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An Evaluation of On-Screen Keyboards for First Time Single Switch Users

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Abstract

This paper presents an evaluation of three designs for on-screen keyboard layouts for use by Single Switch Users (SSUs). SSUs are those users who have a disability which means that they are able to activate a switch into an "on" or "off" position but are not able to locate or position a particular switch. The first keyboard layout design was alphabetically based, the second design was based upon the most frequently occurring letters in the English alphabet and the third design was the standard QWERTY layout found on most keyboards. The research shows that there is no significant difference in words per minute (WPM) for first time users between the three layouts. The researchers believe there was a significant learning effect for users going from one layout to the next and are of the opinion that further research on the layouts with experienced rather than first time users will yield interesting results. The overall aim of the research is to investigate different screen layouts with the goal of finding a screen layout best suited to SSUs.

1 Introduction

Augmentative and Alternate Communication (AAC) refers to any method of communicating that supplements the ordinary methods of speech and hand writing, where these methods are impaired. AAC can be unaided, for example where a person uses gestures or signing to aid communication, or aided, where some equipment such as symbol charts or computers are used. With aided communication, there is a range of technological options available ranging from low technological devices such as photo boards to high technology options such as computers. (Millar & Scott, 1998, pp. 3-5) The main difficulty in the area of AAC is that the rate of communication is between one-half to five WPM (Words Per Minute) (Vanderheiden, 1998), which is no where near the rate of normal conversation where the WPM rates are between 100 and 200. Gunderson (1985) has pointed out that the layout of the letters on the communication device (in the case of this experiment, an on-screen keyboard) and the method used to access it are relevant to the communication rate achieved.

One aspect of AAC is that of Single Switch User (SSU) communication. SSUs are those users who are able to activate a switch into an “on” or “off” position but are not able to locate or position a particular switch. In the field of AAC, there is a wide range of switches available. One way in which switches are classified is into contact and non-contact categories. With a contact switch, a user hits a button, while non-contact switches work by detecting movements of parts of the body. Non-contact switches can detect gross movement such as a flailing arm or very small movements such as an eye blink. (Nisbet & Poon, 1998)

For the purposes of this experiment to find the most efficient on screen keyboard layout, a contact switch (the return key on a keyboard) was used. The authors have also successfully used an eye blink switch based on the electromyrograph (EMG) signals picked up from the facial muscles with the on screen keyboards.

2 Methods of Selection from an On Screen Keyboard

The problem for entering text as a SSU is speed. When an able-bodied user wants to type it is possible to choose a symbol and then select it, so there are two actions available to the user which are locate and select. A single switch user only has one action available. Therefore it is not possible for the SSU to actively locate a letter before selecting it to the same degree as an able-bodied user. A solution to this problem is to have an on-screen keyboard that iterates across the letters and when the user sees the wanted symbol they can use a switch to select that symbol.

In order to select an on-screen symbol there are two options available - direct selection or scanned selection. The choice of selection depends on the disability level and the switch being used. If the user can move their head or any limb in a controlled way, then direct selection may be possible. Direct selection is when the user can make a selection without having to pass through other symbols. If the user is unable to scan through the letters of the alphabet, it is necessary for the application to iterate through the letters allowing the use to select the wanted letter.

In scanned selection the user can choose to accept the current symbol by employing the switch, or not to accept the current symbol by either taking an action or by not taking action for a period of time. The problem with this method is that the SSU must wait until the application locates the correct letter and so there will be periods of inaction, which reduces WPM rates.

Scanned selection can be in one of two forms – linear or grouped. Linear scan selection scans through each available symbol in some order. Grouped scan selection divides the symbols into groups. The user selects a group and then the group is scanned (through linear scanning) and the user then selects the desired symbol. Since the user is selecting from the group and then from within the group, the user needs to make twice as many actions in grouped scan selection as compared to linear scan selection. The positive aspect for the grouped scan selection is that it is faster than the linear scan selection method. As shown in Venkatagiri (2003) the row-column scanning method (used in the layouts in this research) is nearly twice as fast as a linear scanning method.

3 Description of the on-screen keyboard layouts

Three on-screen keyboard layouts were designed and implemented. The first layout organised the letters alphabetically, the second layout ordered the letters according to their frequency in the English language. The third layout organised the letters in accordance with the standard QWERTY keyboard layout.

All three layouts had the same basic structure. There were two arrows: one horizontal arrow and one vertical arrow. The horizontal arrow iterated through the rows of the on-screen keyboard. When the row that contained the desired letter was indicated by the horizontal arrow, the SSU could then activate their switch. This action caused the horizontal arrow to stop on the current row and activated the vertical arrow. The vertical arrow kept iterating through the selected row until the SSU selected a letter by activating the switch when the vertical arrow indicated the correct letter. Once a letter had been selected, both the arrows 'jump' (return) to the first row/first column and then the horizontal arrow began to iterate again. For the purpose of the experiment the iteration occurred at the rate of 1 row or column per second. This rate was customisable so that users could increase their speed as their level of experience increased.

Predictive text was incorporated into the three layouts. When a letter was chosen by the user, the predictive function displayed the most frequently occurring words that begin with that letter. A maximum of five predictive words were displayed on-screen at a time. The predictive words became more refined as the SSU selected more letters. Predictive words were selected in the same way as letters i.e., the SSU stopped the horizontal arrow on the row and then stopped the vertical arrow on the column. After a predictive word was selected a space was provided automatically, so as to increase communication speeds.

3.1 Alphabetical Layout

This layout ordered the letters of the alphabet in alphabetical order – A, B, C etc. The interface had a 7 * 5 layout (Figure 3.1). As well as the 26 letters of the alphabet there were also four basic text editing commands – SPACE, RETURN, CLEAR and DELETE. The SPACE and RETURN commands added a space character and started a new line respectively. The DELETE command acted like the backspace key on a keyboard, deleting the character to the left. The CLEAR command deleted any text typed up to that point.

3.2 "Frequently Occurring" Layout

The "frequently occurring" layout (Figure 3.2) was in essence the same as the Alphabetical layout described in 3.1 except that the alphabet was arranged in a layout based on the most frequently occurring letters in the English language (Appendix 1). The idea behind the most frequently occurring layout is based on Morse's principle. The most frequently occurring letter should be quickest to select. This layout also contained the four text editing options that were available in the Alphabetical layout.

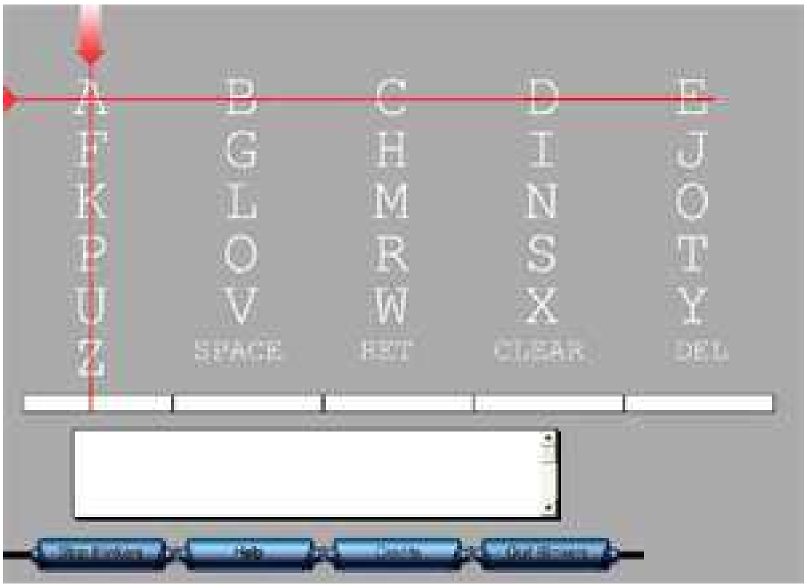


Figure 3.1 – Alphabet Interface

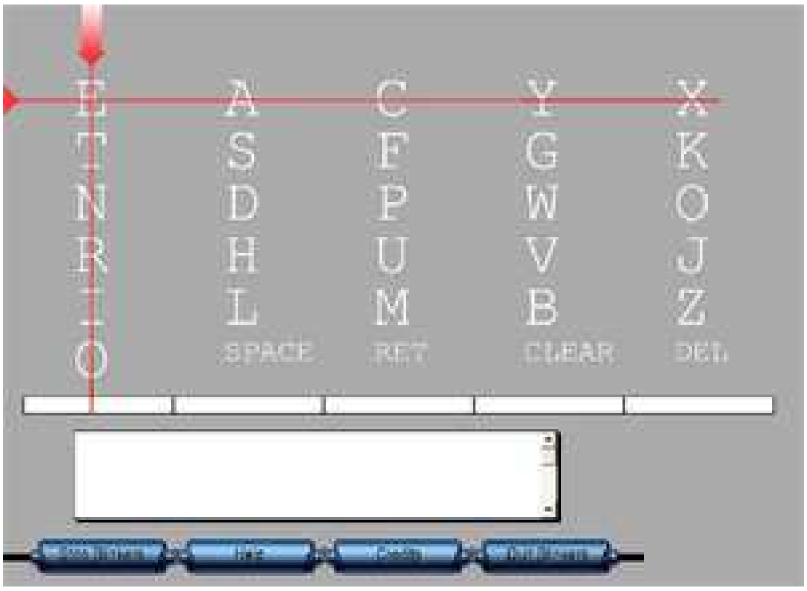


Figure 3.2 – Frequently Occurring Interface

3.3 QWERTY Layout

The QWERTY layout (Figure 3.3) had a different row-column layout to the Alphabetical or Frequently Occurring layouts. This interface had a 4 * 10 design with the formatting options laid out in different locations. The QWERTY layout was slightly different from an ordinary hardware keyboard. There were no numbers present and the positioning of the RETURN and DELETE keys was different. Another difference was that this interface gave the SSU two chances to select a predictive word. This was due to the fact that the field containing the predicted word was spread over two columns.

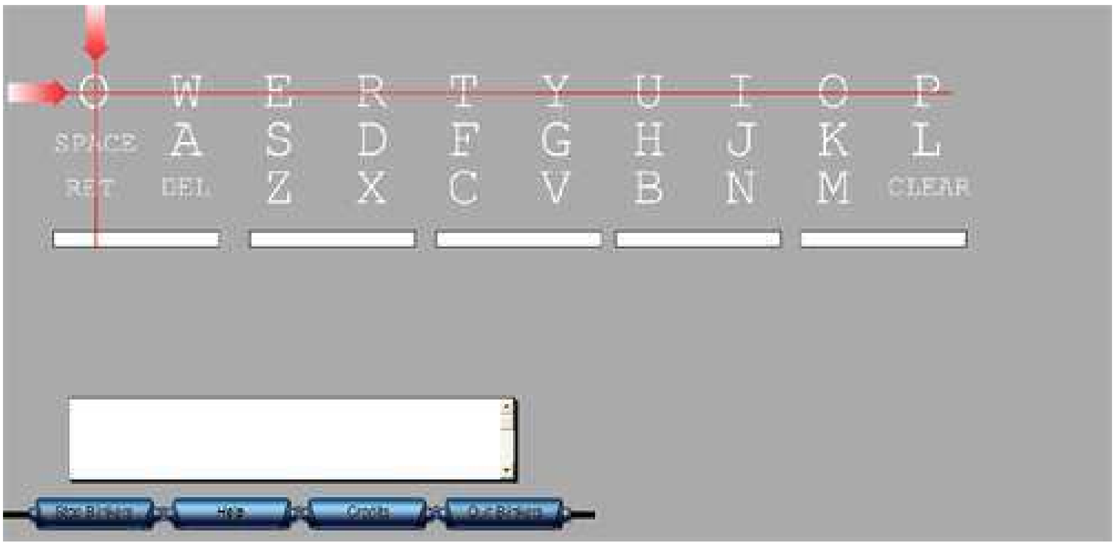


Figure 3.3 – QWERTY Interface

4 Experimental Design

The object of the experiment was to determine if there were significant differences between the efficiency of the three on-screen keyboard layouts described in Section 3. The experimental design was a one-factor analysis of variance (ANOVA). The factor in question was the interface layout with three on-screen keyboard layouts: Alphabetical, Frequently Occurring and QWERTY.

4.1 Subjects

Seven participants were used in this study. Two were female and the remaining five were male. Ages varied from 21 to 56. None of the subjects had any prior experience with using on-screen keyboards. Also, all of the subjects were able-bodied. Each subject was trained in the use of each keyboard prior to testing.

4.2 Procedure

Each of the seven subjects entered 4 sentences using each of the three layouts. The three layouts were all programmed in Macromedia Director. The users used the RETURN key as their switch. The input from the subject appeared on the screen in the field located in the lower half of the screen (Figures 3.1, 3.2, and 3.3).

Once trained in the use of a layout subjects practiced with the interface so that they were comfortable in its use before the testing began. Most subjects said that they felt comfortable with less than one minute of practice. The order of interfaces used by the subjects was varied to minimise the 'learning effect'. The practice period for the first interface was usually longer – lasting up to two minutes.

Each of the three interfaces recorded the data in the same fashion. The time from the first keystroke until the 'RETURN' function was selected (denoting the end of a sentence) was recorded. The number of actions performed was also recorded for further analysis. Time between sentences was not recorded. The arrows scrolled at a rate of 1 second per row or column which was not adjustable by the participants.

The sentences used for this study were those used by James & Reischel (2001) to evaluate speeds of mobile phone text entry. For that study, sentences had been derived from newspapers and general conversation. The sentences are shown in Table 1. Conversational sentences were chosen as the layouts were intended for everyday, conversational use. All words in the sentences were in the predictive text database but the user was not made aware of this prior to the test. In order to judge words per minute scores, the value of 5.98 characters per word was assumed (Dunlop & Crossan 2000). After each subject had completed all three tests they were asked to complete a questionnaire regarding the speed, ease of use and interface preference. The experiment took between 40 minutes and 80 minutes for each subject.

Number.	Sentence	Characters
1	HI JOE HOW ARE YOU WANT TO MEET TONIGHT	39
2	WANT TO GO TO THE MOVIES WITH SUE AND ME	40
3	WE ARE MEETING IN FRONT OF THE THEATRE AT EIGHT	47
4	LET ME KNOW IF WE SHOULD WAIT	29

Table 1 – The four conversational sentences used in the tests.

5 Results

In general the subjects found the act of entering text very tedious and three of the subjects commented on being "exhausted" after completing all three interfaces. Most subjects complained about the amount of focus required to use the interfaces at speed. The frustration at selecting the incorrect letter was usually displayed vocally by all test subjects.

5.1 Performance Results

The mean speeds (in WPM) were 1.6 (standard deviation (s.d.) 0.3), 1.5 (s.d. 0.4) and 1.7 (s.d. 0.4) for the Alphabet, "Frequently occurring" and QWERTY layouts respectively. The ANOVA results showed an experimental F ratio for layout of less than one which implies that there was no significant difference between the three layouts.

5.2 General Observations

No matter what order the subjects tested the interface all (bar one subject) recorded faster WPM rates for the remaining interfaces.

All subjects suggested how the interfaces could be improved. These suggestions varied from using a larger font for the predictive words to reorganising the entire interface.

Most of the subjects continually failed to use the predicted words. It seems that they were focussed on entering the letters. Most subjects (5 of the 7) commented on the positioning of the predictive words being awkward – in scanning the predictive words for the wanted word they would often miss the next letter.

All of the subjects were frustrated by the inability to leave a row without selecting a letter. Subjects 4, 6 and 7 commented that if they were typing there own sentences that they would have been faster.

All subjects agreed that with more practice their times would improve especially with the "Frequently occurring" interface.

5.3 Confounding Factors

The use of the RETURN key as a switch.

This experiment used the RETURN key as a switch. The switch for actual users may range from a signal from a user blink to hitting a large switch with the hand. The difficulty of using a switch by as actual user may reduce WPM rates.

Low number of subjects.

With a greater number of subjects, it is more likely that a significant difference between layouts may have been found.

Prescribed Sentences

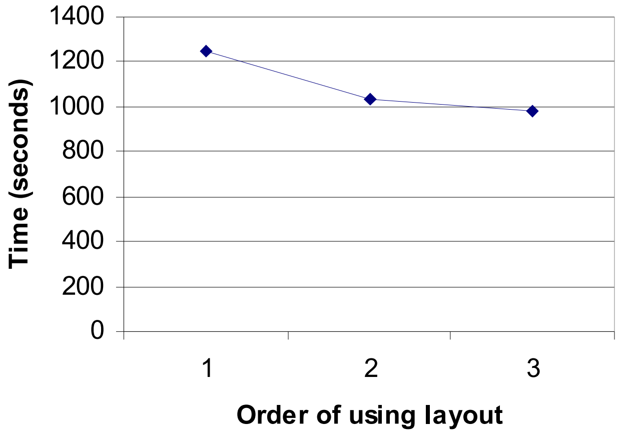
The fact that subjects were using sentences that were not their own meant that the subjects frequently had to move their focus from the interface to the required sentences.

Unrealistic Sentences

Subject 6 noted that in a real world situation a language more similar to the abbreviated text found in text messages might be used. For example using "c u tmrw" as opposed to "see you tomorrow".

Learning Effect

The researchers noticed that there was a learning effect of going from one layout to another, which is illustrated in Graph 1. The points in the graph represent the mean values for all layouts for all participants for those layouts which were completed first, second and third. The graph shows that the layouts which were completed first took an average of 1250 seconds to complete, the layouts which were completed second took an average of 1038 seconds and the layouts which were completed third took an average of 979 seconds.



Graph 1 Mean time to complete the 4 sentences based on order that the layout was taken

6 Comparison with Related Work

A comparison between the work carried out in this study and the work being carried out by Venkatagiri (2003) is shown in Table 2. The Venkatagiri layouts are different to the layouts used in this experiment. The Venkatagiri layouts (43 – key layouts) contain numbers, and some punctuation options – full stop, comma and question mark. None of the Venkatagiri layouts contain a "CLEAR" function.

Venkatagiri's results are simulated and appear much higher than the empirical results discovered in this study. The differences shown in Table 2 could be due to the differences in layout – Venkatagiri's layouts have 13 more symbols to iterate through. Also the layouts in this study have predictive text, which in conjunction with fewer symbols should have shown the layouts proposed in this study to be faster.

It is proposed that the reason for the large gap between the results of this study and the results of Venkatagiri's is the lack of experience in using the layouts for the subjects in this experiment.

	Alphabetical (in WPM)	Frequently occurring (in WPM)	QWERTY (in WPM)
Venkatagiri(2003) – 43 Key Row-Column	2.14	2.53	1.77
This Study – 30 Key Row-Column	1.60	1.54	1.66

Table 2 - Results of this study compared with Venkatairi's 43-key, row-column access layouts

	Alphabetical (in WPM)	Frequently occurring (in WPM)	QWERTY (in WPM)
Venkatagiri(2003) – 43 Key Linear	0.98	1.34	0.77
This Study – 30 Key Row-Column	1.60	1.54	1.66

Table 3 – Venkatairi's 43-key, linear access layouts compared with the results from this study**.**

7 Further Work

An area of further research would be to test the layouts of the interfaces repeatedly with the same subjects to evaluate how experience affects the words per minute rates. This work has already begun and the results for one subject are shown in Table 4 compared with Venkatagiri's results.

	Alphabetical (in WPM)	Frequently occurring (in WPM)	QWERTY (in WPM)
Venkatagiri(2003) – 43 Key Row-Column	2.14	2.53	1.77
Experienced User of this study – 30 Key Row-Column	2.90	3.18	2.92

Table 4 – Experienced user compared with related work.

Smith & Zhai (2001) have used mathematical algorithms to create very productive on-screen keyboards for use with a touch screen. Their "Metropolis" keyboard reported a WPM rate of 43.1 based on Fitts law. Their research incorporates statistical transition probabilities between symbols to improve the keyboard performance. Similar techniques have the potential to improve keyboard layouts for SSUs.

8 Conclusion

This study compared three different interfaces for allowing test input for first time single switch users. The results did not show a significant variance between interfaces. All the results were very close, with the QWERTY interface proving to be the fastest with a rate of 1.7 words per minute. The Alphabet interface was next with 1.6 words per minute and the "Frequently occurring" interface was slowest with a rate of 1.5 words per minute. The researchers felt that further work with experienced users could show a significant difference between the three layouts. The reason for testing experienced users is that the learning effect apparent in this research should be eliminated. In turn the effects of the different layouts should become more apparent.

9 Acknowledgements

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Appendix 1 – English letter frequencies used in “Frequently occurring” interface.

English Letter Frequencies – Per 1000 letters			
Sorted by Letter		Sorted by Frequency	
A	73	E	130
B	9	T	93
C	30	N	78
D	44	R	77
E	130	I	74
F	28	O	74
G	16	A	73
H	35	S	63
I	74	D	44
J	2	H	35
K	3	L	35
L	35	C	30
M	25	F	28
N	78	P	27
O	74	U	27
P	27	M	25
Q	3	Y	19
R	77	G	16
S	63	W	16
T	93	V	13
U	27	B	9
V	13	X	5
W	16	K	3
X	5	Q	3
Y	19	J	2
Z	1	Z	1

Source: http://library.thinkquest.org/28005/flashed/thelab/cryptograms/frequency.shtml