conrad (1960) noted that grouping digits significantly reduces the number of errors in dialing long telephone numbers. He reported that the optimum size of group is three or four digits. However, no empirical data was presented.

In a systematic study of several hundred telephone operators in Great Britain, Conrad and Hille (1957) found that only 70% of all 8-digit numbers were recalled correctly. Performance was even worse for longer numbers: 56% of the 9-digit and 46% of the 10-digit numbers were recalled correctly. Surprisingly, most operators believed that they had remembered correctly when they were actually wrong. A frequent undetected form of error was the transposition or inversion in the order of two digits.

In their early experiments on memory for long telephone numbers, Conrad and Hille (1957) found that many telephone operators would try to break the long 8-10 digit numbers up into smaller groups of digits to make them easier to remember. To explore the effect of grouping on remembering long telephone numbers, they broke 9-digit numbers up in 4 different ways. The pregrouped numbers were printed on cards and read by the operators before dialing. Performance was best (most correct recalls) when the digits were broken down in two sub-groups. Unfortunately, the authors did not publish the percentage of long numbers correctly recalled for each type of grouping. It is, therefore, impossible to determine whether breaking a long number up into three sub-groups was only a little worse or much worse than two sub-groups.

There are two other problems with generalizing from Conrad and Hille's results for telephone numbers to videotex page numbers. First, they presented only 9-digit numbers to the telephone operators whereas in videotex the number of digits could exceed 15. Second, it is not clear from their study whether the breaking up of a long number into two (approximately equal-sized) sub-groups produces optimal recall because: (a) the breaking up of any sized long number (say 24 digits) into two sub-groups is optimal; or (b) the breaking up of any sized number into sub-groups containing 4 or 5 digits each is optimal. The number of digits in the long telephone numbers must be systematically varied to test between these alternative interpretations. Several more recent studies have systematically varied the number of digits.

In a related study of the effect of digit grouping on memory for telephone numbers, Severin and Rigby (1963) presented four different patterns of 7-digit numbers. Each pattern consisted of groupings of digits separated by hyphens: 3-4, 1-3-3, 2-2-3 and 1-2-2-2. Each 7-digit number was presented in written form for four seconds after which subjects were asked to lift a telephone receiver and dial the number. The task is quite realistic and is similar to the task performed by videotex users who study a page number for a few seconds before typing in the entire number on a keyboard from memory. The 3-4 pattern was significantly better (fewer errors) than the other three patterns whose results did not differ from one another. From Figure 1 in their article, the percentage of 7-digit numbers dialed that were completely correct for each pattern was as follows: 3-4 (67.5%), 2-2-3 (60.2%), 1-2-2-2 (59.3%) and 1-3-3 (57.0%). Thus, the way in which digits are grouped in long numbers has a significant effect on the number of errors.

Overall the number of errors was relatively high. Even for the optimum pattern of grouping digits, subjects made at least one error on almost one-third of all the telephone numbers attempted. The implication for videotex is that the entry of even longer page numbers could prove to be a serious and frustrating problem for the user who attempts to remember the entire number long enough to type it all in. Of course, some users will choose to look back at the number several times throughout keying. This situation is discussed in a later section of this report.

There are several limitations to the Severin and Rigby study, however. First, only 7-digit numbers were presented in their experiment, so it is difficult to extrapolate the results to longer numbers. For example, on the basis of only their data, it is impossible to know whether longer numbers should be broken up into two approximately equal-sized groups or whether longer numbers should be divided into subgroups of size three or four. Second, of the three most frequently employed natural groupings of 7-digit numbers found by Thorpe et al. (1965), 3-3-1, 3-4, and 3-2-2, only the 3-4 pattern was presented to subjects in the Severin and Rigby experiment. If these two alternative "natural" groupings of digits had been included in their experiment, they may have proved to be as good as or even better than the 3-4 pattern. Therefore, their conclusion that the optimal method of grouping 7-digit numbers is 3-4 must be considered suspect until the alternative natural groupings of 3-3-1 and 3-2-2 are tested. Third, unbroken sequences of 7-digits were not included in their experiment as a baseline against which to compare the other patterns of grouping. Therefore, it is not clear from their results alone whether the 3-4 pattern of grouping is really superior to an unbroken sequence of 7 digits.

Konz, Brown, Jachindra and Wichlan (1968) conducted a similar study to that of Severin and Rigby. In the Konz et al. experiment, five different patterns of 9-digit numbers were presented: 3-3-3, 3-4-2, 4-5, 2-2-2-2-1, and 9. Hyphens separated the subgroups of digits in each number. Each 9-digit number was presented on a slide for approximately 5.4 seconds before the subject was asked to write the single 9-digit number down on a piece of paper. The 3-3-3 and 3-4-2 patterns had significantly fewer errors than all other patterns and the results for the two patterns did not differ significantly from each other. All four methods of grouping were significantly better than the baseline condition of 9 which had no groupings. In the total of 240 numbers of each pattern presented, the number of errors per pattern was 443 for 3-3-3, 447 for 3-4-2, 514 for 4-5, 541 for 2-2-2-2-1, and 630 for the 9 pattern. In their analysis, Konz et al.

counted each incorrect digit in a number as an error. Therefore, their error data cannot be compared directly to that of Severin and Rigby (1963) who counted the number of 7-digit numbers having one or more errors.

The Konz et al. study avoided two of the limitations of the earlier Severin and Kigby (1963) study. First, Konz et al. included the unbroken sequence of digits as a baseline against which to compare the effectiveness of the various methods of grouping. Second, the set of alternative patterns presented to subjects in the Konz et al. study included the most frequently occurring "natural" grouping: 3-3-3. One limitation of their study is, however, the use of only 9-digit numbers.

Konz et al. also performed an additional experiment on 7-digit telephone numbers, but it is not directly comparable to their 9-digit experiment. In the 7-digit experiment they found no significant differences between the patterns 3-4 and 3-2-2 and several variations on these two basic patterns using emphasis (bold-faced type) for some of the digits.

Heron (1962) reports a partial replication of the Conrad (1960) experiments using 8-digit telephone numbers. In Heron's experiment the 8 digits were presented in one of two ways: serial auditory presentation or simultaneous visual and auditory presentation. Many of the subjects grouped the digits spontaneously during vocal rehearsal. The majority grouped the digits into two groups of size 4. Grouping in 4s during vocal rehearsal significantly increased the number of 8-digit numbers dialled accurately for both auditory and simultaneous auditory and visual presentation. The other patterns of grouping were employed relatively infrequently.

In an extensive investigation of the effect of grouping printed digits for entry on a touch-tone telephone, Klemmer (1968) found that grouping by 3's or 4's was optimal for numbers of different lengths, users of different skill levels, and various orders of presentation. In the first of six experiments, he presented subjects with numbers of 18-21 digits partitioned into uniform groups of 1, 2, 3, 4, 5, 6, 7, or 10 digits. For all subjects the maximum keying speed was for groupings of either 3 or 4 digits. Averaged across all subjects, triplets required the least amount of keying time. There was, however, a high degree of variability and no consistent differences in error rate for different sized groupings. In the second experiment, there were no significant differences among 45 different methods of grouping 7-digit numbers (variability was high probably because of the testing procedure employed). In the third experiment, the best groupings of 7 digits on keying time were 3-4, 4-3, and 3-2-2, the poorest were 1-5-1 and no grouping. Error rates were too low to test for effects of grouping. In the fourth experiment, performance (both error rate and keying time) was better for groupings of 3-3-3 and 3-4-2 than for 5-4 (although not significantly so). In the fifth experiment, subjects performed faster with groupings of 3-3-2-2 and 3-3-4 for 10-digit numbers. The 5-5 grouping was significant slower. In the sixth experiment, two different groupings of 10-digit numbers were tested under conditions of restricted access to the printed telephone numbers (_S_s could look at the printed number as often as they wished but while actually dialling the number was hidden from view). Although subjects consistently keyed in 4 or 5 digits for every look or referral to the stimulus number, they still did significantly better on keying time with a 3-3-2-2 grouping than with a 5-5 grouping. Differences in error rate were not significant. Thus, these six experiments provide additional support for the general superiority in performance of grouping by 3s or 4s for numbers with as many as 18-21 digits. Interestingly, stated preferences for size of grouping in many of these experiments were often for groupings of more than 3 or 4 digits. There was little relationship between preferences and performance.

In another series of experiments on copying printed numbers by entering them on a pushbutton telephone, Klemmer (1969) found that maximum keying speed (the average time for keying each digit) is obtained with groupings of 3's and 4's. In one experiment numbers with 18-21 digits were presented with groupings varying in size from 1 to 10. The average time per digit to key such long numbers was minimized for groupings of size 3 and 4. In another experiment on 7-digit numbers, the 3-4 grouping required significantly less time to key than any of the patterns 2-5, 7, or 1-5-1. Differences in keying speed between the optimum grouping and the ungrouped conditions were usually around 20%. There were no consistent differences in error rate as a function of grouping. Although performance was optimal for groups of 3 or 4 digits, subjects reported a decided preference for groups of 5, 6, or 7 digits.

Copying Tasks

In a study of the factors affecting the speed and accuracy of copying alpha and numeric codes by hand, Conrad and Hull (1967, 1969) found that grouping digits in threes or fours led to significantly fewer copying errors than when the digits were ungrouped for 12-digit numbers. In the Conrad and Hull (1967) experiments, number codes of length 3, 6, 9 and 12 digits were presented to their subjects, and the digits were either grouped in triplets (triplets were separated by a space) or typed in a continuous sequence with no spaces between digits. The codes (numbers) to be copied were typed in a column on the left hand side of the sheet with substantial vertical spacing between successive codes, and subjects copied each code on the right-hand side of the sheet, 2½ inches to the right of the typed numbers on the left. This task is quite similar to that of videotex users who copy a long page number from either a printed directory or an on-line directory by typing in the number on a keypad or keyboard. If anything, the task of videotex users is harder than the present task because users must copy over a much greater distance than 2½ inches, making it more difficult to check the copied number against the original. Each code that was not copied perfectly, that is, all digits correct and in the correct position, was scored as an error. There was no difference between grouped and ungrouped numbers in accuracy of copying for numbers with 3, 6, or 9 digits. For 12-digit codes, however, there were significantly more errors for the ungrouped codes (4.19% incorrect codes) than for the codes with numbers grouped in triplets (2.79% incorrect codes). Their results provide further support for the grouping of digits in triplets in long videotex page numbers. The relatively large number of errors (4.19%) for 12-digit numbers indicates that the seemingly simple task of copying a number is not so easy after all. Moreover, videotex page numbers having more than 12 digits will probably produce even higher error rates than the 4.19% for 12-digit codes.

In a similar study of copying tasks, Cardozo and Leopold (1963) presented by slide projector printed numbers of 3-13 digits and required the subjects to write down each number. The number of errors was essentially zero until numbers contained 6 digits or more after which the number of errors increased rapidly. The error rate was significantly less for grouped than for ungrouped numbers.

Performance on several tasks less closely related to entering long videotex page numbers provides evidence of the general facilitative effect of grouping digits in triplets. Klemmer (1959), for example, reported several experiments on the task of numerical error checking. The task required that subjects compare pairs of numbers to detect any errors, that is, any differences between the two numbers. The number of digits per group was varied systematically from 1 to 10. Accuracy did not change with size of group, but the speed of error checking was highest for triplets and fell off for smaller or larger groups. Compared with grouping by 3's, groups of size 1 were checked an average of 44% slower and groups of size 10 were checked an average of 33% slower. Klemmer and Lockhead (1962) reported error rates of up to 7½ percent for experienced keypunch operators.

The Use of Separators in Pregrouping

If the digits in long videotex page numbers are to be grouped, then several different separators can be used to separate the groups. Klemmer (1968) compared the effects of dashes and blanks as separators for 7-digit numbers in 45 different types of groupings with each number typed on a separate file card. Keying time on a touch-tone telephone was exactly the same for numbers containing blanks as for numbers containing dashes. The number of errors on each was essentially the same. Nor was here any difference in preference: half the subjects preferred dashed and the other half preferred blanks.

Martin et al. (1977) tested three different separators - space, hyphen, and stop (that is, a period) - in 6-digit numbers divided into two groups with three digits each. The 6-digit numbers were displayed on a screen, and the subjects' task was to type out the numbers presented. Results with the space showed fewer errors and faster response times, but the differences were not significant. However, the space was significantly preferred over both the hyphen and the full stop: of the 21 subjects expressing a preference, 19 of them preferred the space. Thus, on the available evidence the use of a space as the separator between groups of digits is to be recommended.

In document page numbers, which utilize a decimal point to separate the page number within the document itself from the index page number of the document, the decimal point can serve as a natural separator in place of the space. No additional separator is required. For example, 52 664.313 and 542.618.

DISCUSSION

At the present time the magnitude or seriousness of the problem of long videotex page numbers for users can only be estimated from the literature on similar problems such as long telephone numbers. Looking up a number in the telephone book and remembering it long enough to dial is quite similar to the task of keying in a videotex page number either from a paper directory or from an on-line directory. The primary difference between these two tasks is the number of digits in the number. Since videotex page numbers are likely to have more than the 7 digits usually found in telephone numbers, the videotex task should be correspondingly more difficult to complete successfully. Severin and Rigby (1963) found that only 57-67% of 7-digit numbers are dialled correctly by university students (the precise percentage depending upon the pattern of grouping employed). For a group of highly trained telephone operators, Conrad and Hille (1957) found that recall for 8, 9, and 10-digit numbers was only 70%, 56%, and 46% completely correct, respectively. Even highly skilled operators make a lot of mistakes. Wickelgren (1964) found 54-67% correct recall when averaged over 6 to 10-digit numbers. Wickelgren (1967) found that 8, 9, and 10-digit numbers were recalled correctly 76%, 70%, and 57% of the time, respectively, for ungrouped numbers. When digits were grouped in triplets (the optimal size of grouping in his experiment), 93%, 87%, and 70% were recalled correctly.

Videotex users may not always try to remember an entire page number long enough to key it in. Instead, they may alternate between memorizing a part of the number and typing it in until the entire page number has been entered. Such a task is in some ways considerably easier than trying to remember the entire number for even a brief period of time. In a systematic investigation of just such a "copying" task, Conrad and Hull (1967) found that for 12-digit numbers 4.2% of the ungrouped and 2.8% of the grouped (triplets) numbers were incorrectly transcribed. Users had only to copy a number that was in the left column into a blank space just 2½ inches to the right. Since videotex users will probably be copying page numbers over distances greater than 2½ inches, the 4.2% error rate for ungrouped numbers and 2.8% rate for grouped numbers probably represent a lower bound to the number of errors that will be found in practice on videotex. Moreover, the error rate should be much higher for the longer numbers typical of videotex. The problem of long numbers is likely to be more serious to the degree that videotex users attempt to remember entire page numbers.

The facilitative effect of grouping is well substantiated by the present analysis of the literature. Grouping, as opposed to no grouping at all, reduces the number of errors and is preferred by almost all users. Grouping in 3's is clearly optimal under most conditions, although grouping in 4's is often almost as good and is even superior under some conditions.

The type of separator employed to form the groups in a number had no effect on performance criteria, but the blank was significantly preferred to other alternatives.

If grouping is employed, than the digits can be grouped either from the left or from the right. For example, the page numbered 12546297 looks like 125 462 97 when grouped from the left but looks like 12 546 297 when grouped from the right. There is no empirical data available pertinent to choosing between the two methods of grouping; however, there are several factors to be considered in choosing between these two methods when designing a videotex page numbering system.

First, when grouping from the left, pages related logically (by the numbering system through the hierarchy) would have exactly the same pattern or grouping of digits except for the last n digits, for example, 125 424 and 125 424 51. This should make it easier for the user to recognize and to remember the same stem. If the pages are grouped from the right, then the patterns of grouping are different and, therefore, more difficult to remember, for example, 12 542 451 and 125 424. Of course, if there is no logical structure among the page numbers, then grouping from the left has no advantage (for recognizing and remembering common stems).

Second, if information providers have a 3-digit number for their section of the tree, then they may wish to retain that triplet and not have it broken up by grouping from the right. For example, if an information provider advertises his videotex number as 925 but some of his pages are numbered 92 511 or 9 251 123, then users may not recognize his pages as easily. But if information providers do not have unique numbers, then grouping from the left is no advantage.

Third, it seems more natural to group starting from the decimal point, as in the ordinary writing of numbers. For example, 12 563 or 141 923. With the decimal point for documents, the decimal point can serve as a natural separator between two groups of 3 digits, for example, 12 864.157.

Fourth, if all page numbers in a directory are lined up with the decimal point in a straight column, then grouping from the right will result in an unbroken pattern of columns of 3-digit strings. For example,

```
   864 192.
    12 543.
 1 862 941.
12 111 861.
   727 444.
```

Except that the rows are of uneven length, the pattern is similar to that found in the white pages of telephone books. Grouping from the left results in broken columns:

```
   542 12
  211 864
    494 1
821 924 2
```

However, if the page numbers are printed from the left as well as grouped from the left, then the column pattern of triplets can be obtained:

```
542 12
211 864
494 112
821 924 2
```

The decimal point can be a problem, however, in trying to line up numbers when grouping from the left:

```
654 946 3
654.911
651 187 243
222 18.887
 65.116
```

However, it is unlikely that individual pages within a document will be referred to extensively in any index (indexing the documents alone is a major problem). Thus, in printed or on-line directories with page numbers left-justified, the column pattern of digits would be obtained. For those occassions in which the decimal must be included in the page number, the page number is likely to occur separate from other page numbers and, therefore, it should be easily read.

These considerations suggest that grouping from the left is probably to be preferred, although there are also advantages to grouping from the right. Unfortunately, there has been no empirical research on this issue. Further research is required to answer this question definitively.

RECOMMENDATIONS

On the basis of the evidence discussed in this report, several recommendations can be made to videotex information providers and others in the videotex information retrieval field:

1. Digits in all videotex page numbers should be grouped in triplets. (Although grouping by 3s was best overall, grouping by 4s was frequently almost as good.)

2. Groups of digits should be separated by a space. (The space was preferred to other separators, but all separators were approximately equal on performance.)

These recommendations apply to the printing of videotex page numbers in paper directories and indexes and in on-line directories and indexes as well as to the display of videotex page numbers on the pages in the database itself (both document and index page numbers).

These recommendations must be qualified to the extent that they are not based directly on empirical investigation of videotex systems. At least three issues require empirical investigation: first, the magnitude of the problem of errors with long page numbers must be determined empirically; second, alternative grouping schemes must be tested in videotex situations; and third, different types of separators between groups must be tested. Notwithstanding the need for empirical research on videotex, these recommendations are based on an extensive, empirically-based literature on very similar problems, such as long telephone numbers.

Two other suggestions can be given. However, they must be considered highly tentative since they are not based on empirical research. Empirical research must be conducted to substantiate them.

1. For document pages using a decimal point to separate the document retrieval digits to the left of the decimal from the internal page number within the document on the right of the decimal, the decimal point can function as a separator in place of the blank space (for example, 725.124 and 693 424.176 242). Since the decimal point is a separator, additional blank spaces between the decimal point and the digits forming the page number are not required.

2. Digits should be grouped in 3s starting from the left (for example, 126 543 and 942 825 12).

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