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Enhancing email text production for users with motor impairments

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Abstract

People with motor impairments who use a switch device to interface with computers have poor access to affordable software for email communication. The MultiMail email package was developed with government support to provide email access solutions for these users and for others with a range of disabilities. In this paper, the development of accessible on-screen keyboards and a word prediction program which facilitates email text production is discussed. Technology solutions were informed by people with disabilities through focus group and survey data. The resulting cross-disability design of MultiMail provides innovative and cost-free solutions to email text production.

Keywords

Accessibility, electronic mail, client centered design

INTRODUCTION

Internet communication can open up a world of opportunities for people with disabilities. An asynchronous communication option such as email provides people with a means of interactive communication that they can regulate to meet their time, health, and energy requirements. For instance, a computer user with a motor impairment can type his/her email message over a longer period of time or complete the message over several sittings. Email messaging does not highlight the person's disability (MacKinnon, 1995) and promotes equality of opportunity. The diverse needs of people with disabilities, however, calls for email software with numerous user options, including interface and text messaging options.

People with severe dexterity and mobility limitations have difficulty interacting with a computer system especially if attendant communicative disabilities rule out speech input. For many of these individuals, computer access is achieved though the use of a switch device. A switch device is an input device that is activated by movement of a part of the body. Reliable movement of the knee, foot, head, finger or mouth activates the switch which is analogous to a single mouse click that the computer system can respond to. For text production, use of a switch device must be accompanied by software that enables the user to produce text with a virtual on-screen scanning keyboard. Typically, each row of letters, numbers or symbols is scanned (highlighted) in sequence. When the row that contains the desired character is highlighted, the user activates his/her switch device, then scanning commences for that row, column by column. When the required character is reached, the switch device is once again activated to select the character.

Scanning is a tedious process and strategies that reduce scanning time and switch activations have attracted considerable research effort over the past 25 years. Keyboard designs based on placing the most frequently used letters in strategic on-screen keyboard positions are well established in the literature (Leshner et al., 1998, Venkatagiri, 1999). However, such keyboard designs have been influenced by calculation of character frequencies appearing in published sources such as books and newspapers. On-line communication, such as email, is a different medium and also requires characters such as @ that do not occur frequently in other contexts.

The aim of this paper is to present multiple keyboard layouts and a word prediction program for switch device users that have been designed in response to consumer input and for particular use in on-line communication. This project is unique in that switch device users have been actively involved in the software design process and on-line sources of text were analysed to derive the character frequencies on which the keyboard designs are based.

This work is part of a larger research and development project aimed at investigating the on-line requirements of users with a disability. The outcomes of this work will be of interest to software designers and rehabilitation engineers tasked with designing or configuring on-screen keyboard systems for improved access for people with significant physical difficulties and theoreticians working on issues of augmentative communication for switch device users.

BACKGROUND

The MultiMail Project

The Australian Federal Government has committed resources to improving on-line access for people with a disability through the Department of Communication, Information Technology and the Arts' AccessAbility program. The Equity Access Research and Development Group at Deakin University received a grant to enhance on-line communication for users with a disability.

The project had two components. The first part was to investigate the on-line requirements of people with disabilities and the second part was to develop an accessible email application informed by these same users. Email software which allows access for computer users with disabilities can be considered to be a 'reasonable accommodation' to on-line access under the Disability Discrimination Act Australia (1992). The Disability Discrimination Act makes discrimination unlawful regarding access to property and services, except where providing non-discriminatory access would involve unjustifiable hardship. Although the Act does not explicitly cover the provision of information systems and services this does not mean that they are exempt as was evident last year when the courts upheld a blind man's right to access the content on the Olympic Web site (QC, 2000).

The rationale and methodology for the first part of the project has already been reported (Keller et al., 2000). People with disabilities and professionals who work with them participated in focus groups that were held in Melbourne, Sydney, and Adelaide. Major themes that emerged from the first phase of the project were:

- Literacy problems are a major obstacle to the use of email. Word prediction, spell check and speech synthesis were identified as important features to aid consumers.
- Complexity needs to be minimised. Suggestions included using clear instructions, intuitive designs and only implementing essential features. Consumers wanted the option of an interface that included only the most basic requirements, for example only providing options to read, send, and print mail.
- A need for contacts. Participants of the focus groups highlighted the need for information and email addresses of electronic interest groups that could send emails, bulletins and newsletters to people who do not have an electronic network of contacts.
- The need for drafts and pro-formas. Feedback indicated that the ability to keep a draft of an email would be an important feature so consumers could save work if they were unable to complete an email message in one sitting. Pro-forma messages were desired by some people.

Research for the Paper

The second part of the project aimed to work with people with disabilities to produce an accessible and usable email client called MultiMail. Participants at focus groups were shown a rudimentary prototype to trigger discussion on the design features and individual requirements, both functional and access, that were considered important for email software. Participants were asked to consider major tasks such as reading and text production. As participants represented people from different disability groups (including switch device users, people with vision impairments, deaf people and those with cognitive disabilities) a diverse range of requirements emerged. Comments from participants were audio-taped and additional notes were made during each session. At the conclusion of the focus group sessions, audio-taped comments and notes were then transcribed and thematically analysed. From the outset the project was driven by the needs of users who were actively involved in making decisions about the scope of the system development. Our aim was to incorporate the requirements and design suggestions of consumers into an email package that could be used by a large number of users with various abilities, including those that use a switch device. The design of the email package was extremely challenging and included the design of scanning keyboards and word prediction which emerged as important requirements. This paper focuses on this part of the overall design process. During the design and development of the software further user input was sought in another focus group and finally during usability testing. For a description of the user-centred design process we used in the project see Keller et al (2001).

SCANNING DESIGN

Background

Email communication, in contrast to World Wide Web use, requires considerable text production. Email is less formal than other forms of paper-based media (Baron, 1998). Turnaround is fast so email messages tend to be more conversational, even telegraphic, although commercial email tends to follow business writing conventions (Gains, 1999). Another difference is that when replying to an email message a sender often responds to points in the other persons email message. This means some of the previous message is mixed with the new message and that text production is mixed with navigation. Switch device users have particular requirements for text production due to physical fatigue and the time-consuming nature of scanning letters, numbers, and symbols for text production (Goossens', 1992). They are also disadvantaged by the lack of switch-activated accessibility options in standard Internet software programs.

For text production switch device users require an on-screen keyboard with scanning. Access to a predicted list of words is also beneficial. Although efficient designs for scanning keyboards (with and without word-prediction) are well established in the literature (Leshner et al., 1998, Venkatagiri, 1999), such keyboard designs have been based on an analysis of formal written texts such as periodicals and literary works. Differences in both the form and production of email communication compared to other written communications meant that existing designs could not be used without some amendment.

Scanning Design

To accommodate the need for an on-screen keyboard, word prediction list, and easy navigation through email messages, a scanning matrix was designed. The scanning matrix contains three basic components; the keyboard, the word prediction list and a navigational block. The general layout is illustrated in Figure 1.

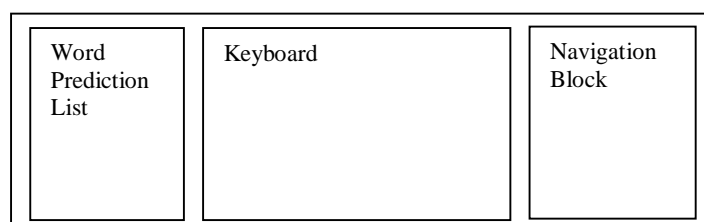


Figure 1: Scanning Matrix

The scanning matrix is positioned underneath the email message. The navigation block allows the text insertion point to be moved within the email message. As letters are selected from the keyboard the word prediction list fills with predicted words. When a word is completed or selected it is inserted into the email message.

The design employs a block scanning method to move between each component of the scanning matrix. That is, first the keyboard layout is scanned as a whole block, followed by the navigational block and then the word prediction list. If a switch activation is detected then the currently scanned block commences row-column scanning.

Each component of the scanning matrix was purposefully designed and incorporates consumer suggestions. The following two sections describe the design rationale and the development of the word prediction component and the keyboard component.

WORD PREDICTION DESIGN AND DEVELOPMENT

Background

Word prediction was identified by participants as an important strategy to assist with both literacy difficulties and text production for switch device users. Word prediction programs are used to assist in the production of text and involve offering the user a list of words after initial letter(s) have been entered. There are a number of word prediction strategies in use with word prediction software. These include spelling, frequency, recency, association and grammar (Klund and Novak, 1995). Most word prediction programs include a built-in dictionary which also contains the frequency with which each word appears in a large body of text. For example, the word *include* might appear 4 times in every thousand words in the selected texts on which the dictionary is based, and so would have a frequency of .004. The texts used to determine words and word frequency are at the heart of the predicted lists.

Ideally, the dictionary used for email word prediction would be based on an analysis of a large body of email messages; however, such a dictionary was not available. Limited project resources prevented us from developing an email-based dictionary so a third party dictionary called CELEX was selected.

Prediction Approach

The CELEX Centre for Lexical Information is a Netherlands based research institute that has compiled three large electronic databases with English, German and Dutch lexical data. The English dictionary we used contains three lexicon types:

- lemma lexicon where only base words are included, for example: jump rather than jumped, jumping, or jumps;
- wordform lexicon where all possible derivations of the base word are also included;
- corpus type lexicon which is essentially an ordered list of all words found in the source word corpus with raw word counts.

The Celex corpus type lexicon was considered the most suitable for the word prediction in MultiMail because it includes word frequencies. One limitation is that the CELEX source corpus is based on an analysis of a total of 284 pre-1987 American English written texts. This means that the language is more complex than we would expect to find in email communication and words such as Internet are not included at all.

Customising the dictionary

Since the CELEX word prediction dictionary is not based on a large analysis of email messages, and because of the previously discussed differences between email communication and formal written text, an important design feature is that the words and frequencies in the CELEX dictionary are customisable by usage.

Conceptually this works as follows. The main dictionary has a data-structure that includes the following fields:

- Entry Type: a flag to indicate if the entry is a single word or an acronym.
- Entry: if the entry type is a word then this field contains the word, if the entry type is an acronym then this field contains the acronym. The actual words the acronym stands for are stored in another data structure.
- Raw Count: at the end of each session the email messages the user has typed are examined. Each time a word is used the raw count for that word is incremented.
- Base Proportion: the frequency of the word from the base CELEX dictionary.
- Dynamic Proportion: this calculation provides the frequency used for the word prediction. It is calculated dynamically at the start of each session and is based on both the base proportion and the raw count.

At the beginning of each session the dynamic proportion for each word is calculated. When the user enters the first letter of a word or acronym a search is made in the main dictionary for words or acronyms beginning with that letter. From this list, a sub-list of n words (where n is the number of words the user has specified to appear in the list) is selected based on the dynamic frequency in the dictionary. With each successive letter entered, the procedure is repeated resulting in better and better predictions. When a word or acronym is selected it is inserted into the email message. At the end of the email session the message is parsed and the raw count for each word is incremented in the main dictionary.

Presentation of List

Although studies show that speed of text generation plateaus at a word list length of about five words (Klund and Novak, 1995) our design allows customisation of word list size of between one and nine words. Presentation of only a few words caters for people with cognitive difficulties, with poor literacy skills, and for people using email and word prediction for the first time. Selection of five to nine words caters for people with good literacy skills or for those who are more familiar with using word prediction. Although the effectiveness of word prediction as a means of increasing text production depends on a number of factors such as key selection time, list search strategy and literacy skills (Koester and Levine, 1996), scanning through a predicted list of words can be an extremely efficient method of text production for switch device users.

Other Word Prediction Considerations

During focus groups, participants were asked about their use of word prediction. Over half of the participants identified the following features as important or very important:

- Ability to add words to the dictionary. However, it was considered important that users were not able to include wrongly spelt words. In response to this requirement new words can only be added through the spell
-

check facility. The user is informed that a word is not in the dictionary and must confirm his/her request to add it.

- Ability to add shortcuts for commonly used phrases.
- Shortcuts appearing as part of the list of words to be selected.

Other issues which were raised included the method used to select the words that appear in the list and the number of words in the list. Consumers recommended a high level of user customisation of these features.

Feedback from focus group participants showed support for words in the selection list to be presented either in frequency or alphabetical order. Research by Lanspa, Wood and Beukelman (1997) also found that people could locate a particular word in a list much more rapidly if words were ordered by word length. Although such gains may not be transferable to word prediction software, especially when short list sizes are used, Lanspa et al's results were encouraging enough for this approach to be added as an option in our design.

In the completed MultiMail software, all words are retrieved from the dictionary based on word frequency but the user can choose to have them presented in word frequency order, word length order or alphabetically.

Cognitive load is another important consideration in using word prediction. Use of word prediction requires text retrieval, visual scanning of options, decision making, and selection. For some people, word prediction is a distraction which interrupts the generation of text (Venkatagiri, 1993, Koester and Levine, 1996). For this reason, word prediction is a MultiMail option rather than a permanent feature.

KEYBOARD DESIGN AND DEVELOPMENT

This section details the design of the virtual on-screen keyboard component of the scanning matrix.

Background

Letters in the English language occur with different frequencies in written text, for example the letter "e" occurs more frequently than the letter "z". Keyboard layouts designed to place the most frequently occurring letters in the most favourable scanning positions are well established in the literature (Leshner et al., 1998, Venkatagiri, 1999) However, early layouts were based only on raw letter and space probabilities, without regard to punctuation marks, numerals and other important keyboard characters such as shift, backspace and carriage return (Leshner et al 1998). Leshner et al (1998) addressed this limitation by designing a layout which elevated more frequently occurring non-letter keyboard characters to more favourable scanning positions. However, the resulting layout is still based on the relative frequencies of characters appearing in essays, stories and letters.

We wanted to determine the relative frequency of characters appearing in on-line communication and to create a keyboard layout optimised for on-line work. For this analysis a large source corpus of on-line communications was required. Ideally such a corpus would have been compiled from the email communications of the group of consumers we were working with but privacy and ethical concerns prevented this.

Developing the source corpus

As an alternative to email messages, public messages posted to Usenet newsgroups were used. Newsgroup messages are a reasonable substitute for email messages in that they are a form of on-line message and are brief and conversational in nature. Newsgroups are essentially on-line discussion forums. The Usenet newsgroup network is divided into seven major groups: ALT, REC, SCI, COMP, SOC, MISC, NEWS. Each group also has a large number of sub groups. The Usenet MISC (miscellaneous) newsgroup available through our Internet Provider contained 168 different news groups with a wide range of topics including activism, writing, disability, kids and jobs.

Using a spreadsheet application, we generated 12 random numbers in the range of 1 to 168. These random numbers were used to select the topic groups from the miscellaneous newsgroup.

Each topic group contained a different number of messages. From the 12 randomly selected topic groups a total of 3489 messages was downloaded and combined into one large file.

Like email messages, newsgroup messages contain header information such as subject, date and parts of a previous message that the user responds to. As we were only interested in the characters that a user would have to generate themselves, a computer program was written to parse the message file and discard all characters which were generated by the system. For example, header information such as Date: Subject: as well as > characters at the beginning of each line of the previously typed message. This stage produced a large file of messages which only contained characters a user would need to type.

Determining raw character frequencies

Another computer program was then written to count the number of times each character occurred in the text. A total of more than 6.2 million characters was processed and the resulting frequencies were ordered from most frequent to least frequent.

The letters and space character occurred in relatively the same frequencies as in the reported literature (the space character is the most frequently occurring character). This is not surprising because we would expect relatively consistent frequencies of letters occurring in English words. However, punctuation, numbers and control characters occurred in different frequencies. The top ten non letter characters found were shift, carriage return, full-stop, dash, comma, zero, one, apostrophe, underscore, forward slash. The @ character also occurred relatively frequently occurring more frequently than the letter j for example. The tilde character occurred almost as frequently as the semi-colon. The characters that occurred least frequently were the left and right curly brackets, the tick character and the tab character. Email messages seem to contain a greater frequency of characters such as carriage returns, dashes, forward slashes, @ signs and tildas. Such differences can be attributed to the informal nature of email and its on-line nature.

Designing the Keyboard

The raw character frequencies provided important background information but did not produce a keyboard design. For this we needed the input of people with disabilities. Additionally, since many positions on a keyboard are equally favourable/unfavourable there is the opportunity to arrange in groups characters that logically belong together such as numbers and punctuation.

User Input

Consumer feedback indicated the desirability of logical positioning of numbers and punctuation. Additionally participants emphasised the importance of easy access to the Backspace key. As the use of this character can not be counted by examining a source corpus participant feedback on its position was vital and resulted in it being placed in a more favourable position that is illustrated in the literature.

As email messages tend to be short and informal it is sometimes difficult to gain a sense of the emotion behind the message. As a result, some conventions have emerged, for example: typing in capitals has come to mean the writer is shouting, and emoticons such as :-) (smile) or <g> (grin) are used to express emotions (Baron, 1998). Initially we thought that it would be desirable to include such emoticons in the layout. However, participants in our project were not interested in using these conventions, perhaps because the 'extra layer' of semantic information that emoticons provide are not regarded as necessary requirements for text production.

Although our principle research effort involved designing an optimised keyboard some consumers requested we include a qwerty keyboard layout and an ABC layout. Although a qwerty keyboard is not as efficient as a frequency based keyboard, people who have acquired a disability through accident or illness may prefer it because of its familiarity. Similarly, some people may need an ABC layout because of familiarity and because of cognitive difficulties which limit the use of other layouts.

Using the relative character frequencies we calculated earlier and expert input of participants we designed several initial keyboards which included shift layouts to access uppercase letters and less frequently occurring characters.

Testing Theoretical Scanning Efficiency

A measure often used to compare the efficiency of various switching arrangements is switch count. Switch count includes both the number of actual switch activations the user makes as well as the number of scan periods it takes to arrive at the required character or word (Leshner et al., 1998). This can be calculated because row column scanning follows a predictable pattern. Rows are scanned from top to bottom and from left to right which means that characters in top rows and left columns take less time to scan. The switch counts of various letter positions in a seven by seven keyboard arrangement are shown in Figure 2. Switch counts remain constant along the diagonals.

2	3	4	5	6	7	8
3	4	5	6	7	8	9
4	5	6	7	8	9	10
5	6	7	8	9	10	11
6	7	8	9	10	11	12
7	8	9	10	11	12	13
8	9	10	11	12	13	14

Figure 2: Switch Counts in a 7x7 layout

To test the theoretical scanning efficiency of our proposed keyboards we created yet another computer program. The program took as input the proposed keyboard layout and a text file containing email communications and it calculated the minimum number of switch counts needed to produce the email communications.

Assuming a switch count is set to one second, then the addition of individual switch counts gave us the theoretical time required to produce the message. This can be seen to represent the best possible time in which someone could produce a message. However, people do make mistakes such as missing the required character and having to re-scan, or selecting an incorrect character thereby requiring a deletion. Despite these shortcomings the program was useful in allowing us to compare the effect of placing different characters in different positions.

Using our program we could compare variations and finally arrived at four distinct keyboards designed for on-line use. A qwerty keyboard modified with letters rather than numbers placed in the first row was designed. This arrangement is described in Venkatagiri (1999) however our design includes additional characters required for on-line work. A simple ABC keyboard with punctuation, numbers and special characters accessible in the word prediction list was also designed. This arrangement allowed us to simplify the keyboard while still having the extra characters available (see Figure 3).

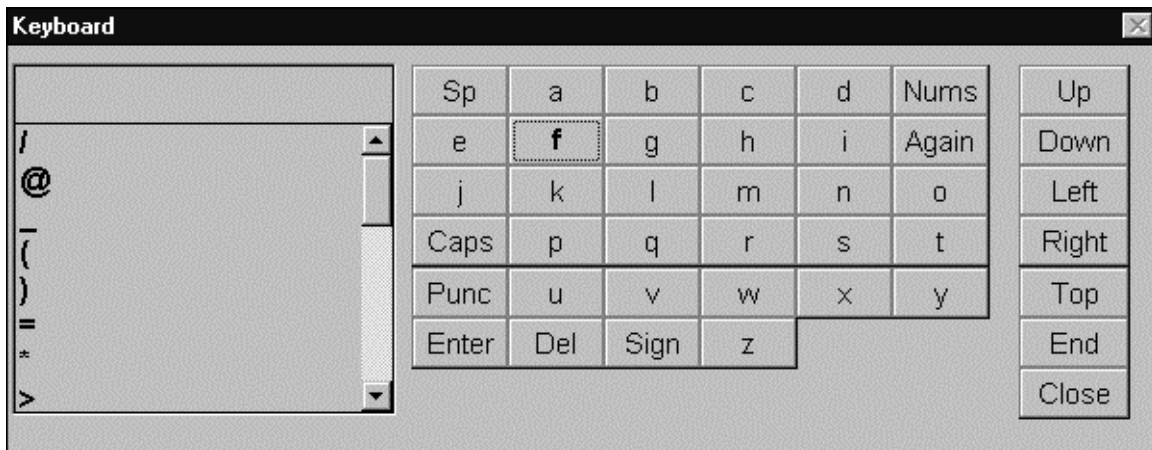


Figure 3: The ABC keyboard shown with signs (other characters) ready for selection in word prediction box.

A keyboard designed to exploit the frequency of characters appearing in on-line communication was also designed and is shown with shift layout in Figure 4. This frequency keyboard, with a logical arrangement of numbers and punctuation, was designed to include all printable characters, in addition to the Space key, Shift key, Backspace (Del) and Enter keys.

Sp	e	o	r	u	c	p
t	a	s	d	m	f	j
n	i	l	w	b	x	q
Sh	h	y	v	0	1	2
Ent	g	k	z	3	4	5
Del	,	:	“	6	7	8
.	/	‘	-	9	()

Figure 4: a. Frequency layout

@	E	O	R	U	C	P
T	A	S	D	M	F	J
N	I	L	W	B	X	Q
_	H	Y	V	!	+	
=	G	K	Z	%	#]
*	<	\$	~	\	[}
?	;	>	&	^	{	`

b. Frequency layout (shift view)

Finally, a simple version of the frequency keyboard was designed (see Figure 5). Like the ABC keyboard, punctuation, numbers and special characters are accessible in the word prediction list. Punctuation and special characters appear in frequency order in the word prediction list while numbers appear from zero to nine.

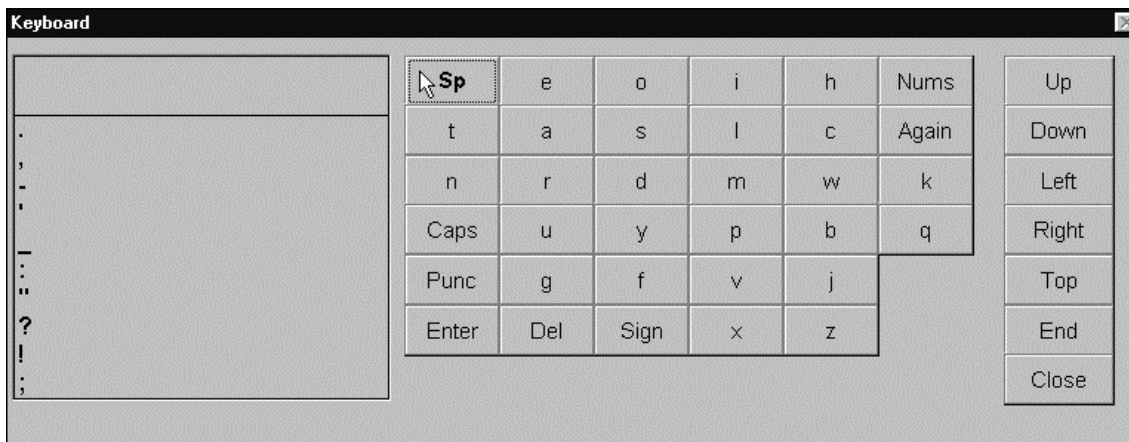


Figure 5: The Simple Frequency keyboard with punctuation symbols ready of selection in the word prediction box.

Comparing The Efficiency Of The Keyboards

After the keyboard designs were finalised the relative efficiency of the four keyboards was computed using the same program we used to determine the number of scan counts per message. Using the same randomly selected messages that were used for determining the character frequencies the four keyboards were compared using the best keyboard as the reference point. The relative performance of the four keyboards are shown in Figure 6.

<i>Keyboard</i>	<i>Relative Frequency</i>
Frequency logical	1
Frequency simple	1.0356
ABC	1.2204
QWERTY	1.3160

Table 1: Relative performance of the four keyboards

Table 1 shows that even using the more efficient modified version, the qwerty keyboard requires more than thirty percent more switch counts than the frequency based keyboard. The ABC keyboard although not as efficient as the frequency models is still better than the qwerty. The frequency simple keyboard is almost as efficient as the frequency logical keyboard but has the advantage of being a very simple design.

CONCLUSIONS AND FURTHER RESEARCH

Email communication differs from other types of written communication in both form and production. This means that established keyboard designs are not particularly well suited to computer users with a severe motor impairment for writing email messages. The three component scanning matrix developed in this project aimed to meet the needs of this group. The navigation block facilitates movement within an email message to allow the user to easily respond to particular points in a received email. The word prediction program, incorporated into the matrix is adaptable; word frequencies are updated by usage and new words and word abbreviations can be added. The keyboard design was informed by an analysis of the frequencies of the characters appearing in Usenet newsgroup messages. However, information provided by experienced switch device users, speech pathologists, and occupational therapists was important in determining the final design.

The MultiMail email project is unique. The designs for the keyboard and word prediction modifications for computer users with motor impairments facilitate on-line work. However, research and development of this type are always going to be challenged by high inter-subject variability, profound learning effects and the time consuming nature of researching scanning behaviour (Koester and Levine, 1994). In addition, the requirement for access via different keyboards to suit various users' needs, compounds the difficulties of research and development in this area.

A study of the characters in email messages rather than other sources is still required for determining character frequency for on-line work. Our use of Newsgroup messages is an advancement on previous sources used for keyboard designs but these messages are not the email communications of switch device users. Analysis of actual email messages and considerable observation of actual scanning behaviour needs to occur. An analysis of the words and word frequencies of email communication is also required to ascertain if a word prediction dictionary based on an on-line source corpus could improve the text production rate of switch device users writing email messages. The implications of mistakes that users make for the efficiency of scanning keyboard layouts when creating email messages also needs investigation.

A limitation of this project was that the effectiveness of the keyboard and word prediction could not be tested together due to time and budget constraints. The effectiveness of the keyboard was measured without considering the effect of a user completing words from the word prediction list. Again to overcome this limitation, many observations of switch device users producing email messages would be required, as well the use of sophisticated models for measuring communication rates and keyboard efficiency.

People with disabilities can be empowered through using the Internet. The asynchronous, text-based nature of email communication is particularly important for people who are challenged in physically accessing a range of people and community activities. MultiMail is an innovative email application designed with the active participation of people with disabilities and it provides a flexible and cost-free solution that can improve equity and access for disadvantaged computer users.

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