PREDICTING COMMUNICATION RATES: EFFICACY OF A SCANNING MODEL

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PREDICTING COMMUNICATION RATES: EFFICACY OF A SCANNING MODEL

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University of Pittsburgh, 2009

Interaction with the surrounding environment is an essential element of ever day life. For individuals' with severe motor and communicative disabilities, single switch scanning is used as method to control their environment and communicate. Despite being very slow, it is often the only option for individuals who cannot use other interfaces. The alteration of timing parameters and scanning system configurations impacts the communication rate of those using single switch scanning. The ability to select and recommend an efficient configuration for an individual with a disability is essential.

Predictive models could assist in the goal of achieving the best possible match between user and assistive technology device, but consideration of an individual's single switch scanning tendencies has not been included in communication rate prediction models. Modeling software developed as part of this research study utilizes scan settings, switch settings, error tendencies, error correction strategies, and the matrix configuration to calculate and predict a communication rate.

Five participants with disabilities who use single switch scanning were recruited for this study. Participants were asked to transcribe sentences using an on-screen keyboard configured with settings used on their own communication devices. The participant's error types, frequencies, and correction methods were acquired as well as their text entry rate (TER) during sentence transcription. These individual tendencies and system configuration were used as baseline input parameters to a scanning model application that calculated a TER based upon those parameters.

The scanning model was used with the participant’s tendencies and at least three varied system configurations. Participants were asked to transcribe sentences with these three configurations The predicted TERs of the model were compared to the actual TERs observed during sentence transcription for accuracy. Results showed that prediction were 90% accurate on average. Model TER predictions were less than one character per minute different from observed baseline TER for each participant. Average model predictions for configuration scenarios were less than one character per minute different from observed configuration TER.

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Table 1. Acronyms and abbreviations

AAC	Augmentative and Alternative Communication
AT	assistive technology
CP	Cerebral Palsy
IDA	Input Device Agent
RIA	Reach Interface Author
SLP	Speech Language Pathologists
TER	text entry rate
SMS	Scanning Model software
UCP	United Cerebral Palsy
XML	Extensible Markup Language

1.0 INTRODUCTION

Communication is a vital component of everyday life. Wants, needs, and desires must often be conveyed in the most efficient manner for both survival and self-fulfillment. This is especially true for individuals who require caregivers to perform their activities of daily living (1). AAC devices assist individuals with speech disabilities who cannot clearly communicate with others. An estimated two million Americans experience this level of speech disability (2). There are many conditions that can affect the ability to communicate and they can be acquired or congenital. The primary causes are neuromuscular conditions such as cerebral palsy, degenerative diseases such as amyotrophic lateral sclerosis (ALS or Lou Gehrig's disease), traumatic brain injury (TBI), stroke, and high level spinal cord injury (SCI) (3).

Conversational speech occurs at a rate of 150 to 200 words per minute (3, 4). It is also not unusual for an individual to type over one hundred words per minute. Although AAC devices perform a remarkable service, the rate of communication can be less than one word per minute (5). Increasing communication effectiveness, regardless of the AAC user's abilities, is of primary importance. Slow communication rates not only impact the individual with the speech impairment, but their communication partners as well. In a qualitative analysis of AAC users, their employers, and fellow employees, the most commonly mentioned example of the multiple challenges associated with communicating using AAC was increased time needed for communicative exchanges (6). Slow communication rates can also lead to passivity and poor impressions of the person who uses an AAC device by the speaking partner (7).

Text entry rate (TER) has been of interest to several researchers. Many refer to the initial work done by Card, Moran, and Newell (8) who studied touch typing speeds for various keyboards. Isokoski and MacKenzie (9) have examined a combined model of text entry rate predictions. Recent interest has focused on TER for mobile computing devices. Personal digital assistants, cell phones, and tablet computers are some of the devices encompassed by the term "mobile computing." Initial mobile computing research focused on TER using soft keyboards (10, 11). Soft keyboards are keyboards that appear on a computer's display screen. Data is entered by tapping on the screen. These studies used models such as Fitt's Law (12) and the Hick-Hyman Law (13, 14) to determine novice and expert TER using various soft keyboard configurations. More current research has concentrated on mobile phones and methods for predicting and improving their TER (15, 16).

Researchers have also explored alternative text entry methods used by individuals with disabilities. Eye tracking systems have been compared to determine the most efficient in regards to text entry (17). Various user interfaces have also been compared against each other. Hansen, Tørning, Johansen, Itoh and Aoki (18) evaluated the text entry performance of eye tracking, head tracking, and mouse user interfaces. The effects of software design were analyzed with respect to word prediction by Tam, Reid, Naumann and O'Keefe (19) and the Dasher user interface by Ward, Blackwell, and MacKay (20). The aforementioned researchers were all trying to determine and explore methods that can improve communication rates.

1.1 SINGLE SWITCH ROW-COLUMN SCANNING

Single-switch scanning is used by individuals with severe motor and communicative disabilities as a method for entering text and data into AT devices. Most often these are computers or AAC devices. Typically, a row-column matrix of items is displayed on a computer screen or AT device. These items are most often letters, numbers, words, or pictures. A single switch is used to select the target item highlighted in the matrix. As shown in Figure 1, each row of the matrix is sequentially highlighted until the user selects the row containing the target item by activating a switch. The columns of the selected row are then scanned until the target item is highlighted and can be selected by activating the switch a second time.

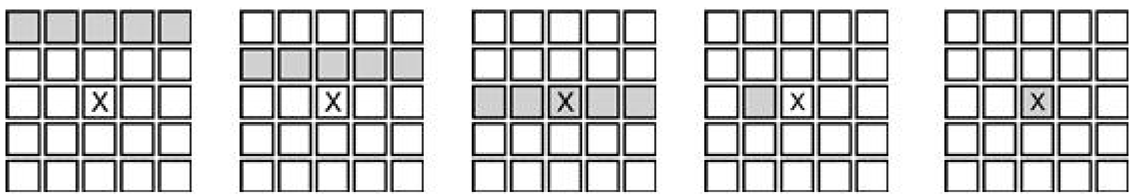

Figure 1 Single-Switch Row-Column Scanning

Although single-switch scanning is very slow, it is often the only alternative for individuals who cannot use other interfaces. Technologies such as eye gaze and speech recognition may be out of reach for individuals with severe spasticity, poor head control, or limited verbal abilities. Direct brain interfaces are still early in the development stage and at this time the most effective versions are rather invasive (21).

Altering timing parameters and scanning matrix configurations can dramatically affect the communication rate of individuals using single switch row-column scanning as their communication method (22).

1.2 CONFIGURATION OPTIONS IN EXISTING SCANNING SYSTEMS

On-screen keyboards and AAC devices offer a wide variety of options for an individual using single switch row-column scanning. The following tables summarize the results of a survey analyzing the adjustable scan settings and user input methods of assistive technology software products that support switch scanning. Twelve of these products are onscreen keyboards that run on the Microsoft Windows platform. Two other Windows products were screen scanners exclusively (CrossScanner and ScanBuddy). Additionally, two products surveyed were augmentative and alternative communication (AAC) devices (Dynavox & Prentke Romich Pathfinder). An Excel spreadsheet (Appendix A) contains the specifications of all products surveyed in regards to controllable parameters, method of input, and the timing units used. The percentages used in the tables below are all relative to the sixteen products surveyed (100% = 16).

Table 2. Scan Settings

Setting	Supported By %	Explanation
Scan Rate	100%	The amount of time an item is available for selection (i.e., highlighted)
Initial Delay	50%	An additional delay added to the first row or column to provide time for the user to recover from a previous switch activation. Different values may be used for rows and columns in some systems.
Loop Count	81%	Determines how many times the system will scan through the columns within a row before resuming between rows
Reverse Scan	19%	The ability to **reverse the direction** of scanning through a row
Stop Scanning	38%	The ability to **stop scanning** a row by selecting an item at the beginning or end of each row
Re-Scan	19%	The ability to **re-scan the row** by selecting an item at the beginning or end of each row

Table 3. Switch Settings

Setting	Supported By %	Explanation
Automatic/Manual Scan Initiation	88%	Determines whether the user must press a switch to initiate scanning, or if scanning is automatic (and continuous). This setting dictates whether two or three switch presses are required to make a selection.
Switch Repeat	50%	Some systems allow a user to hold the switch down to register multiple switch activations.
Repeat Delay	50%	How long the switch must be held down to register the second activation.
Repeat Rate	44%	The length of time between switch activations after the second activation is registered.
Acceptance Delay	69%	The length of time a switch must be activated before an activation is registered.

Most of the products surveyed, especially the more widely used products, have scanning parameters that are adjustable and use seconds as their base units for timing. The user input methods are often slider controls or scroll bars. The vast majority of products supported both automatic and manual scanning. Scan and switch behavior parameters varied greatly in regards to their presence in a product and implementation methods.

1.3 PREVIOUS RESEARCH

Improving the communication rate of individuals who use switch scanning has been explored by several investigators. Adaptive scanning technology attempts to modify scan settings based upon the user's performance. Simpson, Koester, and LoPrestri (23) have found a correlation between a user's switch press time and an appropriate scan rate. This correlation was used by software, the Input Device Agent (IDA), to make a scan rate recommendation based upon the user's performance of switch press tasks monitored by the software. Results showed the communication rate performance for the IDA-selected scan rate was not significantly different than the scan rate chosen by the user.

Researchers have also used selection error data in addition to switch press timing. In early studies, Cronk and Schubert (24) also used selection error data to determine an optimal scan rate. Lesher, Moulton, Higginbotham, and Alsofrom (25) developed a continually adjusting scan rate algorithm based on users' switch response and error rates. This algorithm was used in an experimental study of four different scanning displays.

Ghedira, Pino, and Bourhis (26) have analyzed the log files of their EDITH system (Digital Teleaction Environment for People with Disabilities) to test and develop a method of optimizing scan rates. Their adaptive algorithm was derived from a Model Human Processor (MHP) model of human-computer interaction. They observed successful adaptation for non-disabled and disabled individuals with good control of a single switch.

Determining the optimal settings pertaining to the range of parameters that exist for single switch scanning has also been explored. Abascal, Gardeazabal, and Naray (27) have proposed guidelines to determine settings that maximize an individuals' communication rate. Lesher, Moulton, & Higginbotham (22) performed experiments using various scanning configurations to establish the switch press savings performance for each configuration. Communication rate prediction models have been explored by Damper (28), but his research was not validated with AAC users.

1.4 MOTIVATION

The ability to select and recommend an efficient AAC device and configure it properly for an individual with a disability is essential. Predictive models could assist in the goal of achieving the best possible match between user and device. Prediction of task performance rates through the use of theoretical models allows a researcher to determine the optimal performance rate of the task and the environment that enables the attainment of that rate.

Although the goal of research related to single-switch scanning is to improve the communication skills of disabled individuals, most of the aforementioned research has not included participants with disabilities. Consideration of an individual's single switch scanning tendencies has not been included in communication rate prediction models. The Scanning Model Software (SMS) developed as part of this research utilizes scan settings, switch settings, error tendencies, error correction strategies, and the matrix configuration to calculate and predict a communication rate. This communication or text entry rate (TER) is calculated by using the average error-free selection time of an item in the scanning matrix, the average penalty time for an incorrect selection, a correction, or error, and the associated probabilities of these events occurring. The average selection and penalty times are influenced by the location of an item (character) in the matrix and frequency of use in the English language as well as switch press times. Since the frequency of a character is used in calculating these simulation times, the averages are weighted. This study acquires an individual's switch timing, scan settings, error tendencies, and text entry rate (TER) while performing text entry and switch activation tasks. This baseline data is used as input to the SMS. If TER predicted by the model is accurate under the various scenarios, the SMS can be used as a tool to determine the configuration that achieves the maximum TER rate for a participant based upon their individual tendencies.

2.0 RESEARCH QUESTIONS

2.1 RESEARCH QUESTION 1: SCANNING MODEL ACCURACY

Does the Scanning Model Software (SMS) accurately calculate a participant's Text Entry Rate (TER) within one character per minute using the participant's switch press times, scan settings, error tendencies, and error recovery methods as input parameters?

If the SMS can accurately calculate the TER of a participant using that person's scan settings and error tendencies, when compared to their actual TER rate as calculated by the IDA Sentence test, the SMS accuracy will be validated.

2.2 RESEARCH QUESTION 2: MODEL PREDICTION ACCURACY

Does the SMS accurately predict a participant's TER, under various input configurations that differ from the participants' baseline settings, within one character per minute of the actual TER obtained through the participant's completion of the IDA Sentence tests?

Various input/scan settings can be manipulated within the SMS that will result in scenarios that produce predicted TERs. These predicted TERs will be tested for accuracy by having the test participants perform the IDA Sentence tests using the associated input/scan settings (scenarios). The observed TER will be compared to the SMS's TER prediction.

3.0 INSTRUMENTATION

A laptop personal computer (PC) was used for the study. The laptop functioned as the means for data acquisition and data analysis. The laptop contained software to administer user interface tests, on-screen keyboards for text entry, and a screen activity recorder. It also contained software to assist in data analysis and calculate predicted TER using data acquired from study participants. Laptop hardware consisted of a USB switch interface, a mouse switch interface and a switch.

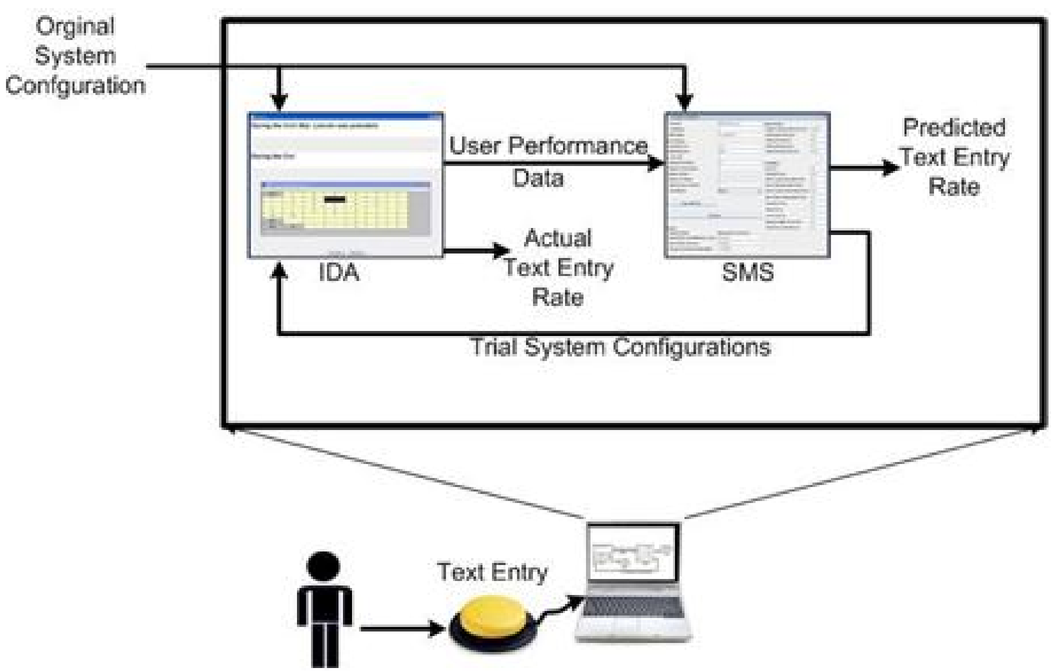

Figure 2 Instrumentation

3.1 COMPASS ACCESS ASSESSMENT SOFTWARE

Compass is assessment software that measures users' skills in various kinds of computer interaction (www.kpronline.com). The software contains eight skills tests, of which two were used in this study: the Switch Test and Sentence Test. The Switch Test (see Figure 3) was used to acquire the participant’s switch-press timing characteristics. The Sentence Test (see Figure 4) evaluated the participant’s ability to transcribe a sentence.

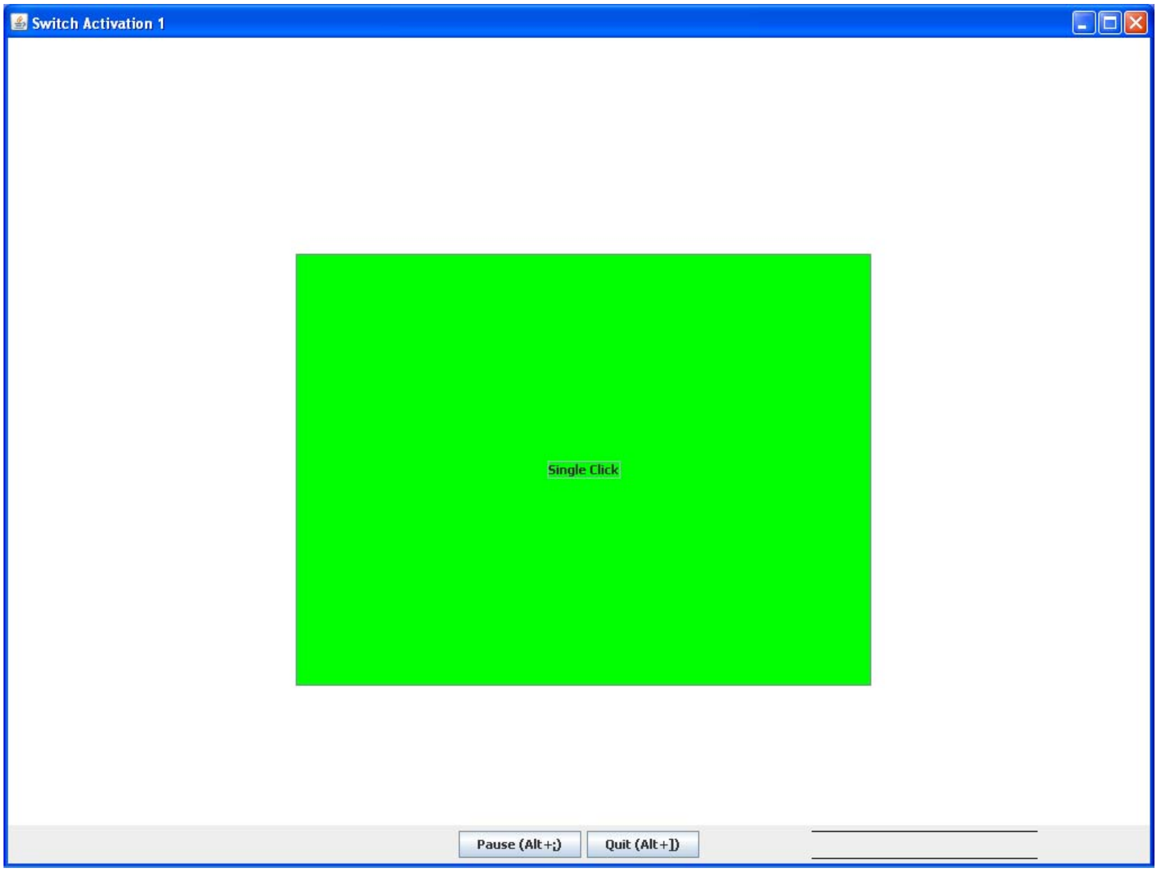

Figure 3 Compass/IDA Switch Test

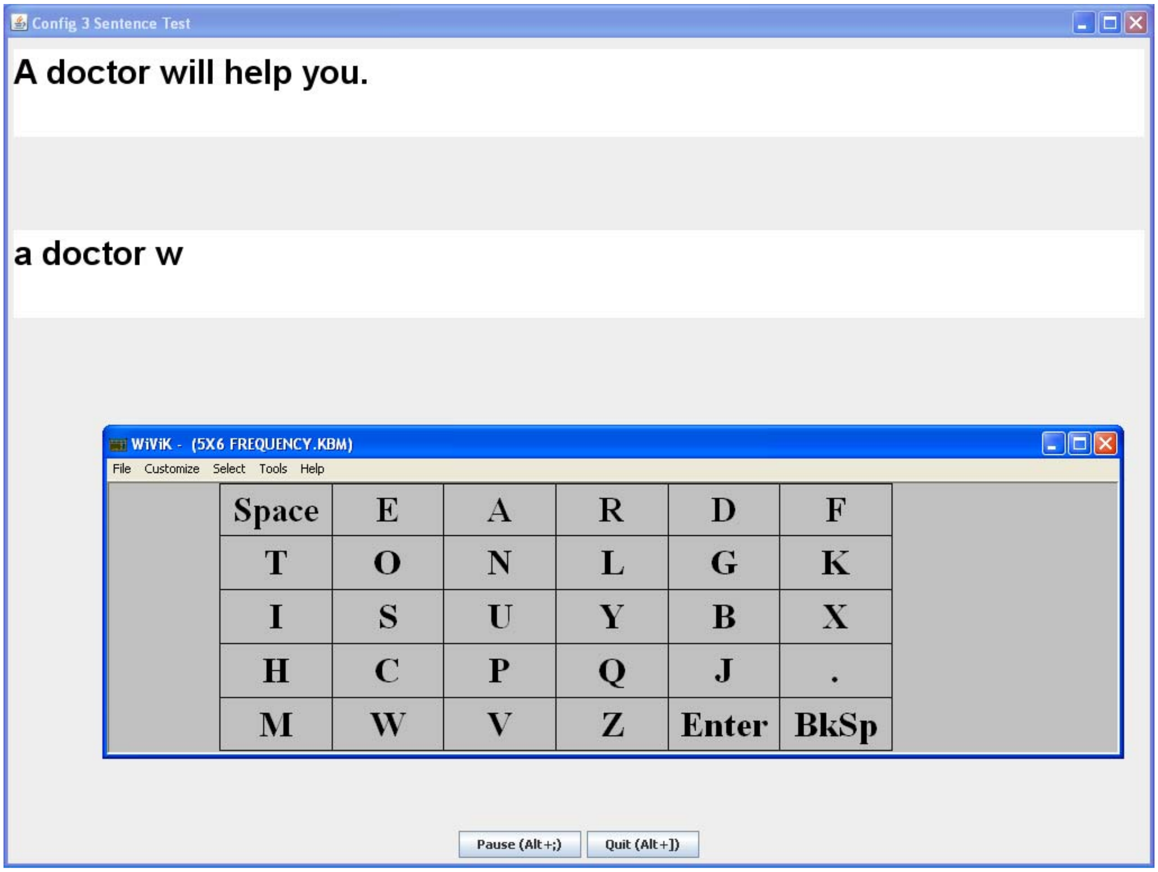

Figure 4 Compass/IDA Sentence Test

3.2 ON-SCREEN KEYBOARDS

The two on-screen keyboards used for the study were the WiViK[1] on-screen keyboard version 3.2 by Bloorview Kids Rehab and the Reach Interface Author (RIA)[2] on-screen keyboard version 5.0 by Applied Human Factors. Each of these products has the ability to create custom on-screen keyboards for single switch scanning. Also, each possesses unique screen

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[1] www.wikik.com

[2] www.ahf-net.com

configuration and setting attributes necessary for this study. The base structure of the custom keyboards contained five rows and six columns. Frequency-based and alphabetic-based layouts were designed for each on-screen keyboard. They were designed to look as similar as possible between products. Figure 5 is a screen shot of the Reach Interface Author frequency-based layout.

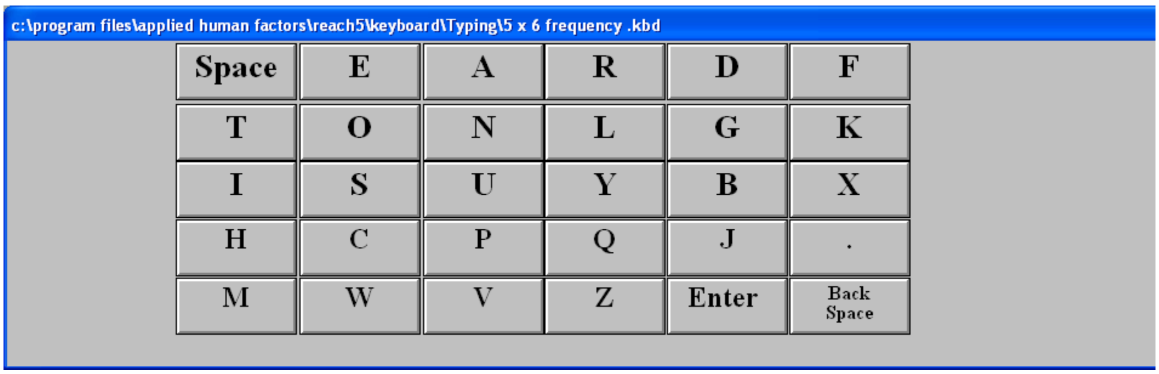

Figure 5. Reach Interface Author

Figure 6 is a screen shot of the WiViK frequency-based layout.

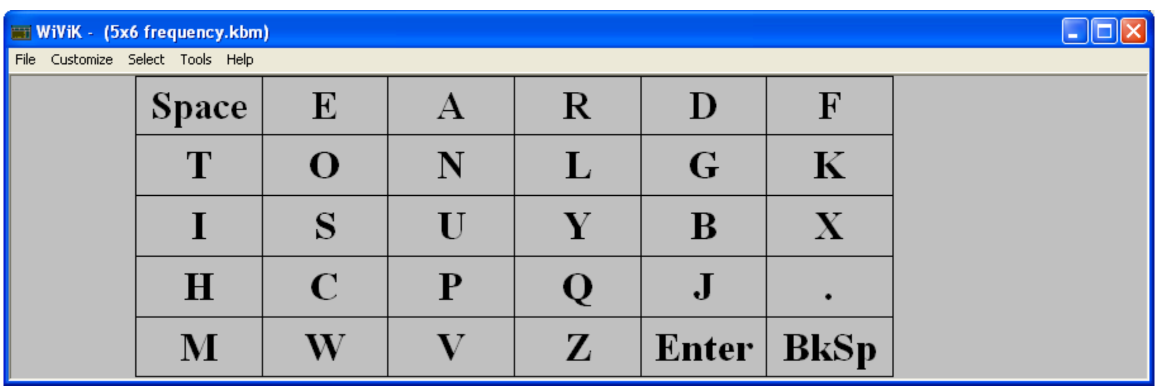

Figure 6. WiViK

3.2.1 Reach Interface Author

Reach Interface Author provides the ability to set the scan rate, initial delay, and the number of times the scan cycle is repeated. It contains two unique features that are used in the study. The first is a setting that allows a reverse scan option prompt to be displayed at the beginning of a scanned row when it is selected. Activating a switch when the prompt is displayed initiates the reversal of the scan direction through the columns of that row. The second is a setting that displays a prompt at the end of a selected row offering the user an option to continue scanning that current row. Activating the switch when this 'Continue' scanning prompt is displayed continues the scanning through that row starting with the first column.

3.2.2 WiViK

The WiViK on-screen keyboard provides the ability to set the scan rate, initial delay, and the number of times the scan cycle is repeated for a selected row. Since WiViK can be configured to scan a selected row for a predetermined count (loop), it was used to implement two scanning keyboards to be used in the study. These keyboards could be used when the loop count for the selected row scan was greater than one. One keyboard contained the baseline 5 X 6 matrix with an additional button in the first column of each row to end scanning of that row when selected. Figure 7 is a screen shot of the WiViK frequency-based layout with a *Stop* button at the beginning of each row. The second keyboard was also the baseline 5 X 6, but the button to stop scanning was in the last column of each row. Figure 8 is a screen shot of the WiViK frequency-based layout with a *Stop* button at the end of each row.

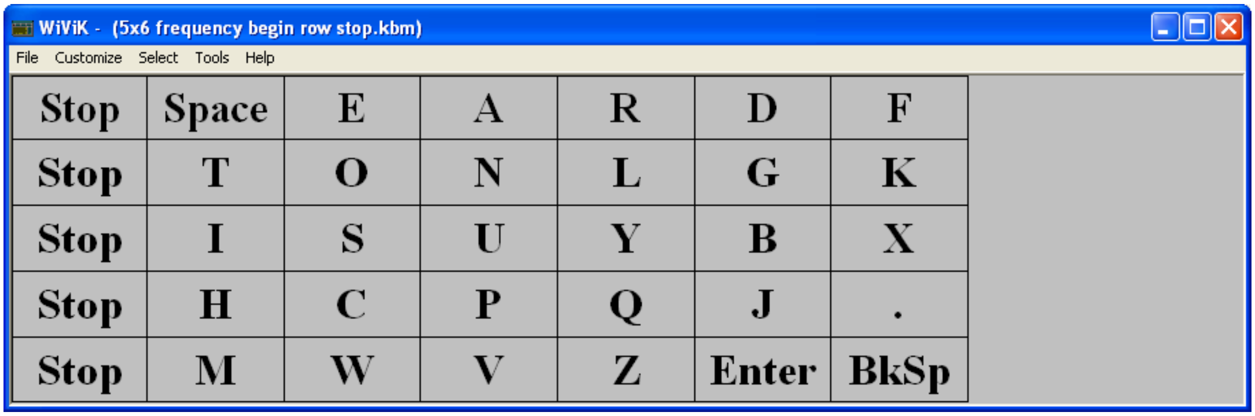

Figure 7 WiViK keyboard with a beginning of row Stop

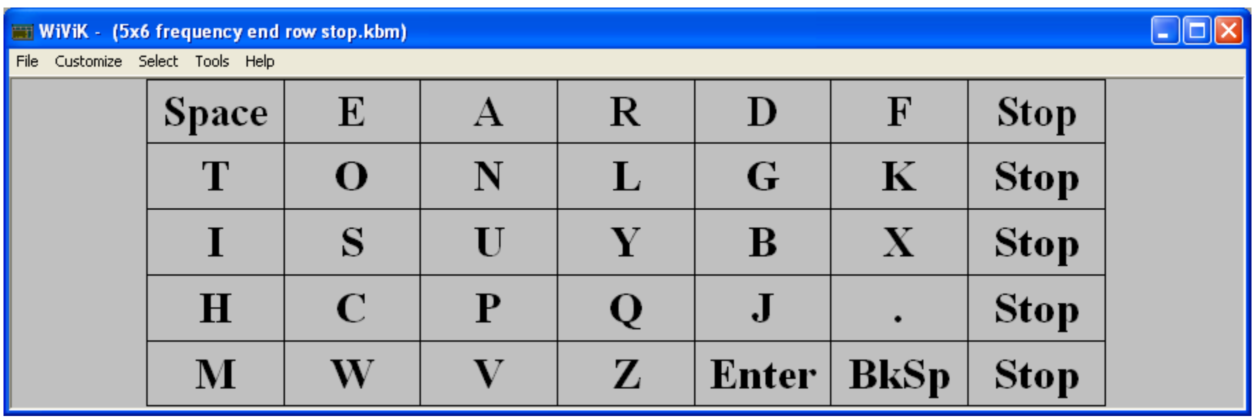

Figure 8. WiViK keyboard with an end of row Stop

3.3 MORAE RECORDER

Each Sentence Test trial was recorded using Morae usability testing software by TechSmith. The recorder was used to capture on-screen activity for later analysis.

3.4 USB SWITCH INTERFACE

The Swifty USB Switch Interface[3] by Origin Instruments was used to accommodate the WiViK on-screen keyboard since it required switch presses as input as opposed to mouse clicks. The Swifty has configurable emulation modes and was set for joystick emulation via its DIP switches. This mode was chosen to reduce inadvertent mouse clicks.

3.5 USB SWITCH ADAPTED MOUSE

The Switch-Adapted optical mouse[4] by Infogrip, Inc. is a standard mouse with two standard 1/8" plugs for switches. It has been adapted so switch activation can be used for left and right mouse clicks. The Switch-Adapted mouse was used for the IDA/Compass Switch Test and Reach Interface Author.

3.6 SWITCHES

Each participant used some type of switch as an interface to the computer to perform scanning and create switch timing data. All participants except one (RW) used their own switch. For RW,

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[3] www.orin.com

[4] www.infogrip.com

a similar button switch was substituted and functioned properly. **Error! Reference source not found.** shows the switches used.

Table 4. Participant switches.

Participant	Switch
RW*	Jelly Bean Button Switch
DS	Jelly Bean Button Switch
GS	Tash Micro Light Switch
DR	Electromyographic (EMG) switch
KM	Jelly Bean Button Switch

* indicates that the switch was supplied by the investigator.

3.7 SCANNING MODEL SOFTWARE

The SMS is a Java-based program designed and developed for this study. SMS utilizes single-switch row-column settings, the scanning matrix configuration, and the participant's scanning tendencies to calculate a TER prediction. Refer to Figure 9 for a screen shot of the application. The participant's switch press times, scan settings, and matrix layout are the System Configuration parameters input to SMS. The User Characteristic input parameters consist of the error types, error frequencies, and error correction methods of the participant. Tables 5, 6, 7, 8 and 9 contain details regarding all SMS parameters.

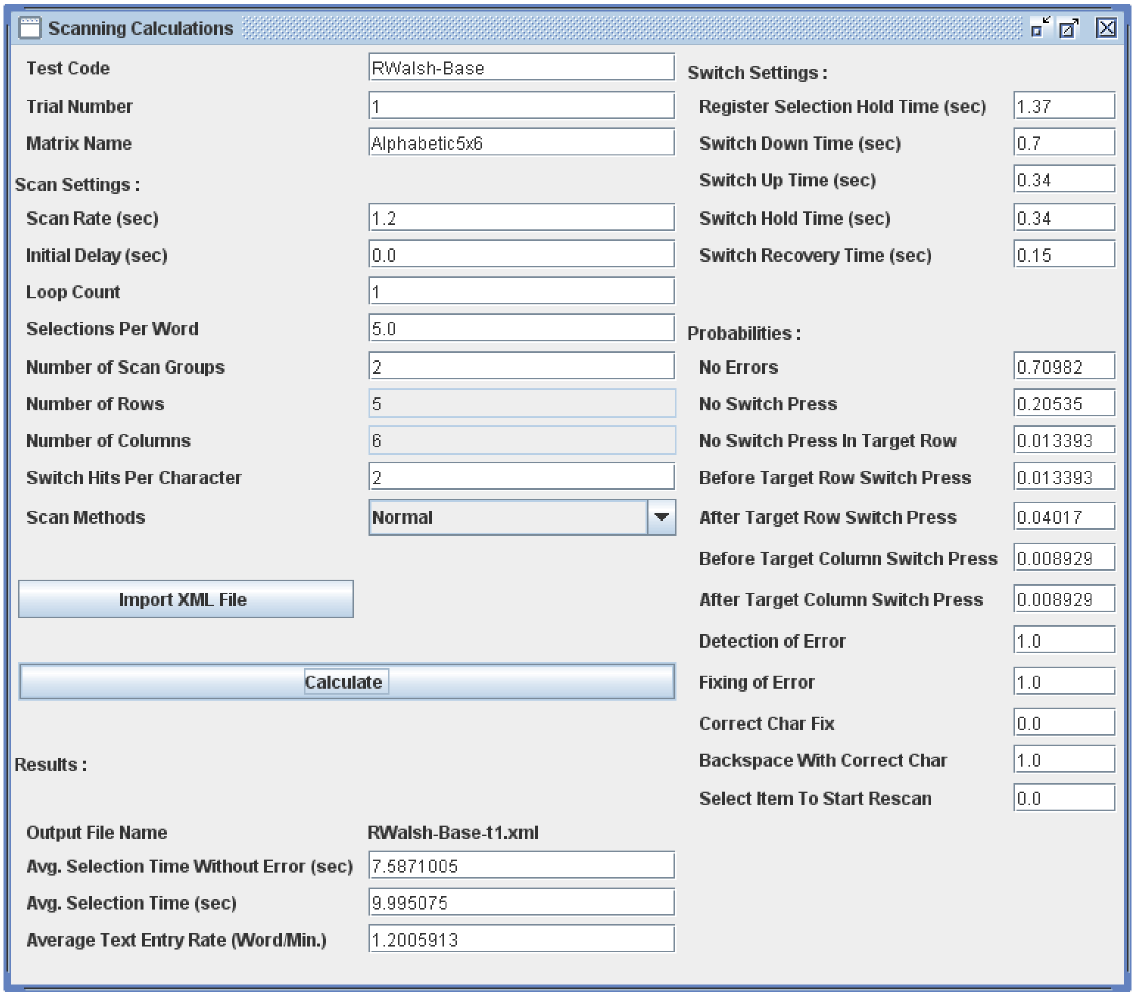


Figure 9. Scanning Model Software (SMS)

Table 5. SMS Scan Settings parameters

Setting	**Units**	**Description**
Scan Rate	seconds	length of time an item is highlighted for selection
Initial Delay	seconds	delay added to first row or column
Loop Count	integer	number of iterations through the columns of a selected row
Selections per word (avg.)	integer	average number of matrix items per word
Number of Scan Groups	integer	number of scan groups (i.e. 2 for row, column)
Number of Rows	integer	number of rows in scanning matrix (access in XML input file)
Number of Columns	integer	number of columns in scanning matrix (access in XML input file)
Switch Hits Per Character	integer	number of switch hits to select a character

The following table contains the selections for the Scan Methods drop-down menu.

Table 6. SMS Scan Methods parameters

Scan Methods	Units	Description
Normal scan	boolean	enables normal formal scan option
Reverse scan	boolean	enables reverse scan option
Optimal scan	boolean	enables optimal reverse scan option
Stop scan – begin row	boolean	enables stop scan item at beginning of rows
Stop scan – end row	boolean	enables stop scan item at end of rows
Continue scan – end row	boolean	enables continue scan item at end of rows

The following table contains the definitions for the scanning matrix. These fields are accessed through XML input file (see details below)..

Table 7. Matrix Configuration parameters

Matrix Element	Units	Description
Item (character)	character	item to be selected in matrix
Row	integer	row location of item
Column	integer	column location of item
Frequency	percent	item's frequency of use in English language

User characteristics consist of switch press times, probabilities of various error types, and the probabilities of error correction methods.

Table 8. SMS Probabilities (User Characteristics Parameters)

Probability Setting	Units	Description
No Errors	percent	probability of making a selection without error
No Switch Press	percent	probability of not pressing switch for a selection when scanning through rows
No Switch Press in Target Row	percent	probability of no switch press when scanning through the columns within a row
Before Target Row Switch Press	percent	probability of a switch press before target row
After Target Row Switch Press	percent	probability of a switch press after target row
Before Target Column	percent	probability of a switch press before target column

Switch Press		
After Target Column Switch Press	percent	probability of a switch press after target column
Detection of Error	percent	probability of detecting an error
Fixing of Error	percent	probability of fixing an error
Correct Char Fix	percent	probability of leaving incorrect char and adding correct
Backspace With Correct Char	percent	probability of deleting incorrect char and adding correct
Select Item to Start Rescan	percent	probability of selecting an incorrect char to exit (not used)

Table 9. SMS Switch Settings Parameters

Switch Press Setting	**Units**	**Description**
Register Selection Hold Time	seconds	amount of time switch must be held down to register a selection (switch press time)
Switch Down Time	seconds	amount of time to activate/press switch
Switch Up Time	seconds	amount of time to release/deactivate switch
Switch Hold Time	seconds	amount of time switch is held down (activated)
Switch Recovery Time	seconds	amount of time elapsed between switch release and next press

Data can be input into the application via an XML (Extensible Markup Language) file. The file is imported by selecting the *Import XML File* button and the associated text boxes are filled with the imported data. Field types in the file include: test tracking, switch press times, error probabilities, error correction probabilities, scan settings, and the scanning matrix (size, keys, location, frequency) as described above. The input filename must have an xml extension (i.e. RMank-Base-t1.xml). Appendix A contains an example input XML file. Data can also be entered directly into the text box fields available in the SMS dialog box (see Figure 9).

The SMS calculations are initiated when the *Calculate* button is selected. At that time the output results file is generated and the *Results* data is displayed in the SMS dialog box. Details regarding other scanning settings and the calculation formulas can be found in Appendix C (31).

The SMS results output consists of an output XML file and three calculated values displayed in the application's dialog box. The output XML file contains a list of all input parameters, all TER calculations, and the switch press times. The output filename is the Test Code field and Trial Number field appended together (i.e. RMank-Base-t1.xml). The name of the output results file is also displayed in the *Results* section of the SMS screen. Appendix D contains an example output XML file. The three calculated results displayed on screen are: the average selection time per character without error in seconds, the average selection time per character with error in seconds, and the average TER in words per minute.

3.8 MORAE MANAGER

Each Sentence Test trial was reviewed using Morae Manager usability testing software by TechSmith. The playback data includes a screen capture of the entire desktop and time stamped events such as keystrokes and system events

4.0 METHODOLOGY

4.1 STUDY DESIGN

This study was a pilot study to determine the effectiveness of the Scanning Model Software (SMS) as a reliable tool for calculating and predicting the text entry rate of individuals who use single switch row-column scanning as their interface method to computers and AT.

4.2 PARTICIPANTS

Participants were recruited by consulting with the staff of the United Cerebral Palsy (UCP) Center of Pittsburgh. Inclusion and exclusion criteria were conveyed to the staff. Possible study participants who met the criteria were asked if they were interested in participating.

4.2.1 Inclusion criteria

Eligible participants were between the ages of 21 and 65. Participants had to be single switch scanners with the cognitive ability to transcribe sentences. Participants also had to possess the visual acuity to see a computer with the screen resolution set to 1024x768 pixels.

4.2.2 Exclusion criteria

Participants who did not have the cognitive ability to transcribe sentences were excluded from this study.

4.2.3 Participants

Five individuals participated in this study. The primary diagnosis for all five participants was cerebral palsy. Each participant used a wheelchair for mobility and an AAC device to communicate. All five accessed their AAC device using single-switch scanning.

4.3 PROTOCOL

4.3.1 Setup

The test environment was set up prior to the arrival of the participant. All required applications were started and initialized where necessary. Data folders were created for storage of the Morae recordings and Compass/IDA results. Detailed instructions for setup are provided in Appendix E.

4.3.2 Informed Consent

The consent form was presented to each participant when they arrived. The form and the specific nature of the study were explained. The consent form is provided in Appendix F.

4.3.3 Questionnaire

Each participant was asked to fill out the preliminary questionnaire in Appendix G. This information was acquired to assess the impact of independent variables such as scanning usage and to identify potential confounding factors. It also allowed acquisition of the single-switch row-column scanning settings used by the participant for their AAC device. These settings were used in the determination of initial scan settings for the baseline Sentence Tests in Compass/IDA.

4.3.4 Positioning

Each participant was positioned in front of the data acquisition computer. Their ability to see the screen was assessed. All participants used an AAC device mounted to their wheelchair that required removal for computer screen visibility. The height and distance of the computer was then altered for optimal visibility.

4.3.5 Practice

Each participant had the option of practicing both the Sentence Test and the Switch Test. The Compass/IDA software contains a practice mode that allowed each participant to try each configuration before data was recorded.

4.3.6 Breaks

A short beak occurred between trials to save the Morae recording and configure the system for the next trial. The participant was asked if a longer break was necessary at this time.

4.3.7 Data Collection

The participant's System Configuration and User Characteristic data were acquired for on-screen keyboard setup to be used in the IDA/Compass Sentence Test and as input to the SMS. The following flow chart illustrates the data collection protocol.

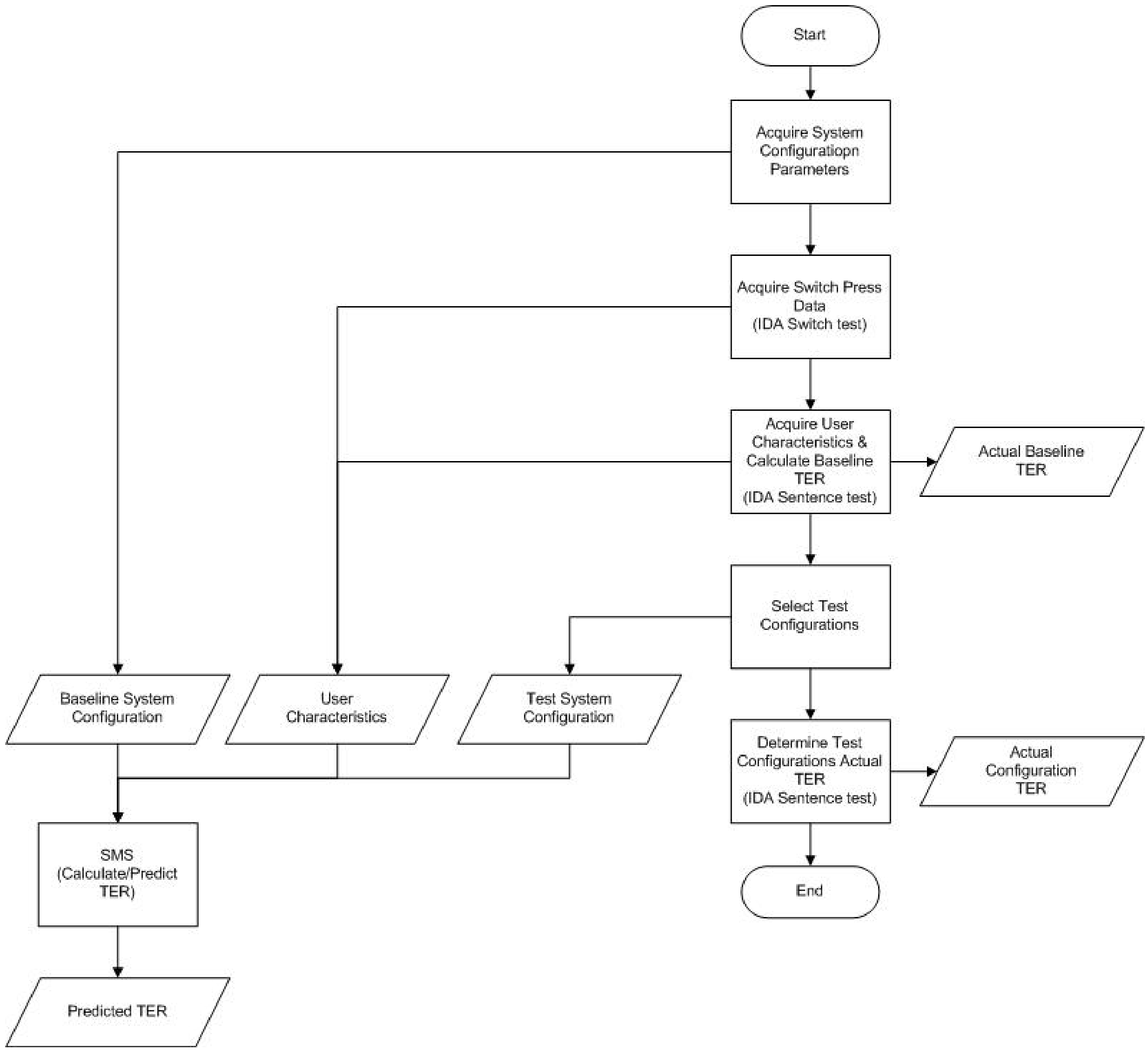


Figure 10. Data collection flow chart

4.3.7.1 Acquire System Configuration Parameters

The System Configuration parameters such as *scan rate*, *initial delay*, matrix layout, and *loop count* used for the on-screen keyboard in the baseline IDA/Compass Sentence Test and as input parameters to SMS were determined by examination of the participants' current AAC device scan settings. The recommended scan rate from the results of the IDA/Compass Switch test was also taken into consideration (see next section). Based upon that information, a scan rate was selected to approximate their everyday settings relative to their switch press capabilities.

The following table contains the baseline configurations used by each participant.

Table 10. Baseline configurations

Participant	Matrix	Scan Rate (sec)	Init Delay (sec)	Loop Count	Scan Method	Keyboard (WiVik or RIA)
RW	Alpha	1.2	0	1	Normal	RIA
DS	Alpha	1.4	0	1	Normal	RIA
GS	Alpha	1.5	0	1	Normal	RIA
DR	Alpha	1.0	0	1	Normal	RIA
KM	Freq	0.9	0	1	Normal	RIA

4.3.7.2 Acquire Switch Press Times

Data from the Switch Test was used as input to the SMS. The specific timing data acquired was the single switch-press time, hold time, up time, down time, and recovery time. The Switch test results also include a recommended scan rate based upon the .65 rule (23). This recommended scan rate and the current scan rate of the study participant's communication device were taken into consideration when determining the initial scan rate for the first trials of the Sentence Test. If the IDA/Compass recommended and participant's own scan rate were the same or within roughly 0.20 seconds, the participant's current rate was used. In the case of a more significant difference, the details of the Switch test were examined for extreme switch press times or other indications of inaccurate results. When the test results appeared reliable and a significant difference occurred, which was the situation for one participant, an average of the recommended and current scan rate was used. The Compass/IDA software saved the acquired switch data to an output file automatically.

Table 11 details the mapping of the switch settings.

Table 11. Switch Press Settings

IDA Switch Test Results	SMS Input Parameters
Press Time	Switch Press Down Time
(Release Time/2)	Switch Press Hold Time
(Release Time/2)	Switch Press Up Time
(Click Interval - Release Time)	Switch Press Recovery Time
Total Time	Register Selection Hold Time

4.3.7.3 Acquire User Characteristics and Determine Actual Baseline TER

The Sentence Test evaluated the participant's ability to transcribe a sentence and determined the participant's actual baseline TER. This test was also used to acquire user characteristics. These included the number of participant errors, the type of error correction methods used, and the frequency of these errors. The first Sentence Test trials established the baseline results used as input to the SMS. The Morae Recorder was started prior to the start of each Sentence Test session and stopped when the test session had been completed. The Compass/IDA software saved the acquired transcription data to an output file automatically. The data was also entered in an Excel spreadsheet.

Study participants were instructed to transcribe 2 sentences as efficiently and accurately as possible. Participants were also asked to correct all errors. A target sentence was presented in a window with a text entry box below it. The participant used the on-screen keyboard Reach Interface Author (RIA) to select characters via single-switch row-column scanning. Once the sentence had been copied and punctuation selected, the “Enter” key was selected to end the trial and present the next sentence. The presented sentences included characters in accordance with their frequency of occurrence in standard English text as per MacKenzie and Soukoreff (29). The sentences were between 22 and 40 characters long.

A 5 x 6 matrix was used to be consistent with the matrixes used in IDA/Compass. Character/item positions in the matrix were determined by alphabetical order or frequency of use in the English language (30). Each element of the matrix also contained a data field representing frequency of use in the English language.

TER and error tendencies were acquired by examining the results of the baseline Sentence Test trials (See Figure 11). Each Sentence Test trial was reviewed using Morae Manager usability testing software by TechSmith. The Manager was used to view and analyze the Morae recordings. The playback data includes a screen capture of the entire desktop and time stamped events such as keystrokes and system events. The recordings were analyzed to characterize the participant’s errors as they occur during a scanning session. The tracked errors were a) before target row selection, b) after target row selection c) before target column selection, d) after target column selection, e) no target selection, and f) no column selection in target row. The probabilities of these errors were input to the SMS.

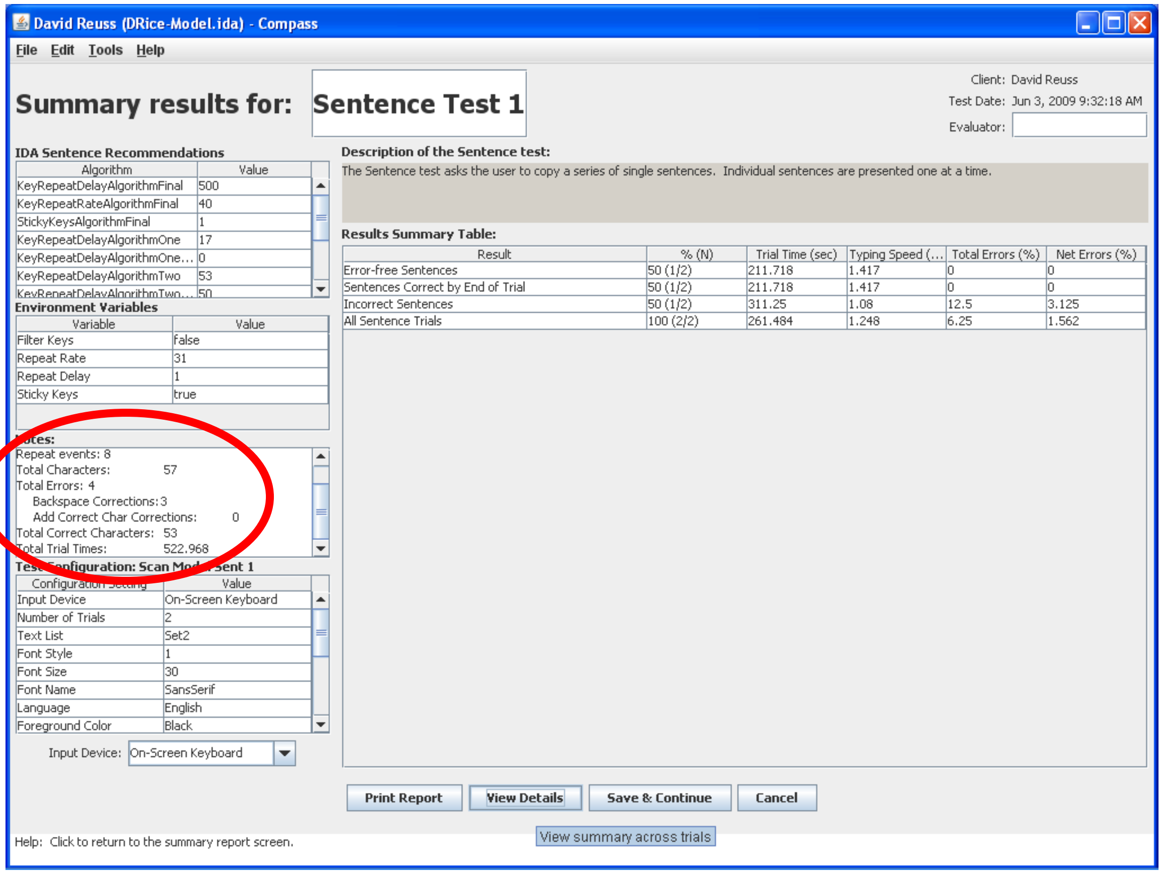


Figure 11. IDA/Compass Sentence Test

TER was calculated by dividing the number of correctly transcribed characters by the total trial time (seconds) and converting the result to characters per minute.

TER = (correct characters / total trial time) * (60 seconds / 1 minute)

TER = (correct characters / total trial time) * (60)

The total trial time was adjusted in certain circumstances to obtain an accurate TER. A bug with the on-screen keyboard, start delays by the study participant, and various interruptions added time to the trial length. The duration of these events were subtracted from the total trial time. First, the Reach Interface Author on-screen keyboard contained an ephemeral bug that would cause scanning to stop until the switch was activated again. When this bug occurred, the switch activated, and the scan cycle completed; the timestamps were noted. The duration of the wait period and scan cycle was subtracted from overall Sentence Test trial time. Some study participants occasionally delayed the start of sentence transcription which skewed their TER. In these cases, the start time of the Sentence Test was noted (the initial display of the sentence to be transcribed) and the timestamp of the scan cycle in which the first attempt at transcription occurred. The time period between test start and scan cycle start were subtracted from overall Sentence Test trial time. Other adjustments related to lost focus on the keyboard and unintended interruptions during Sentence Test transcription.

The error tendencies were entered into SMS as probabilities of the error occurring during a selection attempt. The probabilities were determined by the following formulas:

Total Selection Events = (correct characters + number of errors)

Error Probability = (Error Type /Total Selection Events)

SMS input parameters consist of seven error probabilities and the probability of an error-free selection. Table 5 in Section 3.7 describes the User Characteristic parameters in more detail.

Error correction parameters reflect the probabilities of detecting, fixing, and the method of correcting an error. Since participants were instructed to fix all errors, the *Fixing of Error* probability was set to 1.0 for all trials. The *Detection of Error* probability was calculated by examining the baseline Sentence Test results. The number of errors actually corrected was divided by the total numbers of errors. The *Correct Char Fix* and *Backspace With Correct Char* probabilities were determined by dividing the number of specific error type correction by the number of actual corrections. Section 3.7 describes the User Characteristic parameters in more detail.

4.3.7.4 Calculate Baseline TER using SMS

A baseline TER is calculated by SMS. The previous sections have detailed the acquisition of both System Configuration and User Characteristic data required by SMS to calculate TERs. In addition to those parameters, SMS uses a few more system parameters as input.

The *Selections Per Word* and *Number of Scan Groups* were held constant at five and two respectively for all modeling simulations. The two scan groups were row and column. Five selections/characters per word was used to calculate text entry rate in words per minute. The *Scan Method* field contains scanning options related to the matrix functionality and layout. The options consist of *Normal, Reverse, Stop-End of Row, Stop-Start of Row, End of Row-Continue,* and *Optimal*. Appendix B contains details for the Scan Method setting. The *Normal* option was used for all baseline calculations since every participant used normal forward scanning on their communication device.

Each baseline configuration for the participants was entered as input to SMS using XML files. The resulting text entry rate predictions were output to an XML file. Details are described in section 3.7. The TER was entered into an Excel spreadsheet in addition to being automatically saved to a file by SMS.

4.3.7.5 Select Test Configurations

Several test configuration scenarios were chosen for each participant. Each participant had at least three configuration scenarios. Two participants (RW and GS) had four scenarios as time allowed for additional testing. The configurations were determined by examining the test results and Morae recording to ascertain configurations most likely to impact the participants TER based upon their type, frequency, and correction methods for errors.

The following parameters were modified/enabled to augment the scanning configuration:

1. Scan Rate – could be modified when very few or an extreme amount of errors occur
2. Initial Delay – could be modified when many scanning errors occur when target is in the first row or column of the matrix
3. Loop Count – could be modified if the targeted column in a row is often missed
4. Matrix layout (frequency vs. alphabetic) – could be modified when targets are missed due to a lack of letter location awareness or to acquire improved TER because of letter position.
5. Abort Scan Methods
    a) End of row Stop scanning option – Used with loop count > 1 and wrong row selected often.
    b) Beginning of row Stop scanning option– Used with loop count > 1 and wrong row selected often.
    c) End of row Continue scanning option– Used with loop count = 1 and missed column often.
6. Reverse scan through columns in a row

The following tables contain the configuration scenarios for each participant.

Table 12. RW system configurations

Configuration	Matrix	Scan Rate (sec)	Init Delay (sec)	Loop Count	Scan Method	Keyboard (WiViK or RIA)
1	Alpha	1.25	0	5	Stop-End	WiVik
2	Freq	1.2	0	1	Normal	RIA
3	Alpha	1.2	0.8	1	Normal	RIA
4	Freq	1.2	0.8	1	Normal	RIA

Table 13. DS system configurations

Configuration	Matrix	Scan Rate (sec)	Init Delay (sec)	Loop Count	Scan Method	Keyboard (WiViK or RIA)
1	Freq	1.4	0	1	Normal	RIA
2	Alpha	1.4	0.8	1	Normal	RIA
3	Alpha	1.5	0	1	Stop-End	WiVik

Table 14. GS system configurations

Configuration	Matrix	Scan Rate (sec)	Init Delay (sec)	Loop Count	Scan Method	Keyboard (WiViK or RIA)
1	Freq	1.5	0	1	Normal	RIA
2	Freq	1.0	0	1	Normal	RIA
3	Freq	1.0	0.5	1	Normal	RIA
4	Alpha	1.0	0	1	Normal	RIA

Table 15. DR system configurations

Configuration	Matrix	Scan Rate (sec)	Init Delay (sec)	Loop Count	Scan Method	Keyboard (WiViK or RIA)
1	Freq	1.0	0	1	Normal	RIA
2	Freq	1.0	0.5	1	Normal	RIA
3	Freq	0.8	0	1	Normal	RIA

Table 16. KM system configurations

Configuration	Matrix	Scan Rate (sec)	Init Delay (sec)	Loop Count	Scan Method	Keyboard (WiViK or RIA)
1	Alpha	1.2	0	1	Normal	RIA
2	Freq	1.2	0	1	Normal	RIA
3	Freq	1.2	0.3	1	Normal	RIA

4.3.7.6 Calculate Predicted Configuration TERs using SMS

Each configuration scenario for the participants was entered as input to SMS using XML files. The resulting text entry rate predictions were output to an XML file. Details are described in section 3.7. The TER was entered into an Excel spreadsheet in addition to being automatically saved to a file by SMS.

4.3.7.7 Determine Test Configurations Actual TER

Each configuration scenario for the participants was implemented by modifying the configuration settings and the matrix layout of the on-screen keyboards. These configurations were used to perform an additional IDA/Compass Sentence Test under those conditions. The resulting data was entered into an Excel spreadsheet in addition to being automatically saved to a file by IDA/Compass.

5.0 DATA

5.1 DEPENDENT VARIABLES

TER is the total number of characters or words that can be transcribed in a fixed period of time. The IDA/Compass TER was calculated by dividing the number of correctly transcribed characters by the total trial time (seconds) and converting the result to characters per minute.

$$TER = (\text{correct characters} / \text{total trial time}) * (60 \text{ seconds} / 1 \text{ minute})$$

The SMS TER was calculated by using the average time per error-free selection and the average penalty times per error type. The probability of an error-free or a specific error type was multiplied by the respective selection or penalty time. (31).

5.2 ERRORS

5.2.1 Confounders

Confounding variables include the cognitive level, switch activation, nature of disability, language skills, and fatigue of the participant. Due to the diverse nature of the participants and the dearth of single switch scanners, each participant's data was analyzed on its own.

The Reach Interface Author on-screen keyboard contained a software bug that caused scanning to occasionally stop at the first row and column of the scanning matrix. This bug was completely random. Scanning was re-initiated by a switch activation. Analysis of the Morae recording for each IDA/Compass Sentence Test trial allowed for acquisition and subsequent removal of the delay for a more accurate sentence transcription time.

5.2.2 Measurement

The IDA/Compass Sentence Test trials begin timing upon display of the sentence to be transcribed. All participants delayed transcription (initial matrix selection) a widely varying amount of time until they read and processed the sentence. SMS does not take this delay into account. The Morae recording for the Sentence Test trials was used to determine this delay and extract it from the TER calculation.

5.2.3 Human Error

5.2.3.1 Participant

Each participant's attention deviated from the task of scanning. This wandering attention varied between participants. It caused timing delays and selection errors. Fatigue was evident for several participants as the study proceeded. This caused missed switch presses and lack of focus. For two participants, fatigue was evident so early in the study that the number of transcribed sentences per trial was reduced from two to one. Cognitive issues appeared to affect some participants' ability to correctly transcribe certain words. These participants sometimes skipped a word.

5.2.3.2 Researcher

In an attempt to have the scanning matrixes similar across test trials and onscreen keyboards, a 5 x 6 matrix was used. This was the size used by IDA/Compass in the Scanning Test. One element of the layout was changed to accommodate this goal. The question mark character was replaced by [Backspace]. This changed caused the [Enter] key to be adjacent to the [Backspace] key. On three occasions the participant selected [Enter] instead of [Backspace]. That caused IDA/Compass to end that sentence transcription and move on to the next sentence if any remained to be transcribed. In hindsight, the [Backspace] should have been moved.

6.0 ANALYSIS

6.1 RESEARCH QUESTION 1: SCANNING MODEL ACCURACY

6.1.1 Participant RW

The SMS predicted a TER 8.26% greater than the participant's actual baseline TER of 5.571 characters per minute. This translated to a difference of 0.460 characters per minute. RW's probability of an error-free selection was 70.98%. The majority of RW's errors were the inability to select a target row. This error comprised 20.53% of all selection opportunities. Selecting an incorrect target can have substantial influence on TER due to the penalty for correction. This error occurred 1.78% of all selection opportunities. All errors were corrected by selecting the backspace key and typing the correct target letter. This participant also exceeded the time limit of 6 minutes per sentence for two sentence transcriptions (8 characters of 36 for the fourth sentence and 3 of 29 for the last sentence were not transcribed).

6.1.2 Participant DS

The SMS predicted a TER 9.56% greater than the participant's actual baseline TER of 4.915 characters per minute. This translated to a difference of 0.469 characters per minute. DS's probability of an error-free selection was 78.29%. The majority of DS's errors were the inability to select a target row. This error comprised 9.30% of all selection opportunities. Selecting an incorrect target occurred 3.87% of all selection opportunities. All errors were corrected by selecting the backspace key and typing the correct target letter. This participant also exceeded the time limit of 6 minutes per sentence for two sentence transcriptions (4 characters of 26 for the first sentence and 3 of 34 for the third remained to be transcribed).

6.1.3 Participant GS

The SMS predicted a TER 11.94% less than the participant's actual baseline TER of 5.187 characters per minute. This translated to a difference of 0.619 characters per minute. GS's probability of an error-free selection was 73.49%. The majority of GS's errors were the inability to select a target row. This error comprised 20.48% of all selection opportunities. Selecting an incorrect target occurred 2.4% of all selection opportunities. All errors were corrected by selecting the backspace key and typing the correct target letter. This participant only transcribed one sentence for each of the two baseline Sentence Tests. GS had difficulty actuating the switch during setup and practice. In an attempt to conserve energy, the number of transcribed sentences was reduced. This may have affected GS's average TER due to the reduced amount of data available. GS also had issues with the switch test. He had difficulty activating the switch at the onset of each part of the two part test. These two lengthy activations significantly raised the switch press times used in the SMS. These lengthy activations did not occur in subsequent testing. The difference between the Switch test results and the switch activation times that occurred during the Sentence test may have impacted the model prediction. This participant also exceeded the extended time limit of 7 minutes per sentence for sentence transcription (4 characters of 37 remained to be transcribed).

6.1.4 Participant DR

The SMS predicted a TER 15.16% greater than the participant's actual baseline TER of 6.124 characters per minute. This translated to a difference of 0.928 characters per minute. DR's probability of an error-free selection was 62.29%. The majority of DR's errors were due to the inadvertent activation of the switch which almost exclusively occurred on the first row of the matrix after a previous selection in the matrix. This error comprised 20.76% of all selection opportunities. Selecting an incorrect target occurred at a rate of 4.37% of all selection opportunities. Errors were corrected at a rate of 91.66 % by selecting the backspace key and typing the correct target letter.

When re-examining the error correction data, it was observed that several errors were not counted appropriately. The majority of this participant's incorrect target selections occurred in a row other than the row where the target selection was located due to inadvertent switch activations. These errors were different in that they did not fall neatly into the category of errors counted. The inadvertent selection was sometimes several row and columns away from the target character. This classification error caused an inaccurate error count for use in SMS and higher TER predictions for this participant.

6.1.5 Participant KM

The SMS predicted a TER 11.08% greater than the participant's actual baseline TER of 4.959 characters per minute. This translated to a difference of 0.520 characters per minute. KM's probability of an error-free selection was 54.83%. The majority of KM's errors were the inability to select a target row (22.58%) and the selection of a row after the target row (14.51%).

Selecting an incorrect target occurred 4.83% of all selection opportunities. All errors were corrected by selecting the backspace key and typing the correct target letter.

Due to the placement of the [backspace] key next to the [enter] key on the on-screen keyboard, the opportunity to terminate a sentence transcription by accidentally selecting [enter] instead of [backspace] existed. This occurred halfway through the transcription of three sentences. This may have affected KM's average TER due reduced amount of data available. This participant also exceeded the time limit of 6 minutes per sentence for the first sentence transcription (16 characters of 39 remained to be transcribed).

6.1.6 Summary

The following table contains the actual baseline TER obtained from IDA/Compass Sentence Test trials, SMS predicted TER, and the difference between the two as a percentage and in characters per minute. The last row represents the average taken across participants.

Table 17. Baseline Text Entry Rates

Participant	**IDA TER (char/min)**	**SMS TER (char/min)**	**Difference (%)**	**Difference (chars/min)**
RW	5.571	6.032	8.260	0.460
DS	4.915	5.385	9.560	0.469
GS	5.187	4.568	-11.940	-0.619
DR	6.124	7.053	15.160	0.928
KM	4.959	5.479	10.490	0.520
All (average)	5.351	5.703	11.082	0.599

The 95% confidence interval for the difference between the actual baseline TER and the predicted TER by SMS were calculated using t-distribution due to the smaller size of the sample.

Table 18. 95% confidence intervals for baseline TER

Units	Mean	Standard Deviation	Low	High
TER Error (%)	11.082	2.645	5.440	16.722
TER Error (char./min.)	0.599	0.194	0.185	1.014

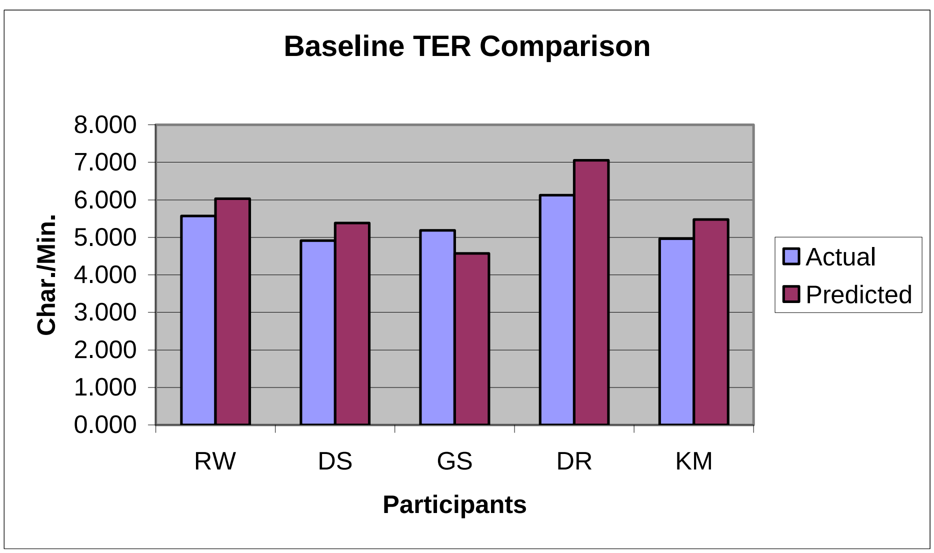


Figure 12. Baseline TER comparison

The following figure shows the SMS error percentage for the baseline Sentence Test.

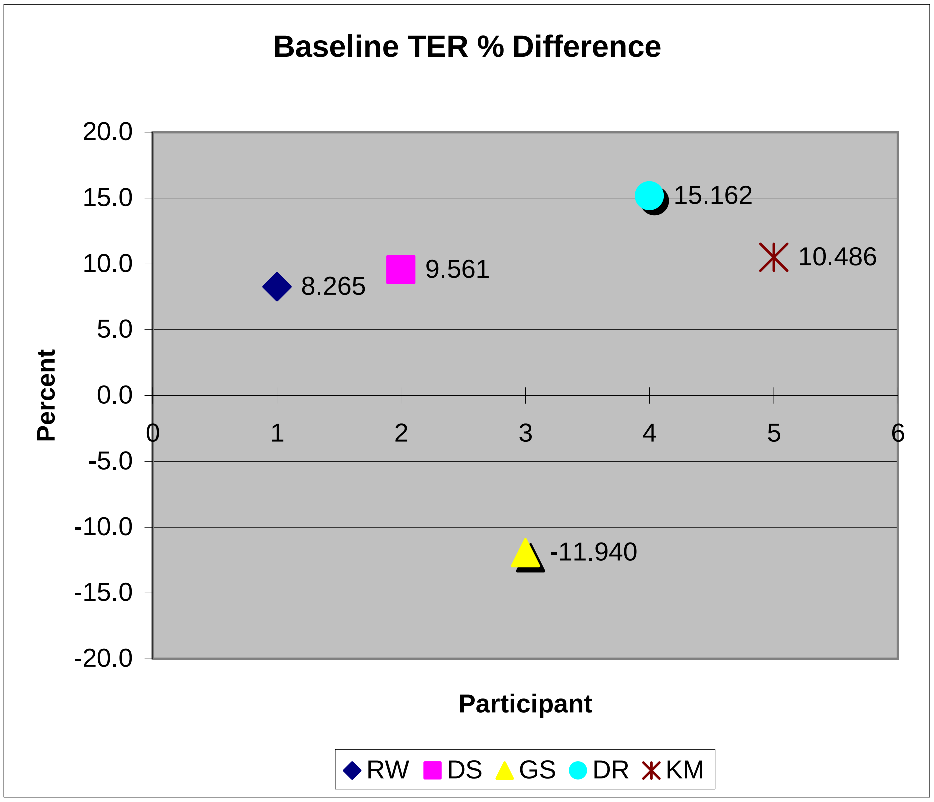


Figure 13. Baseline model error %

The following table contains probabilities of error free selection and selection errors for the participant's baseline sentence transcription tests. The last column contains the average of all participants.

Table 19. Baseline selection type rates

Type	RW (%)	DS (%)	GS (%)	DR (%)	KM (%)	Avg. (%)
Error Free Selection	70.98	78.29	73.49	62.30	54.84	67.98
Before Target Row	1.34	3.88	2.41	20.77	2.42	6.16
After Target Row	4.02	3.88	0.00	2.73	14.52	5.03
Before Target Col	0.89	2.33	1.20	3.28	0.00	1.54
After Target Col	0.89	1.55	1.20	1.09	4.84	1.91
No Target Selected	20.54	9.30	20.48	8.20	22.58	16.22
No Column selected	1.34	0.78	1.20	1.64	0.81	1.15

6.2 RESEARCH QUESTION 2: MODEL PREDICTION ACCURACY

6.2.1 Participant RW

The first configuration for RW consisted of an alphabetic keyboard layout (WiVik) with a [Stop] item at the end of each row to terminate scanning. The loop count was set to 5 and the scan rate to 1.25 seconds. The SMS predicted a TER 2.81% greater than the participant's actual TER of 5.728 characters per minute. This translated to a difference of 0.161 characters per minute. RW's probability of an error-free selection was 78.87% for this system configuration. Almost all of RW's errors were the inability to select a target row. This error comprised 18.30% of all selection opportunities. Only one incorrect target was selected and it was corrected with the backspace key and typing the correct target letter. RW exceeded the time limit of 6 minutes per sentence for the second sentence transcription (1 character of 38 remained to be transcribed). This configuration was chosen to test SMS accuracy with a scan method/layout modification (end of row-Stop). System configuration with other scan methods (reverse, continue) were tried, but implementation methods chosen by the creators of the on-screen keyboards dissuaded participants from using those features. Participants did not use or refused to use these features due to the implementation method of a pop-up message.

The second configuration for RW consisted of a frequency-based keyboard layout with a scan rate 1.20 seconds. The SMS predicted a TER 4.51% greater than the participant's actual TER of 7.023 characters per minute. This translated to a difference of 0.317 characters per minute. RW's probability of an error-free selection was 76.13% for this system configuration. This participant's primary errors were the inability to select a target row (15.90%) and the selection of a row after the target row (6.81%). Only one incorrect target was selected and it was corrected with the backspace key and typing the correct target letter. This configuration provided the highest TER of the four configurations tested with RW.

The third configuration for RW consisted of an alphabetic based keyboard layout with a scan rate 1.20 seconds and 0.8 second initial delay. The SMS predicted a TER 13.20% less than the participant's actual TER of 6.014 characters per minute. This translated to a difference of 0.794 characters per minute. RW's probability of an error-free selection was 89.47% for this system configuration. This participant's only type of error for this configuration was the inability to select a target row (10.52%). There were no incorrect selections. Both sentences were correct. RW reduced errors and achieved a higher TER than predicted.

The fourth configuration for RW consisted of a frequency-based keyboard layout with a scan rate 1.20 seconds and 0.8 second initial delay. The SMS predicted a TER 5.25% less than the participant's actual TER of 6.726 characters per minute. This translated to a difference of 0.353 characters per minute. RW's probability of an error-free selection was 78.46% for this system configuration. The primary type of error for this configuration was the inability to select a target row (18.46%). There were no incorrect selections. Both sentences were correct. RW reduced errors again and achieved a higher TER than predicted.

Table 20. RW TER Results

Configuration	IDA TER (char/min)	SMS TER (char/min)	Difference (%)	Difference (chars/min)
1	5.728	5.890	2.815	0.161
2	7.023	7.340	4.511	0.317
3	6.015	5.221	-13.201	-0.794
4	6.726	6.373	-5.249	-0.353
All	6.373	6.171	6.808	0.417

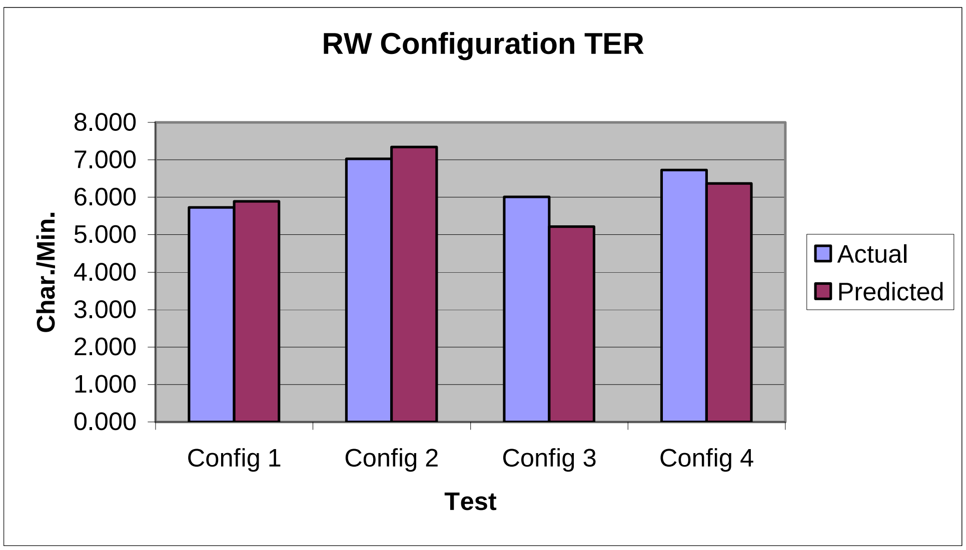


Figure 14. RW configuration TER

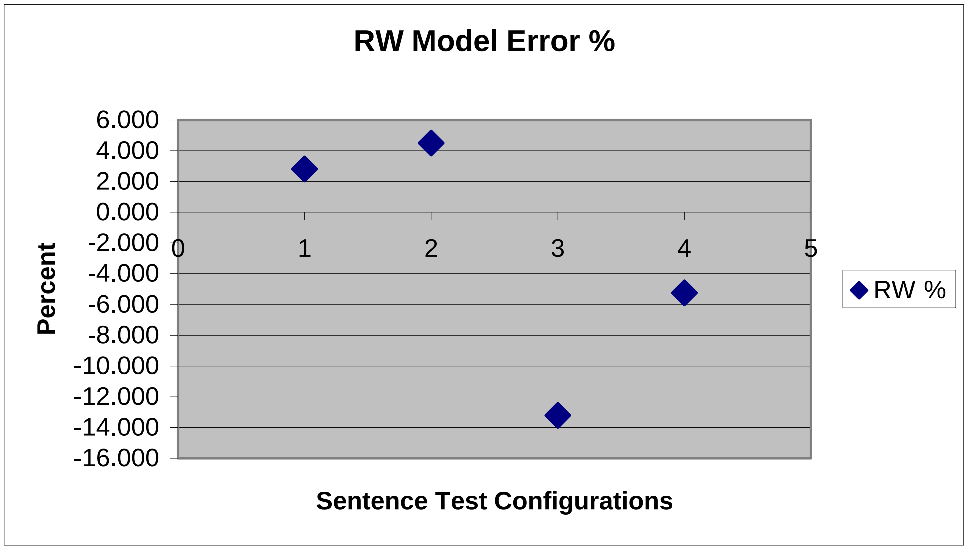


Figure 15. RW model error %

The following table contains probabilities of error free selection and selection errors.

Table 21. RW selection type rates

Type	Config. 1 Rate (%)	Config. 2 Rate (%)	Config. 3 Rate (%)	Config. 4 Rate (%)	Avg. (%)
Error Free Selection	78.87	76.14	89.47	78.46	80.74
Before Target Row	0.00	1.14	0.00	0.00	0.28
After Target Row	1.41	6.82	0.00	3.08	2.83
Before Target Col	0.00	0.00	0.00	0.00	0.00
After Target Col	0.00	0.00	0.00	0.00	0.00
No Target Selected	18.31	15.91	10.53	18.46	15.80
No Column selected	1.41	0.00	0.00	0.00	0.35

6.2.2 Participant DS

The first configuration for DS consisted of a frequency keyboard layout with a scan rate of 1.4 seconds. The SMS predicted a TER 10.46% less than the participant’s actual TER of 7.315 characters per minute. This translated to a difference of 0.765 characters per minute. DS’s probability of an error-free selection was 82.85% for this system configuration. Most of DS's errors were the inability to select a target row. This error comprised 12.85% of all selection opportunities. Only one incorrect target was selected and it was corrected with the backspace key and typing the correct target letter. This configuration was chosen to test the participants' ability with the frequency-based layout.

The second configuration for DS consisted of an alphabetic based keyboard layout with a scan rate 1.4 seconds and 0.8 second initial delay. The SMS predicted a TER 7.32% less than the participant's actual TER of 5.117 characters per minute. This translated to a difference of 0.375 characters per minute. DS's probability of an error-free selection was 89.23% for this system configuration. This participant's primary errors were the inability to select a target row (4.61%) and the selection of a row after the target row (3.07%). Only one incorrect target was selected and it was corrected with the backspace key and typing the correct target letter. This participant exceeded the time limit of 6 minutes per sentence for both sentence transcriptions (8 characters of 33 for the first sentence and 2 of 36 for the second remained to be transcribed).

The third configuration for DS consisted of an alphabetic keyboard layout (WiVik) with a [Stop] item at the end of each row to terminate scanning. The loop count was set to 5 and the scan rate to 1.5 seconds. The SMS predicted a TER 9.71% less than the participant's actual TER of 5.733 characters per minute. This translated to a difference of 0.557 characters per minute. DS's probability of an error-free selection was 90.47% for this system configuration. This participant did not have significant errors of any one type or frequency. Two incorrect targets were selected and both were corrected with the backspace key and typing the correct target letter. Both sentences were correct.

Table 22. DS TER results

Configuration	IDA TER (char/min)	SMS TER (char/min)	Difference (%)	Difference (chars/min)
1	7.315	6.550	-10.458	-0.765
2	5.118	4.743	-7.321	-0.375
3	5.733	5.177	-9.709	-0.557
All	6.055	5.490	9.163	0.565

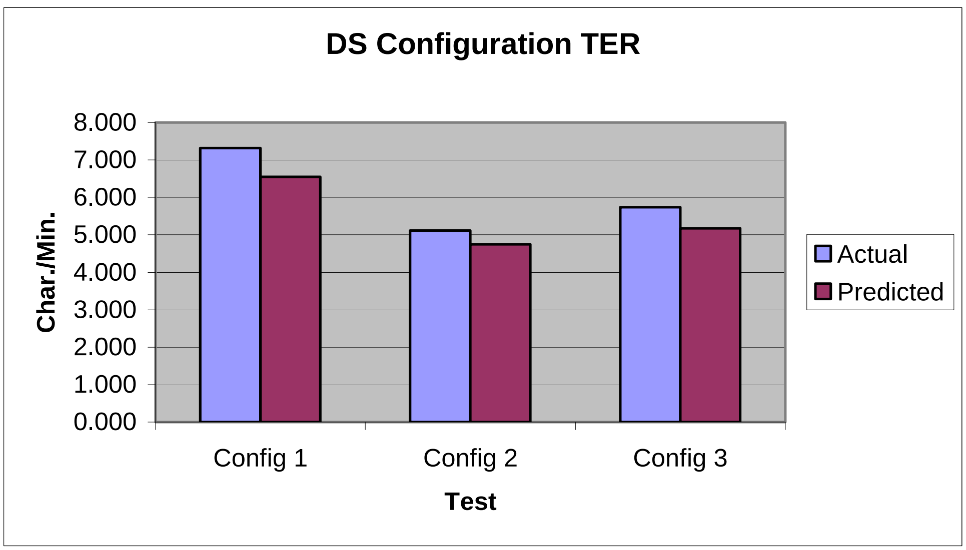


Figure 16. DS configuration TER

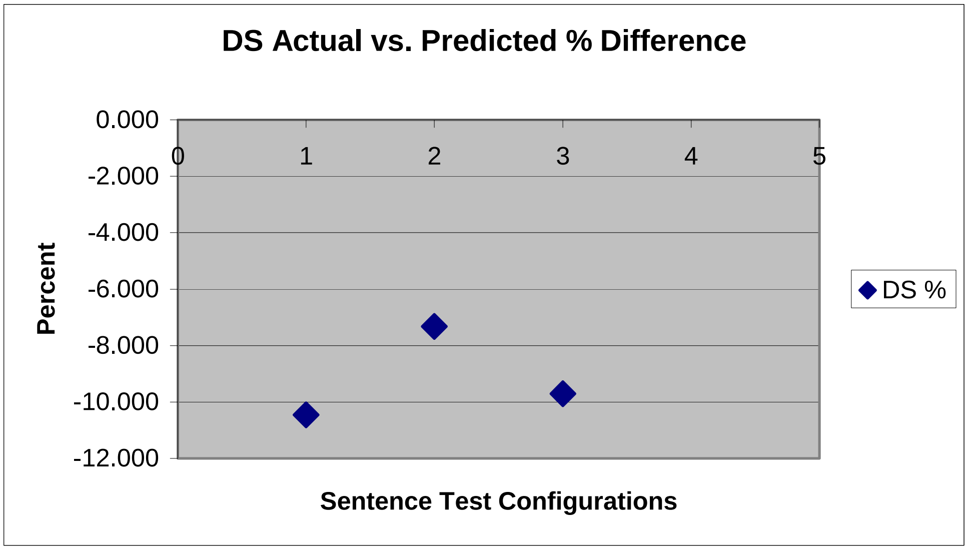


Figure 17. DS model error %

The following table contains probabilities of error free selection and selection errors.

Table 23. DS selection type rates

Type	Config. 1 Rate (%)	Config. 2 Rate (%)	Config. 3 Rate (%)	Avg. (%)
Error Free Selection	82.86	89.23	90.48	87.52
Before Target Row	0.00	1.54	3.17	1.57
After Target Row	2.86	3.08	1.59	2.51
Before Target Col	0.00	0.00	0.00	0.00
After Target Col	1.43	1.54	3.17	2.05
No Target Selected	12.86	4.62	1.59	6.35
No Column selected	0.00	0.00	0.00	0.00

6.2.3 Participant GS

This participant only transcribed one sentence for the first, second, and fourth configuration Sentence tests. GS had difficulty actuating the switch during setup and practice. In an attempt to conserve energy, the number of transcribed sentences was reduced. The number was later increased back to two based upon the effectiveness of switch activations in the early tests, but reduced again.

The first configuration for GS consisted of a frequency keyboard layout with a scan rate of 1.5 seconds. The SMS predicted a TER 2.72% less than the participant's actual TER of 5.591 characters per minute. This translated to a difference of 0.152 characters per minute. GS's probability of an error-free selection was 71.15% for this system configuration. Most of GS's errors were the inability to select a target row. This error comprised 17.30% of all selection opportunities. Only one incorrect target was selected and it was corrected with the backspace key and typing the correct target letter. This participant exceeded the extended time limit of 7 minutes per sentence for sentence transcription (3 characters of 40 remained to be transcribed). This configuration was chosen to test the participants' ability with the frequency-based layout.

The second configuration for GS consisted of a frequency-based keyboard layout with a scan rate of 1.0 seconds. The SMS predicted a TER 1.66% less than the participant's actual TER of 6.784 characters per minute. This translated to a difference of 0.112 characters per minute. GS's probability of an error-free selection was 63.41% for this system configuration. This participant's primary error was the inability to select a target row (26.82%). One incorrect target was selected and it was corrected with the backspace key and typing the correct target letter. The scan rate was reduced for this configuration because the fatigue and inability to timely activate the switch was not as evident in the first configuration test as it was during practice and orientation.

The third configuration for GS consisted of a frequency-based keyboard layout with a scan rate of 1.0 seconds and initial delay of 0.5 seconds. The SMS predicted a TER 8.38% greater than the participant's actual TER of 5.671 characters per minute. This translated to a difference of 0.475 characters per minute. GS's probability of an error-free selection was 64.47% for this system configuration. This participant's primary errors were the inability to select a target row (21.05%) and the selection of a row before the target row (7.89%). Three incorrect targets were selected and all were corrected with the backspace key and typing the correct target letter. Two sentences were transcribed and both sentences were correct. The initial delay was added to this configuration because GS's errors in the previous test were primarily missed selections in the first row. Instead of decreasing errors, this additional delay altered the switch timing of GS and increased them.

The fourth configuration for GS consisted of an alphabetic keyboard layout with a scan rate of 1.0 seconds. The SMS predicted a TER 3.57% less than the participant's actual TER of 6.029 characters per minute. This translated to a difference of 0.215 characters per minute. GS's probability of an error-free selection was 69.04% for this system configuration. Most of GS's errors were the inability to select a target row. This error comprised 26.19% of all selection opportunities. Only one incorrect target was selected and it was corrected with the backspace key and typing the correct target letter. The sentence was correct. This configuration was selected to compare against the frequency test with the same scan rate.

Table 24. GS TER results

Configuration	IDA TER (char/min)	SMS TER (char/min)	Difference (%)	Difference (chars/min)
1	5.592	5.440	-2.719	-0.152
2	6.785	6.672	-1.658	-0.112
3	5.671	6.147	8.384	0.475
4	6.030	5.814	-3.570	-0.215
All	6.019	5.728	5.654	0.315

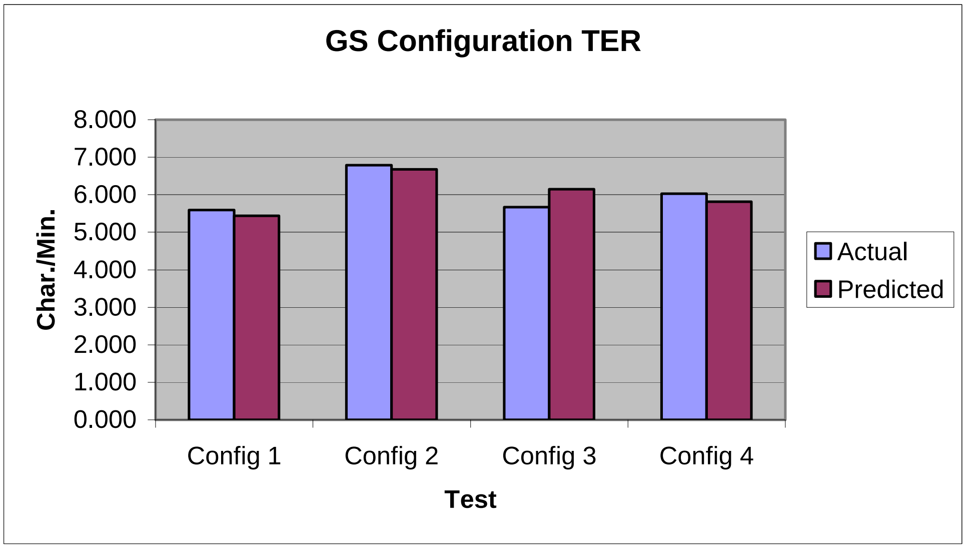


Figure 18. GS configuration TER

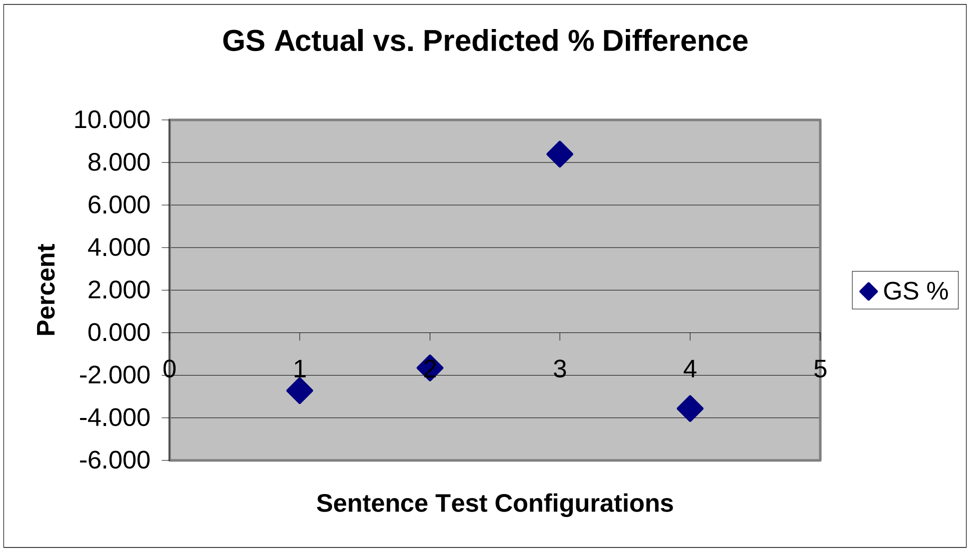


Figure 19. GS model error %

The following table contains probabilities of error free selection and selection errors.

Table 25. GS selection type rates

Type	Config. 1 Rate (%)	Config. 2 Rate (%)	Config. 3 Rate (%)	Config. 4 Rate (%)	Avg. (%)
Error Free Selection	71.15	63.41	64.47	64.47	65.88
Before Target Row	3.85	2.44	7.89	7.89	5.52
After Target Row	3.85	4.88	2.63	2.63	3.50
Before Target Col	1.92	0.00	2.63	2.63	1.80
After Target Col	0.00	0.00	1.32	1.32	0.66
No Target Selected	17.31	26.83	21.05	21.05	21.56
No Column selected	1.92	2.44	0.00	0.00	1.09

6.2.4 Participant DR

The first configuration for DR consisted of a frequency keyboard layout with a scan rate of 1.0 seconds. The SMS predicted a TER 16.10% greater than the participant's actual TER of 7.381 characters per minute. This translated to a difference of 1.189 characters per minute. DR's probability of an error-free selection was 64.21% for this system configuration. The majority of DR's errors were selections before the target row due to unintentional switch presses. This error comprised 21.05% of all selection opportunities. Other significant errors were the lack of a target selection at 6.31% and selections before the column target (5.26%). Five incorrect targets were selected. All were corrected with the backspace key and typing the correct target letter. This configuration was chosen to test the participants' ability with the frequency-based layout.

The second configuration for DR consisted of a frequency-based keyboard layout with a scan rate of 1.0 seconds and an initial delay of 0.5 seconds. The SMS predicted a TER 41.06% greater than the participant's actual TER of 5.374 characters per minute. This translated to a difference of 2.207 characters per minute. The probability of an error-free selection was 55.96% for this system configuration. This participant's primary error was row selections before the target row (27.52%). Again, most of selections early row selections were observed to be inadvertent switch presses. Errors of before (4.58%) and after (5.50%) target column selection are significant due to the correction time penalty. An incorrect target was selected in thirteen instances. The incorrect selection was corrected with the backspace key and typing the correct target letter eleven times. Two sentences were transcribed and both sentences were correct. The initial delay was added to this configuration in an attempt to reduce the selection errors on the first row. Since the switch activations on the first row were unintended, the delay did not reduce any errors.

A classification error caused an inaccurate error count for use in SMS and higher TER predictions for this participant. That was even more significant for this configuration test because of increased amount of errors the participant accrued. This test was also interrupted and temporarily paused. Although the Morae recording was reviewed to adjust the timing issue that occurred, it was difficult to discern the exact time of the interruption. The combination resulted in 41% difference between the actual and SMS predicted TER.

The third configuration for DR consisted of a frequency-based keyboard layout with a scan rate 0.8 seconds. The SMS predicted a TER 11.43% greater than the participant's actual TER of 8.991 characters per minute. This translated to a difference of 1.028 characters per minute. DR's probability of an error-free selection was 62.61% for this system configuration. This participant's primary errors were the inability to select a target row (14.95%) and the selection of a row before the target row (14.01%). One incorrect target was selected and corrected with the backspace key and typing the correct target letter. Two sentences were transcribed and both sentences were correct. The configuration increased the scan rate in an attempt to increase TER.

Table 26. DR TER results

Configuration	**IDA TER (char/min)**	**SMS TER (char/min)**	**Difference (%)**	**Difference (chars/min)**
1	7.381	8.570	16.103	1.189
2	5.374	7.581	41.057	2.207
3	8.992	10.020	11.434	1.028
All	6.968	8.306	20.939	1.338

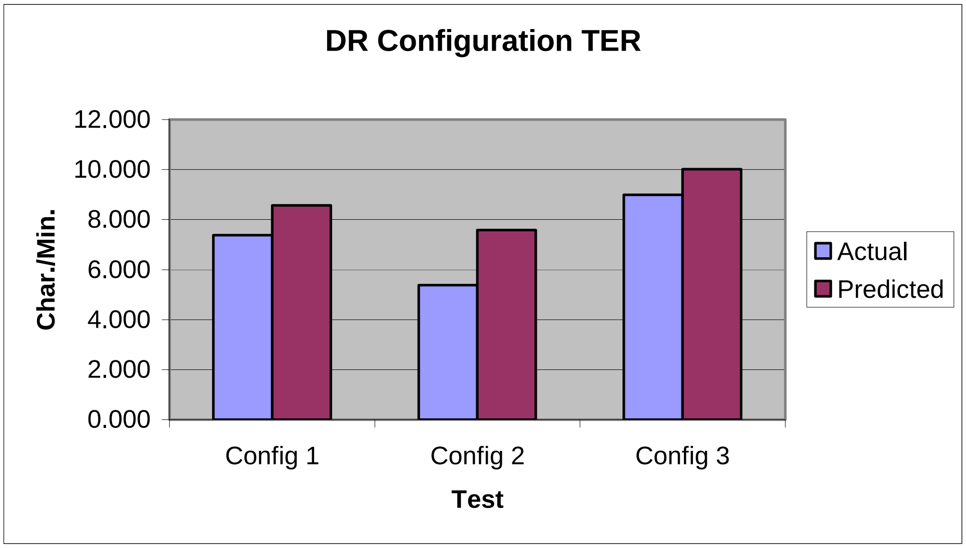


Figure 20. DR configuration TER

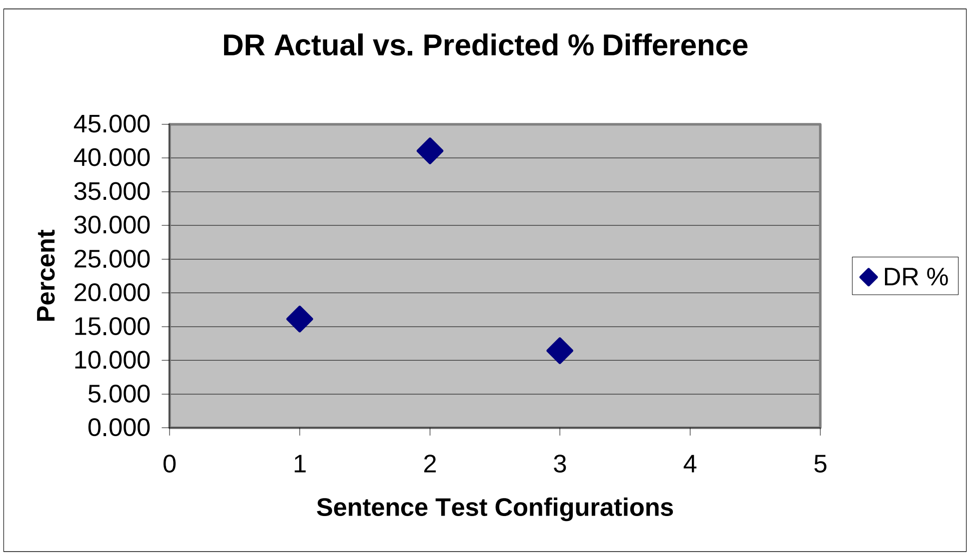


Figure 21. DR model error %

The following table contains probabilities of error free selection and selection errors.

Table 27. DR selection type rates

Type	Config. 1 Rate (%)	Config. 2 Rate (%)	Config. 3 Rate (%)	Avg. (%)
Error Free Selection	64.21	55.96	62.62	60.93
Before Target Row	21.05	27.52	14.02	20.86
After Target Row	3.16	2.75	5.61	3.84
Before Target Col	5.26	4.59	0.93	3.59
After Target Col	0.00	5.50	0.00	1.83
No Target Selected	6.32	1.83	14.95	7.70
No Column selected	0.00	1.83	1.87	1.23

6.2.5 Participant KM

The first configuration for KM consisted of an alphabetic keyboard layout with a scan rate of 1.20 seconds. The SMS predicted a TER 13.86% less than the participant's actual TER of 5.282 characters per minute. This translated to a difference of 0.732 characters per minute. KM's probability of an error-free selection was 68.91% for this system configuration. This was a significant increase from the baseline error-free probability of 45.16%. Many of KM's errors were the inability to select a target row. This error comprised 17.56% of all selection opportunities. Selections before and after the target row were both at 5.40%. Two incorrect targets were selected. Both were corrected with the backspace key and typing the correct target letter. KM inadvertently selected the [enter] key and terminated the transcription of the first sentence prematurely. The sentence had six more characters to transcribe. The scan delay in this configuration was increased from the baseline rate in an attempt to reduce the large amount of selection errors that occurred in the baseline tests.

The second configuration for KM consisted of a frequency-based keyboard layout with a scan rate of 1.20 seconds. The SMS predicted a TER 11.42% less than the participant’s actual TER of 5.900 characters per minute. This translated to a difference of 0.674 characters per minute. KM’s probability of an error-free selection was 61.17% for this system configuration. This participant’s primary error was the inability to select a target row (28.23%). There were no incorrect target selections. This configuration was selected to use a frequency-based keyboard to increase TER. This configuration provided the highest TER of the three configurations tested with KM.

The third configuration for KM consisted of a frequency-based keyboard layout with a scan rate of 1.20 seconds and a 0.3 second initial delay. The SMS predicted a TER 3.32% less than the participant’s actual TER of 5.147 characters per minute. This translated to a difference of 0.171 characters per minute. KM’s probability of an error-free selection was 66.66% for this system configuration. The error of not selecting a target comprised 22.66% of all selection opportunities. Selections before and after the target row were both at 4.0%. Four incorrect targets were selected. All were corrected with the backspace key and typing the correct target letter. KM exceeded the time limit of 6 minutes per sentence for the second sentence transcription (7 characters of 33 remained to be transcribed). The initial delay was added in an attempt to reduce errors that occurred when targets were located in the first row of the matrix.

Table 28. KM TER results

Configuration	IDA TER (char/min)	SMS TER (char/min)	Difference (%)	Difference (chars/min)
1	5.282	4.550	-13.858	-0.732
2	5.901	5.227	-11.421	-0.674
3	5.147	4.976	-3.323	-0.171
All	5.323	5.058	9.772	0.524

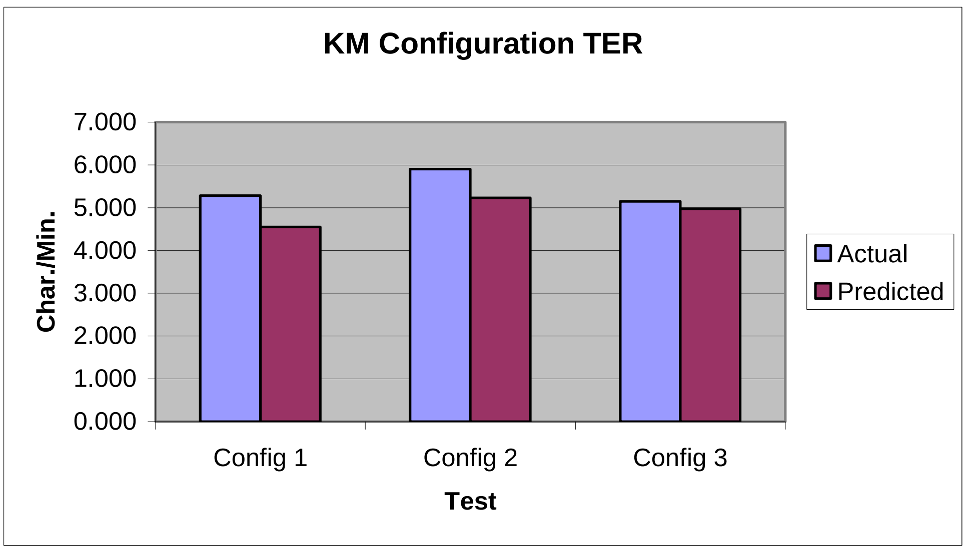


Figure 22. KM configuration TER

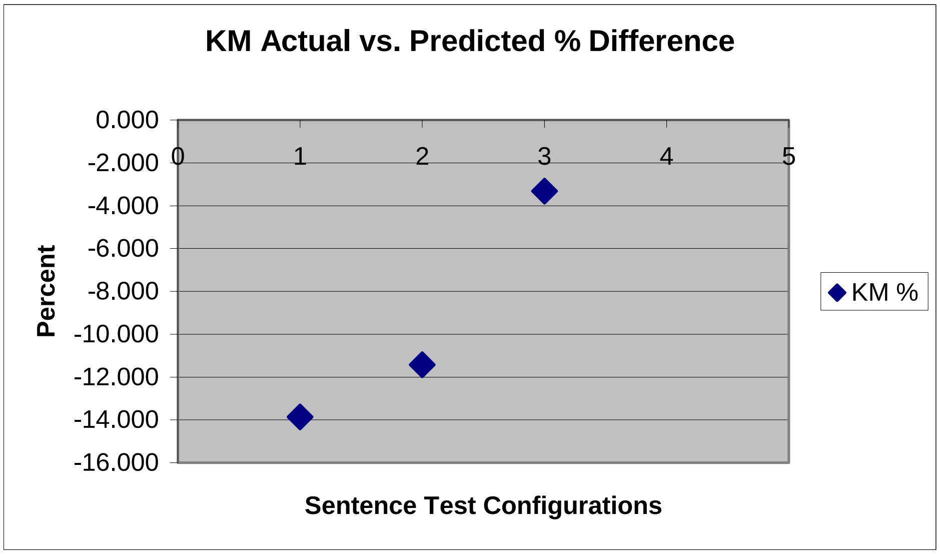


Figure 23. KM model error %

The following table contains probabilities of error free selection and selection errors.

Table 29. KM selection type rates

Type	**Config. 1 Rate (%)**	**Config. 2 Rate (%)**	**Config. 3 Rate (%)**	**Avg. (%)**
Error Free Selection	68.92	61.18	66.67	65.59
Before Target Row	5.41	4.71	4.00	4.70
After Target Row	5.41	4.71	4.00	4.70
Before Target Col	2.70	0.00	0.00	0.90
After Target Col	0.00	0.00	1.33	0.44
No Target Selected	17.57	28.24	22.67	22.82
No Column selected	0.00	1.18	1.33	0.84

6.2.6 Summary

Figure 24 shows the model error percentage for all participants across both baseline and configuration IDA/Compass Sentence Tests.

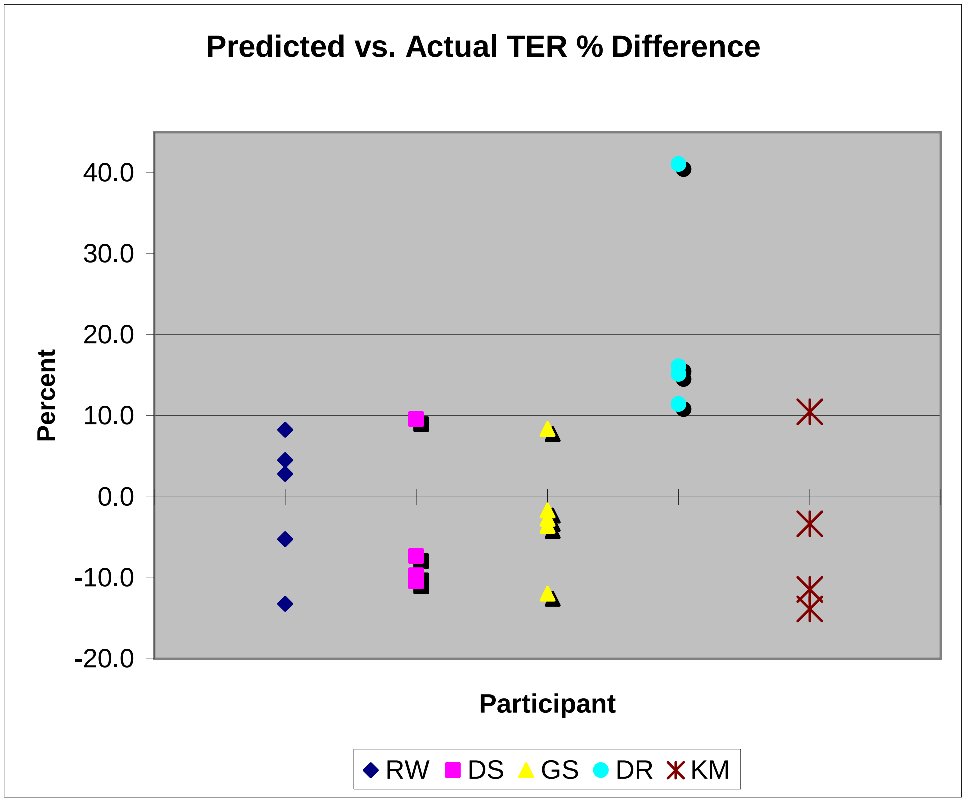


Figure 24. Predicted vs. actual TER difference

The 95% confidence interval for the difference between the actual configuration TERs and the predicted TER by SMS were calculated using t-distribution due to the smaller size of the sample.

Table 30. 95% confidence intervals for configuration TER

Units	Mean	Standard Deviation	Low	High
TER Error (%)	10.417	7.300	-5.147	25.982
TER Error (char./min.)	0.642	0.482	-0.386	1.670

7.0 DISCUSSION

7.1 RESEARCH QUESTION 1: SCANNING MODEL ACCURACY

The predicted SMS text entry rates using each participant's baseline system configuration and user characteristics were within one character per minute of the actual TERs acquired via IDA/Compass. Differences ranged from 0.460 to 0.928 characters per minute, with an average difference of 0.59.

Although all baseline TER predictions by SMS were within one character per minute of the actual TER acquired through the IDA/Compass Sentence tests, several issues may have affected accuracy. These include incorrect error classification, premature transcription termination, and the transcriptions timeouts. An automated error counting mechanism could improve the accuracy of the error count and classification. This could be integrated into the Sentence test itself. Timeouts and early transcription termination allow for the possibility of letter frequencies disproportionate to the frequencies of English usage utilized by SMS to calculate TER. Premature termination of transcription can be resolved by simply rearranging the matrix layout to reduce the probability of selecting [enter] inadvertently. Timeouts were used in an attempt to maintain a relative fixed length of time for the study. These could be lengthened to allow for complete sentence transcription or the study could be completed two sessions.

7.2 RESEARCH QUESTION 2: MODEL PREDICTION ACCURACY

The predicted SMS text entry rates using various system configurations and the participant's user characteristics were within one character per minute of the actual TERs acquired via IDA/Compass for four of the five study participants. Differences among all participants ranged from 0.112 to 2.207 characters per minute, with an average difference of 0.642. The average difference for the participant outside of the one character per minute threshold was 1.474 characters per minute.

7.2.1 Participant RW

RW reduced errors for all configurations when compared to the baseline error-free selection rate of 70.98%. This could be attributed to practice, sentences that were easier to transcribe, or use of a configuration better suited to RW's tendencies. It was believed that error reductions were the primary reason for differences between predicted and actual TER. This theory was tested for configuration 3 by running the model with the configuration 3 system parameters and error probabilities (in place of the baseline probabilities). The results showed a 4.3% difference in TER's compared to the 13.20% difference using the baseline error probabilities. The results supported the idea that changing error probabilities affect model accuracy.

Although RW increased TER for all configurations, frequency-based layouts showed the highest TER. An initial delay did reduce errors of selecting rows after the target row, but this reduction was not enough to offset the overhead of the initial delay. A frequency-based layout without an initial delay provided the highest TER.

7.2.2 Participant DS

In all three configurations, DS reduced errors from the baseline error probabilities and achieved a higher TER than predicted. The reduction in errors contributed to a lower TER prediction by the model. A frequency-based layout without an initial delay provided the highest TER for this participant.

7.2.3 Participant GS

The reduction in the number of sentences per test may have affected GS's average TER due to the limited amount of data available. GS's error probabilities were rather stable during all tests and could be the reason average difference between predicted and actual TER was 4.08%. A frequency-based layout with a scan rate of 1.0 seconds (1.4 seconds was baseline) without an initial delay provided the highest TER for this participant. Initial delays disrupted the timing of GS and resulted in increased errors. Further tests are necessary to determine if these errors could be mitigated with practice.

7.2.4 Participant DR

In all three configurations, DR's TER was at least 11.0% less than the model predicted TER. The classification error described in the section 1.7.6 baseline summary caused an inaccurate error count for participant DR. These inaccurate error probabilities resulted in the configuration tests predicted TERs to be significantly higher than the actual TER. DR's increased errors in configuration 2 also contributed to a large TER difference between predicted and actual. A frequency-based layout with a scan rate of 0.8 seconds provided the highest TER for this participant. An initial delay had negative TER consequences for DR, but there were many problems with the configuration 2 test that also contributed to a reduced TER.

7.2.5 Participant KM

All of the SMS predictions were below the actual TER. This could be due to the high probability of errors established in the baseline test and the reduction of errors in the configuration tests. Test data showed that a frequency-based layout without an initial delay resulted in the highest TER for this participant.

7.2.6 Summary

While model accuracy was within the target range of one character per minute on average, the model was affected by several factors. Some participants reduced their number of errors in a configuration test, resulting in error rates different from the probabilities established by the baseline. Since the baseline error probabilities/tendencies are used by SMS for the configuration TER calculations, a change in the actual Sentence test performance in terms of errors can result in a difference between actual and predicted TER. The configuration tests for KM are an example. An increase of errors from the baseline probabilities can cause a TER prediction higher than the actual TER (Configuration 2 of DR is an example). Certain configurations did occasionally increase errors. In configuration 3 of GS the addition of an initial delay caused more selection errors. The change in error probabilities between baseline and configuration testing had the greatest impact on TER accuracy. The most prevalent error for all participants was the failure to make a selection during a scanning pass through the matrix. The prevalence of this error made it difficult to ascertain the impact of various scanning errors on the predictive accuracy in the model.

Overall, SMS predictions were lower for 11 of the 17 configuration tests. This under estimation can be attributed to the reduction of errors by participants. Three of the five participants reduced errors in all configuration tests and one participant's error rates remained relatively stable. Only one participant had all TER predictions higher than their actual TER. This was participant DR. The classification error described in the section 1.7.6 baseline summary also caused an inaccurate error count for participant DR. These inaccurate error probabilities resulted in the configuration tests predicted TERs to be significantly higher than the actual TER.

The SMS uses weighted average selection and penalty times based on character frequency for TER calculations. Even though IDA/Compass sentences vary letter combinations, with the limited sample and randomly chosen sentences, the letter frequencies in the IDA/Compass sentences can differ from the source corpus used to establish model character frequencies. This is more of an issue for the tests that were prematurely terminated or participants who transcribed fewer sentences.

7.3 DESCRIPTIVE

Several observations were made throughout the various stages of the data acquisition and analysis. During the study, four of the five participants had comments in regard to the scanning matrix layout. These participants did not care for the frequency-based layout and preferred the alphabetic layout. Interestingly, the TER for all participants was higher when using the frequency-based layout compared to the alphabetic (keeping all other variables constant) despite the participants lack of familiarity or dislike of the layout. The majority of the time the increased TER was achieved even with a larger percentage of errors. The frequency-based matrix is designed to reduce scan steps and time to the most often used letters, but the lack of familiarity may have also increased the cognitive load and resulted in a participant paying closer attention to the transcription task.

As expected, targets in the first row resulted in more errors than targets in other areas of the scanning matrix. This can be attributed to lack of initial delay and recovery time from a previous selection. Some scanning configurations contained an initial delay. Although the intention of this delay is to reduce errors for selections in the first row or column of a matrix, it caused errors for two participants. It appears that their switch activation was based on anticipation and was initiated prior to the highlighting of the desired matrix selection. As a result, their timing was disrupted and switch activation would occur prematurely. This occurred despite sentence transcription practice with the initial delay setting.

All participants used the backspace to delete an incorrect character and typed the correct character when implementing a method of error correction. No participant chose the method of leaving the incorrect character and simply typing the correct one.

8.0 CONCLUSIONS

The purpose of this study was to test the accuracy of a software model's (SMS) predictions for the TER of individuals who use single switch row-column scanning as their method of communication. Results showed that the predicted TERs were within one character per minute of actual TERs on average. The average difference between actual and predicted TER for all tests was 10.10% with a difference of 0.603 characters per minute. Due to interruptions during one participant test, a significantly large TER difference occurred. If this one test is removed from the average calculations, the TER difference becomes 8.62% and 0.527 characters per minute.

The actual TERs acquired from the IDA/Compass Sentence test generally ranged from five to seven characters per minute for all system configurations. Limitations related to the design of scanning method configuration options in on-screen keyboards (i.e. reverse scan, continue scan) relegated system configuration changes primarily to the areas of scan rate, initial delay, and matrix layout. Manipulation of the aforementioned settings did result in TER improvement for most participants. The maximum TER gains for each participant were in the range of 1.0 to 2.5 characters a minute. Each participant's highest TER occurred with a frequency-based keyboard configuration and a scan rate equal to or less than their baseline scan rate. In addition to TER improvement, switch positioning and activation were observed. Although switch alterations were not a focus of this study, changes for some participants may result in an improved communication rate. Even with improved TERs, all participants were still below the threshold of two words per minute. Manipulating the scan timing settings to a greater extent could affect TER and cause various selection errors. Significantly increasing the scan rate, for example, would speed matrix scanning, but probably induce more selection errors. The ability to test other scan configurations in conjunction with a scan rate would be valuable in determining an individual's TER potential. It has been shown that able-bodied individuals can generate between 6 and 8 words per minute using single switch row-column scanning (23). Although a disabled individual may not approach those levels, there is much room for improvement. Even an increase from 2 to 3 words per minute is significant. Configuration options other than those modified in this study should be explored.

In order to explore the potential for TER improvement, modifications to both the SMS and IDA/Compass would be necessary. One goal of the SMS is to assist in determining the optimal TER for a single switch scanner. Using an individual's error tendencies allows for a more accurate TER prediction of a known configuration. If a different configuration is modeled in an attempt to reduce errors and improve TER, the model's prediction for a successful configuration (one that improved TER and reduced errors) will be less than the actual TER acquired during a transcription test. This is due to a reduction in the user's error probabilities when compared to the baseline. Adding a degree of machine learning to the SMS would enhance prediction accuracy. A simple example of using rule based prediction would be a scenario where a significant number of selection errors occur when attempting to select a target in the first row of a matrix. Adding an initial delay to this configuration should reduce those errors. The model algorithm would account for the probable reduction in errors during TER calculation.

The IDA/Compass Sentence test was a valuable tool in acquiring the actual TER for the various configurations. This test would again be used with an updated SMS. One method to reduce error classification issues that occurred during this study would be to add the error counting to the Sentence test. Additionally, the integration of a configurable (size and layout) on-screen keyboard in the Sentence Test would allow for better error tabulation and support testing of various system configurations. Ideally, the on-screen keyboard would incorporate features found in each of the keyboards used for this study. These options would include settings for: scan rate, initial delay for the first row, initial delay for remaining rows, loop count for rows, and loop count for columns. Integrated scan methods would include: reverse scan, continue scan, stop scan (start & end of row). The additions would allow IDA/Compass explore a wide range of configurations in an effort to determine the best TER for a single switch scanner.

9.0 FUTURE WORK

The initial design of this study intended to acquire the errors made by an individual using single switch row-column scanning through a modified version of the Scan Test in IDA/Compass. The software was modified and tabulated the error information correctly, but did not simulate the process of text entry to the extent necessary to cause all the errors and the frequency they occur when composing a phrase in “real time”. The Scan Test presented one character at a time and the user would initiate scanning. This method allowed the user to pre-scan the matrix and then initiate the scanning sequence. The solution to this problem for this study was to use the Morae recording of each Sentence Test and “manually” tabulate the scanning errors. A future solution would be to modify the IDA/Compass Sentence Test to programmatically count these errors. Modifying the Scan Test by creating a configurable initial delay for the onset of scanning will allow a more accurate assessment of a dynamic scanning system and would be of use for scanners incapable of sentence transcription.

In addition to the aforementioned issue, one goal of this study was to evaluate configurations using matrixes with reverse, continue, and stop scanning functionality/selections. It was determined early in the study, that the on-screen keyboards that possessed these features were not functioning as desired due to design implementation methods (a pop-up button/selection instead of a fixed position in the scanning matrix). The cognitive load to use these features dissuaded study participants from considering them as an option during sentence transcription. A solution to this issue would also be a modification to the Sentence Test task in IDA/Compass. A configurable on-screen keyboard incorporated in the Sentence Test structure would allow various scan configurations to be implemented. The implementation of these configuration options would be in a manner that fit into the existing matrix format/structure, therefore allowing the configurations to be tested without the distractions of a dynamic and ever changing on-screen keyboard.

Modifying SMS to use additional single switch user tendencies observed throughout data collection will improve the accuracy of TER calculations. After a sentence was presented for transcription in the Sentence Test, many participants would delay the start of sentence transcription until they had read and processed the sentence. This “processing” time was acquired through analysis of the Morae recording and subtracted from the trial time when calculating actual IDA/Compass TER. A “processing” time added as a SMS input parameter will account for this delay. Inadvertent switch presses and subsequent selections were also observed during sentence transcription. The current model did not account for these events very well. The probability of this event occurring will be added as a SMS input parameter.

As a means of improving the accuracy of the SMS, future studies may have multiple test sessions performing the Sentence Test transcription with a variety of sentences. This will also assist in reducing participant fatigue.

Future development on this project consists of the following:

1. Adding more comprehensive error and correction method identification to the IDA Sentence Test. This includes tracking the same 6 selection errors as this study, the error free selection rate, and error correction methods. In addition, the current target character/location will be tracked with each error.

2. Providing general support for scanning system configurations with an integrated on-screen keyboard within the IDA Sentence Test consisting of semi-configurable alphabetic and frequency based matrix layouts, adjustable scan rate, initial delays for rows and columns, and a row/column loop count.
3. Adding more sophisticated system configurations such as matrix layouts with stop-scanning, reverse scanning and continue scanning to the Sentence Test.
4. Create rules used to select potential system configurations that optimize TER performance based on user characteristics and test those rules using SMS. This entails collecting user data to establish validity of those rules. The effect the new configurations on errors will be determined. Configurations selected to optimize TER intend to reduce errors as one means of improving performance. The reduction in errors will disrupt predictions. User data will give guidelines to adjust model probabilities accordingly.
5. Integrating SMS into IDA so that predictions can be made and tested dynamically in one environment. Recommendations of systems configurations by an integrated IDA and SMS will expedite the assessment and testing of a scanning configuration. An integrated decision engine (SMS) in IDA will generate an initial set of recommendations based on the established rules (if they proved valid) and by using SMS to automatically run through all possible system configurations; recommending those which have the potential provide the best TER.

APPENDIX A : SCANNING SYSTEMS SURVEY

Product Name	Scan Rate Min	Max	Increments	Units	Input Method	Initial Delay (row) Min	Max	Increments	Units	Input Method
Click-N-Type	20.00	200.00	1.00	unknowr	2	N/A	N/A	N/A	N/A	0
Clicker 5	0.05	60.00	0.10	sec	3,4	0.10	60.00	0.10	sec	3,4
Cube Writer	500.00	5000.00	50.00	msec	4	N/A	N/A	N/A	N/A	0
Discover Pro	0.00	99.00	1.00	unknowr	3, 4	N/A	N/A	N/A	N/A	0
EZ Keys	0.10	20.00	0.05	sec	3	0.05	10.00	0.05	sec	3
Gus! Access Keyboard	?	?	0.25	sec	1, 2	N/A	N/A	N/A	N/A	0
KeyVit	0.00	99900.00	10.00	msec	4	N/A	N/A	N/A	N/A	0
QualiKEY	1.00	9.90	0.10	sec	3, 4	N/A	N/A	N/A	N/A	0
REACH Interface Author	0.10	10.00	0.10	sec	3, 5	0.10	10.00	0.10	sec	3, 5
Special Access to Windows	0.10	10.00	0.10	sec	4	0.10	20.00	% of scan rate	sec	4
WiViK	0.25	4.00	0.25	sec	1, 3	0.25	20.00	various (0.25-4.0)	sec	3
Prentke Romich Pathfinder Pl	0.10	5.00	0.10	sec	4	N/A	N/A	N/A	N/A	0
Dynavox	0.00	99.00	1.00	unknowr	2	0.00	2000.00	100.00	msec	2
Talking Screen	0.50	20.00	0.50	sec	3	0.50	20.00	0.50	sec	3
ScanBuddy	0.10	10.00	0.10	sec	3	0.10	10.00	0.10	sec	3
CrossScanner	Slow	Fast	unknown	unknowr	1	N/A	N/A	N/A	N/A	0

Initial Delay (col)			Loop Count			Input	Scan Behavior			Input	Scan Mode	
Max	Increments	Units	Min	Max	Inc	Method	Reverse Scan	Stop Scan	Re-Scan	Method	Automatic	Manual
N/A	N/A	N/A	1	10	1	2	N	N	N	0	N	N
60.00	0.10	sec	1	20	1	3,4	Y	Y	Y	5	Y	Y
N/A	N/A	N/A	N/A	N/A	N/A	0	N	N	N	0	Y	Y
N/A	N/A	N/A	1	9	1	3,4	N	Y	N	5	Y	Y
10.00	0.05	sec	1	10	1	3	N	N	N	0	Y	Y
N/A	N/A	N/A	2		1	3	N	N	N	0	Y	Y
199800.00	10.00	msec	0	99	1	4	N	N	N	0	Y	Y
N/A	N/A	N/A	1	99	1	3,4	N	N	N	0	Y	Y
10.00	0.10	sec	1	5	1	3, 5	Y	N	Y	3, 5	Y	Y
20.00	% of scan rate	sec	N/A	N/A	N/A	0	N	Y	N	5	Y	Y
20.00	various (0.25-4.0)	sec	0	10	1	3	Y	Y	N	5	Y	Y
N/A	N/A	N/A	0	10	1	4	N	N	N	0	Y	Y
2000.00	100.00	msec	1	4	1	2	N	Y	Y	5	Y	Y
20.00	0.50	sec	1	10	1	3	N	N	N	0	Y	Y
10.00	0.10	sec	1	5	1	3	N	Y	N	5	Y	Y
N/A	N/A	N/A	N/A	N/A	N/A	0	N	N	N	0	N	N

Input Method	Switch Behavior				Input Method
	Switch Repeat	Repeat Delay	Repeat Rate	Acceptance Delay	
0	N	N	N	N	0
5	Y	Y	Y	Y	3,4
5	N	N	N	N	0
5	Y	Y	Y	Y	2,5
5	Y	Y	Y	Y	3
5	N	N	N	N	0
5	Y	Y	Y	Y	4
5	N	N	N	Y	4
5	N	Y	N	Y	4
5	Y	Y	Y	Y	4
5	Y	N	N	Y	1
5	Y	Y	Y	Y	5
5	N	N	N	Y	1
5	Y	Y	Y	Y	3
5	N	N	N	N	0
0	N	N	N	N	0

Input Control Methods		
Code	Name	Input Control Description
0	none	no user control
1	incremental	level of variable can be modified without numerical feedback
2	qualitative interval	level of variable can be modified on an undefined numeric scale
3	quantitative interval	level of variable can be modified on a defined numeric scale
4	continuous	the variable is defined and can be directly entered
5	selection	variable is selected from list or feature is enabled by check/radio button

APPENDIX B : SMS INPUT XML FILE FORMAT


```
<?xml version="1.0" encoding="UTF-8"?>
<ScanParameters>

 <TrialNumber>1</TrialNumber>
 <TestCode>RMank-Base</TestCode>

 <Settings>
  <ScanRate>1.20</ScanRate>
  <InitialDelay>0.8</InitialDelay>
  <LoopCount>1</LoopCount>
  <NumOfRows>5</NumOfRows>
  <NumOfCols>6</NumOfCols>
  <ReverseScan>FALSE</ReverseScan>
  <OptimalScan>FALSE</OptimalScan>
  <BeginRowStopScan>FALSE</BeginRowStopScan>
  <EndRowStopScan>FALSE</EndRowStopScan>
  <ContinueScanAtRowEnd>FALSE</ContinueScanAtRowEnd>
 </Settings>

 <Probabilities>
  <ErrorFreeSelection>0.9</ErrorFreeSelection>
  <NoSwitchPress>0.025</NoSwitchPress>
  <NoSwitchPressInTargRow>0.025</NoSwitchPressInTargRow>
  <SwitchPressBeforeTargetRow>0.025</SwitchPressBeforeTargetRow>
  <SwitchPressAfterTargetRow>0.025</SwitchPressAfterTargetRow>
  <SwitchPressBeforeTargetCol>0.025</SwitchPressBeforeTargetCol>
  <SwitchPressAfterTargetCol>0.0</SwitchPressAfterTargetCol>
  <DetectingError>1.0</DetectingError>
  <FixingError>0.2667</FixingError>
  <CorrectCharFix>0.00</CorrectCharFix>
  <BackspaceWithCorrectChar>0.2667</BackspaceWithCorrectChar>
  <IncorrectSelectToExitScan>0.0</IncorrectSelectToExitScan>
 </Probabilities>

 <SwitchPressTimes>
  <SwitchHitsPerChar>2</SwitchHitsPerChar>
  <HoldTimeToRegisterSelection>1.37</HoldTimeToRegisterSelection>
  <DownTime>0.7</DownTime>
  <HoldTime>0.34</HoldTime>
  <UpTime>0.34</UpTime>
  <RecoveryTime>0.15</RecoveryTime>
```

```
 <Single>0.5</Single>
 <Double>2.30</Double>
 <Triple>3.35</Triple>
</SwitchPressTimes>

<SelectionsPerWord>5.0</SelectionsPerWord>

<NumberOfScanGroups>2</NumberOfScanGroups>

<Matrix>
     <MatrixName>Alphabetic5x6</MatrixName>

     <Item>
           <Key>a</Key>
           <Row>1</Row>
           <Column>1</Column>
           <Frequency>0.06306713</Frequency>
     </Item>
     <Item>
           <Key>b</Key>
           <Row>1</Row>
           <Column>2</Column>
           <Frequency>0.01210027</Frequency>
     </Item>
     <Item>
           <Key>c</Key>
           <Row>1</Row>
           <Column>3</Column>
           <Frequency>0.01909225</Frequency>
     </Item>
     <Item>
           <Key>d</Key>
           <Row>1</Row>
           <Column>4</Column>
           <Frequency>0.03576957</Frequency>
     </Item>
     <Item>
           <Key>e</Key>
           <Row>1</Row>
           <Column>5</Column>
           <Frequency>0.09757778</Frequency>
     </Item>
     <Item>
           <Key>f</Key>
           <Row>1</Row>
           <Column>6</Column>
           <Frequency>0.01649440</Frequency>
     </Item>
     <Item>
           <Key>g</Key>
           <Row>2</Row>
           <Column>1</Column>
           <Frequency>0.01684738</Frequency>
     </Item>
     <Item>
           <Key>h</Key>
           <Row>2</Row>
```

```
        <Column>2</Column>
        <Frequency>0.04945014</Frequency>
</Item>
<Item>
        <Key>i</Key>
        <Row>2</Row>
        <Column>3</Column>
        <Frequency>0.05302780</Frequency>
</Item>
<Item>
        <Key>j</Key>
        <Row>2</Row>
        <Column>4</Column>
        <Frequency>0.00118101</Frequency>
</Item>
<Item>
        <Key>k</Key>
        <Row>2</Row>
        <Column>5</Column>
        <Frequency>0.00751517</Frequency>
</Item>
<Item>
        <Key>l</Key>
        <Row>2</Row>
        <Column>6</Column>
        <Frequency>0.03253001</Frequency>
</Item>
<Item>
        <Key>m</Key>
        <Row>3</Row>
        <Column>1</Column>
        <Frequency>0.01974424</Frequency>
</Item>
<Item>
        <Key>n</Key>
        <Row>3</Row>
        <Column>2</Column>
        <Frequency>0.05291058</Frequency>
</Item>
<Item>
        <Key>o</Key>
        <Row>3</Row>
        <Column>3</Column>
        <Frequency>0.05935676</Frequency>
</Item>
<Item>
        <Key>p</Key>
        <Row>3</Row>
        <Column>4</Column>
        <Frequency>0.01334276</Frequency>
</Item>
<Item>
        <Key>q</Key>
        <Row>3</Row>
        <Column>5</Column>
        <Frequency>0.00072467</Frequency>
</Item>
```

<Item>
<Key>r</Key>
<Row>3</Row>
<Column>6</Column>
<Frequency>0.04504855</Frequency>
</Item>
<Item>
<Key>s</Key>
<Row>4</Row>
<Column>1</Column>
<Frequency>0.04850397</Frequency>
</Item>
<Item>
<Key>t</Key>
<Row>4</Row>
<Column>2</Column>
<Frequency>0.07133499</Frequency>
</Item>
<Item>
<Key>u</Key>
<Row>4</Row>
<Column>3</Column>
<Frequency>0.02286781</Frequency>
</Item>
<Item>
<Key>v</Key>
<Row>4</Row>
<Column>4</Column>
<Frequency>0.00723075</Frequency>
</Item>
<Item>
<Key>w</Key>
<Row>4</Row>
<Column>5</Column>
<Frequency>0.01849518</Frequency>
</Item>
<Item>
<Key>x</Key>
<Row>4</Row>
<Column>6</Column>
<Frequency>0.00119727</Frequency>
</Item>
<Item>
<Key>y</Key>
<Row>5</Row>
<Column>1</Column>
<Frequency>0.01581755</Frequency>
</Item>
<Item>
<Key>z</Key>
<Row>5</Row>
<Column>2</Column>
<Frequency>0.00070790</Frequency>
</Item>
<Item>
<Key>.</Key>
<Row>5</Row>

```
            <Column>4</Column>
            <Frequency>0.01232725</Frequency>
      </Item>
      <Item>
            <Key>sp</Key>
            <Row>5</Row>
            <Column>3</Column>
            <Frequency>0.19050025</Frequency>
      </Item>
      <Item>
            <Key>ret</Key>
            <Row>5</Row>
            <Column>5</Column>
            <Frequency>0.00071</Frequency>
      </Item>
      <Item>
            <Key>bk</Key>
            <Row>5</Row>
            <Column>6</Column>
            <Frequency>0.005</Frequency>
      </Item>

 </Matrix>

</ScanParameters>
```

APPENDIX C : SCAN METHOD SETTING

There are six options for the scan method setting of the Scanning Model Software (SMS). This setting is used to set scanning matrix configuration and functionality options used for text entry rate (TER) calculations. In all options, the original matrix as defined in the input XML file remains, but items/buttons are added to the matrix for the mathematical calculation.

Scan Method	Function
Normal	Forward scanning with matrix layout defined in XML input file.
Reverse Scan	Reverse scan item/button in first column of each matrix row that will scan columns in reverse direction when selected.
Stop Scan Item (start of row)	Stop scan item/button in first column of each matrix row that will stop scanning of current row when selected.
Stop Scan Item (end of row)	Stop scan item/button in last column of each matrix row that will stop scanning of current row when selected.
Continue Scan Item (end of row)	Continue scan item/button in last column of each matrix row that will continue the scanning of current row when selected.
Optimal	Reverse scan item/button in first column of each matrix row that will scan columns in reverse direction when selected. This assumes optimal selection (i.e. using reverse button desired matrix selection is in the second half of the row and forward scanning when item is in first half of row).

APPENDIX D : SCAN SETTINGS AND FORMULAS

Modeling One-Switch Row-Column Scanning

Quantity	Var	Units	Default Value
Time to select the item in row i and column j	T_{ij}	seconds	
Scan rate	R	seconds/scan period	
Scan steps to item in row i and column j	S_{ij}		
Average number of selections per word	C		5
Initial delay	I	seconds	
Switch hits per character	H		2 or 3
Time switch must be held down to register a selection	K	seconds	
Switch press down time	P_d	seconds	
Switch press hold time	P_h	seconds	
Switch press up time	P_u	seconds	
Switch press recovery time	P_r	seconds	
Single switch press	P_1	seconds	$P_1 = K$
Double switch press	P_2	seconds	$P_2 = P_d+P_h+P_u+P_r+K$
Triple switch press	P_3	seconds	$P_3 = 2(P_d+P_h+P_u+P_r)+K$
X switch presses in a row	P_x	seconds	$P_x = (x-1)*(P_d+P_h+P_u+P_r)+K$
Number of scan groups	G		2 (rows, columns)
Number of rows in matrix	r		
Number of columns in row i	c_i		
Loop count	L		
Probability of error-free selection	P_c		We can get this from IDA Phase I
Probability of not pressing switch	P_n		
Probability of pressing switch too early	P_e		
Probability of pressing switch too late	P_l		.025 (from .65 rule)
Probability of detecting error	P_d		
Probability of fixing error	P_f		
average penalty per selection when switch not pressed on target row	$D_{n,row}$		
average penalty per selection when	$D_{e,row}$		

switch is pressed before target row			
average penalty per selection when switch is pressed after target row	$D_{l,row}$		
average penalty per selection when switch not pressed on target column	$D_{n,col}$		
average penalty per selection when switch is pressed before target column	$D_{e,col}$		
average penalty per selection when switch is pressed after target column	$D_{l,col}$		

Times to be modeled:

- No errors
- Errors of omission
  - Fail to press the switch to select the correct row at first opportunity
  - Fail to press the switch to select the correct column at first opportunity
- Errors of commission
  - Select row too early
  - Select row too late
  - Select column too early
  - Select column too late

When a user selects the wrong row (either too early or too late), there must be a mechanism for aborting the column scan. The options available on commercial products are:

1. A fixed "loop count" that defines the number of times the columns within each row are scanned before row-scanning recommences
2. A "stop scanning" item at the beginning of the row
3. A "stop scanning" item at the end of the row
4. Selecting an (incorrect) item within the row

When the user selects the correct row, but fails to make a column selection, there must be some way to cause the system to scan through the row again. The options available on commercial products are:

1. A fixed "loop count" that defines the number of times the columns within each row are scanned before row-scanning recommences
2. A "continue scanning" item at the end of the row that can be selected to re-initiate scanning through the row

Things we can measure:

- Switch press time
  - Single switch press
  - Double switch press
  - Triple switch press
- Error probabilities
  - Failure to press switch

    - Fail to press the switch to select the correct row at first opportunity
    - Fail to press the switch to select the correct column at first opportunity
  - Press switch too early
    - Select row too early
    - Select column too early
  - Press switch too late (this is presumably 2.5% based on .65 rule)
    - Select row too late
    - Select column too late
- Error correction probabilities (these add to 1)
  - Immediately corrects a typo (selects backspace, then types in correct character)
  - Doesn't correct a typo, doesn't fill in correct letter
  - Doesn't correct a typo, puts in correct letter after it

Things we can set:

- Scan rate
- Initial delay
- Item to reverse scan through columns within row
- Abort scanning method
  - Loop count
  - "Stop scanning" item at beginning of row
  - "Stop scanning" item at end of row
  - "Continue scanning" item at end of row
- Where scanning starts after a selection is made
  - First row in matrix
  - Row where last selection was made
- Where scanning starts after column scanning is aborted
  - First row in matrix
  - At the row where column scanning was aborted
  - At the row before column scanning was aborted
  - At the row after column scanning was aborted

Types of items that can be in a matrix:

- Static
  - Character
  - Stop scanning
  - Reverse scan direction
- Dynamic
  - Character prediction
  - Word prediction

A system can respond to a switch in several ways:

- Register selection as soon as a switch down is registered ($K = P_d$)
- Register a selection after the switch is held down for a set time ($K = P_d + P_h$)
- Register a selection as soon as a switch up is registered ($K = P_d + P_h + P_u$)

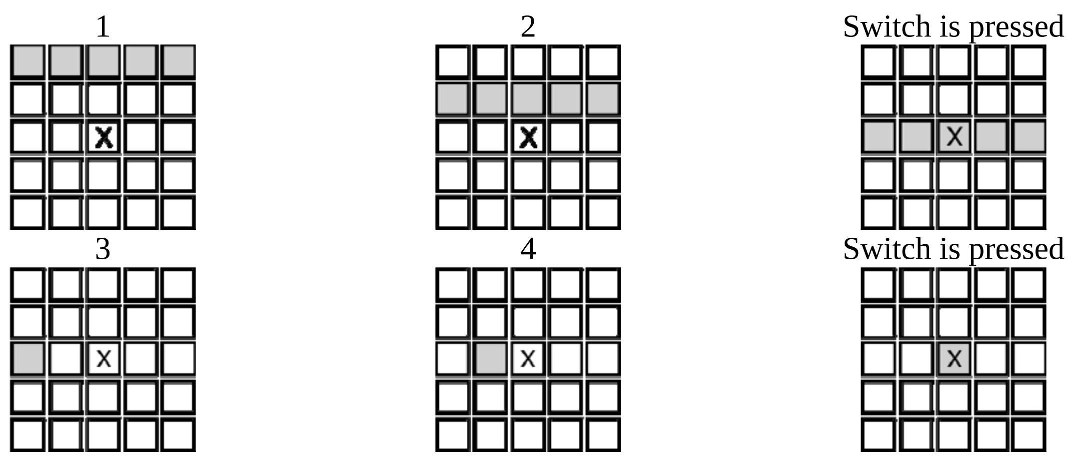
- Register repeat selections if the switch is held down ($K_1 = P_d$; $K_2 = P_d + P_h$)

D.1 SELECTIONS

D.1.1 Correct Selections

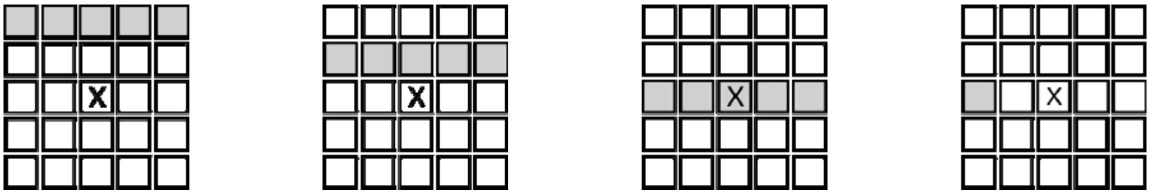
Here we assume that the person makes no errors. The fewest number of scans are needed to reach the target, and the target is selected immediately.

Scan steps (assuming forward scanning) to a target character in row *i* and column *j* is given by:
$S_{ij} = (i - 1) + (j - 1) = i + j - 2$

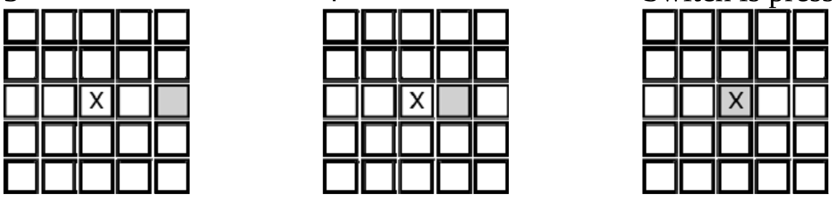


If the user can reverse the scan direction through a row, however, then the number of scan steps is given by:
$\overline{S}_{ij} = (i-1)+(c_i - j) = i + c_i - j - 1$

1 2 Switch pressed twice in a row (once to select row, once to reverse scanning)



3 4 Switch is pressed



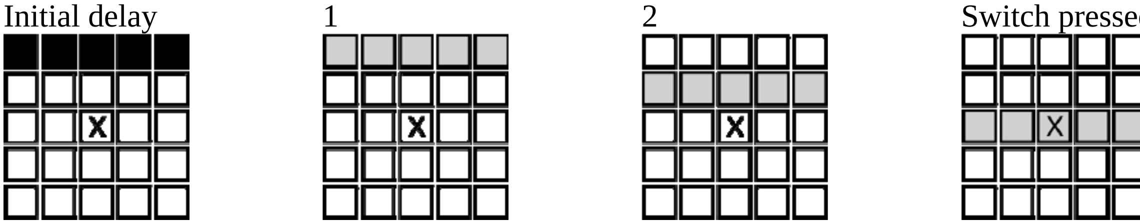
D.1.2 Time to select a character (Forward Scanning)

T = [scan rate] * [scan steps] + [switch press time] * [switch hits] + [init delay] * [num groups]
T = (R)(S) + (K)(H) + (I)(G)

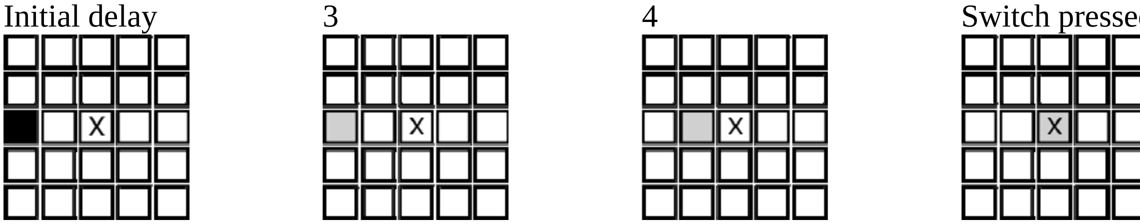
Other than first row and first column

$$T_{ij} = (R)(S_{ij}) + 2K + 2I$$

Initial delay 1 2 Switch pressed



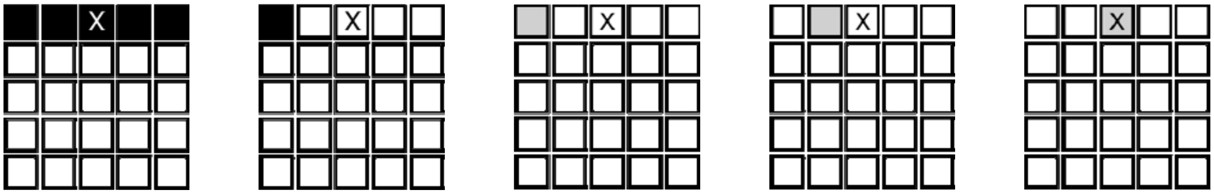
Initial delay 3 4 Switch pressed



First row

$$T_{ij} = (R)(S_{ij}) + (K)(H_{ij}) + I$$

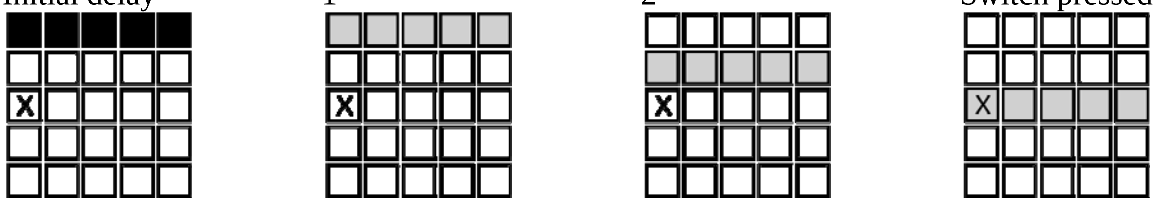
Switch pressed Initial delay 1 2 Switch pressed



First Column

$T_{ij} = (R)(S_{ij}) + (K)(H_{ij}) + P_2$ QUESTION

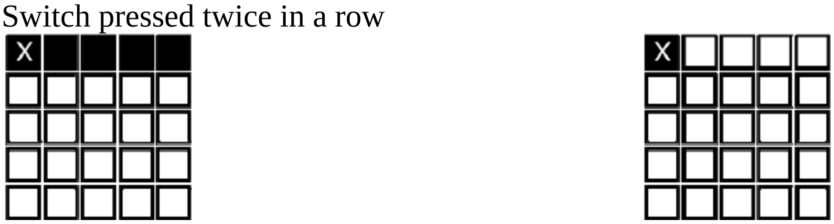
Initial delay 1 2 Switch pressed twice



First row and first column

$T_{ij} = (R)(S_{ij}) + P_2 = P_2$

Switch pressed twice in a row



D.1.3 Time to select a character (Reverse Scanning)

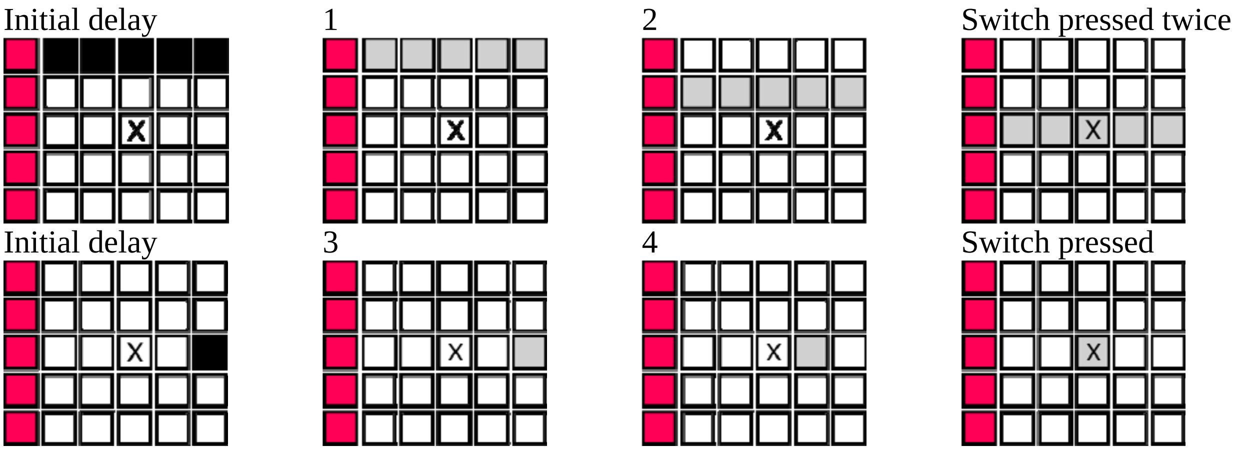
In this instance, we're assuming that there is no initial delay when the reverse column scan is initiated. In other words, the user reaches the desired row, hits the switch once to select the row, hits the switch a second time to reverse scanning, and then reverse scanning commences.

T = [scan rate] * [scan steps] + [switch press time] + [double switch hit time] + [init delay for rows]

T = (R)(S) + (K) + P_2 + (I)

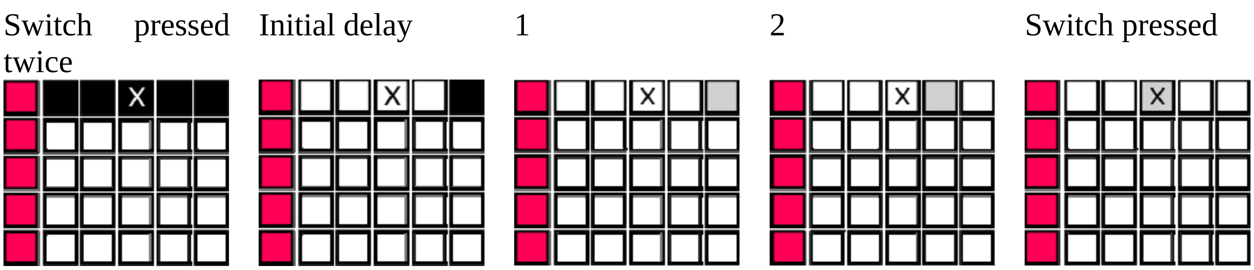
Other than first row and last column

$T_{ij} = 2I + (R)(\bar{S}_{ij}) + P_2 + K$



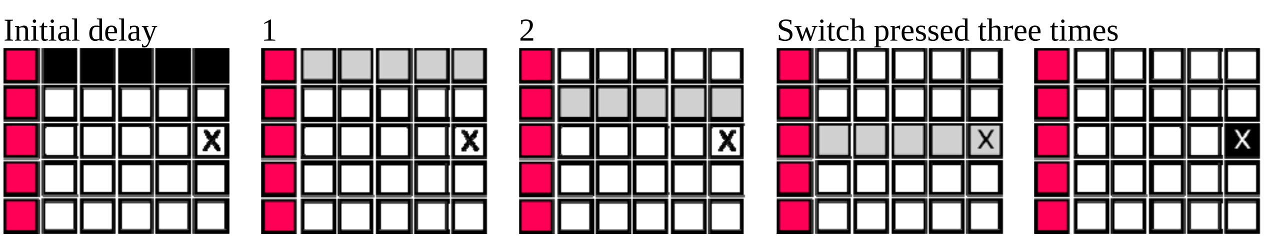
First row

$T_{ij} = P_2 + I + (R)(\bar{S}_{ij}) + K$



Last column (in any row other than the first)

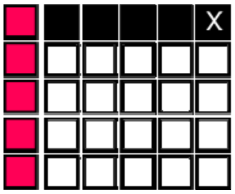
$T_{ij} = I + (R)(\bar{S}_{ij}) + P_3$



First row and last column

$T_{ij} = (R)(S_{ij}) + P_3 = P_3$

Switch pressed three times in a row



D.1.4 Selections With One Error

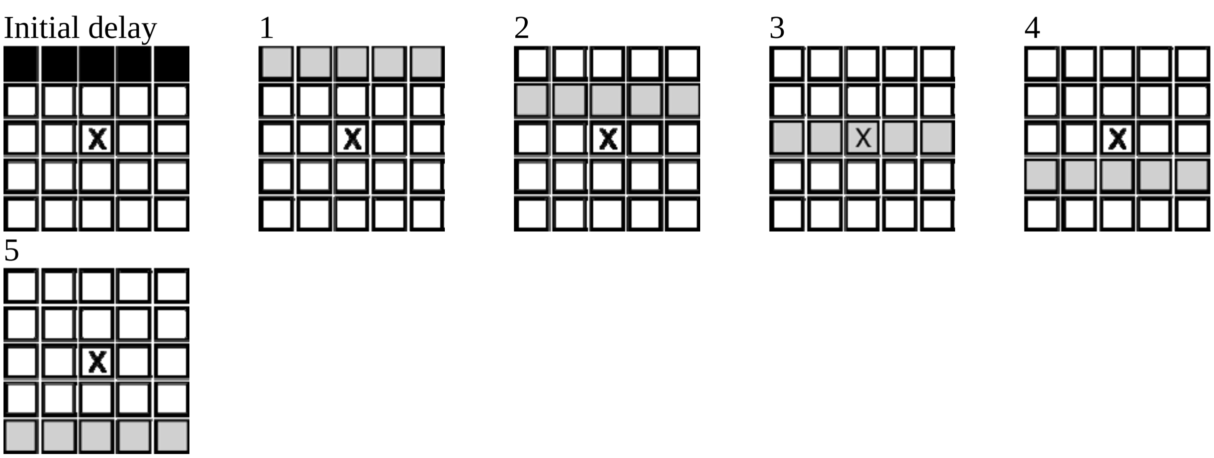
Here we assume that one error occurs. This may be an error of omission (failing to press the switch) or commission (pressing the switch at the wrong time). We can calculate the time penalty associated with each type of mistake. The total time is then:

T_{ij+p} = [time for an error-free selection] + [time penalty]
$T_{ij+p} = T_{ij} + D$

FAILING TO SELECT THE TARGET ROW

In this case, the user scans through all the rows in the matrix once and then scans through again to make a selection.

$D_{n,row}$ = [scan rate] * [number of rows] + [initial delay]
$D_{n,row} = (R) * (r) + I$



Question: Is the initial delay added in each time the first row is highlighted? Or is it only added in the first time the first row is highlighted? We can check this by putting in a ridiculously large initial delay and letting the scan wrap around. Here, we are assuming that the initial delay is added each time.

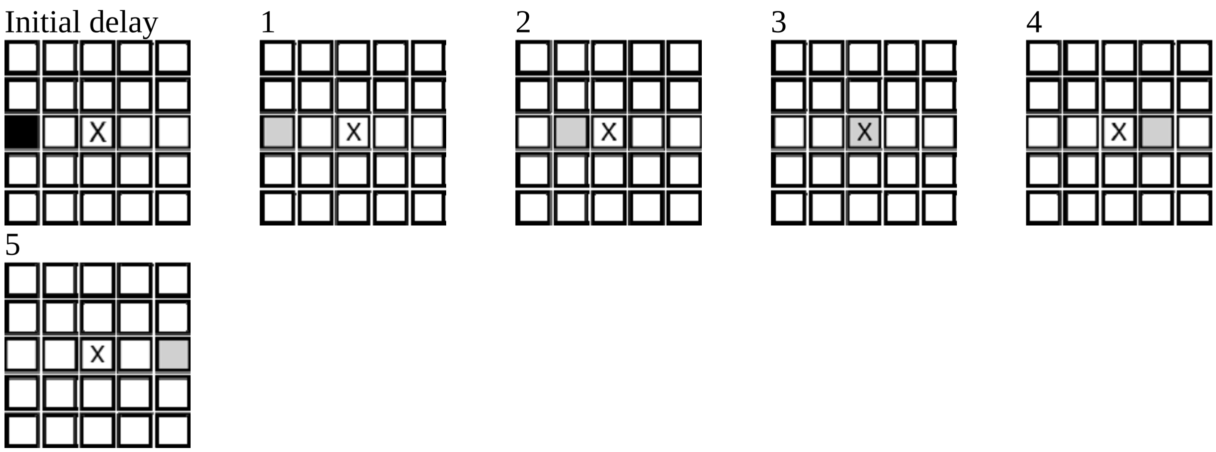
FAILING TO SELECT THE TARGET COLUMN

In this case, the user selects the target row then fails to press the switch when the target column is highlighted.

LOOP COUNT GREATER THAN 1

In this case, row scanning automatically restarts at the beginning of the row once the end of the row is reached. The user must therefore scan through all the columns within the row once.

$D_{n,col}$ = [scan rate] * [number of columns] + [initial delay]
$D_{n,col} = (R) * (c_i) + I$

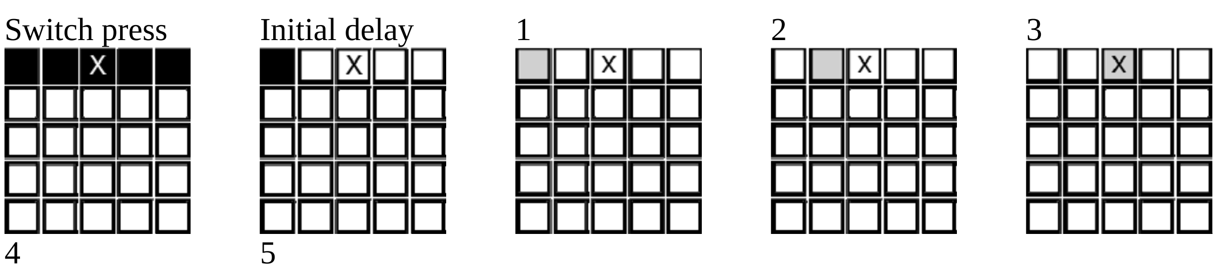


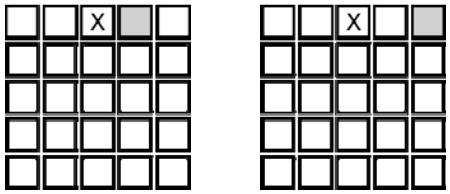
Question: Is the initial delay added in each time the first column is highlighted? Or is it only added in the first time the first row is highlighted? We can check this by putting in a ridiculously large initial delay and letting the scan wrap around. Here, we are assuming the delay is added each time

LOOP COUNT OF 1, NO OPTION TO RE-SCAN ROW

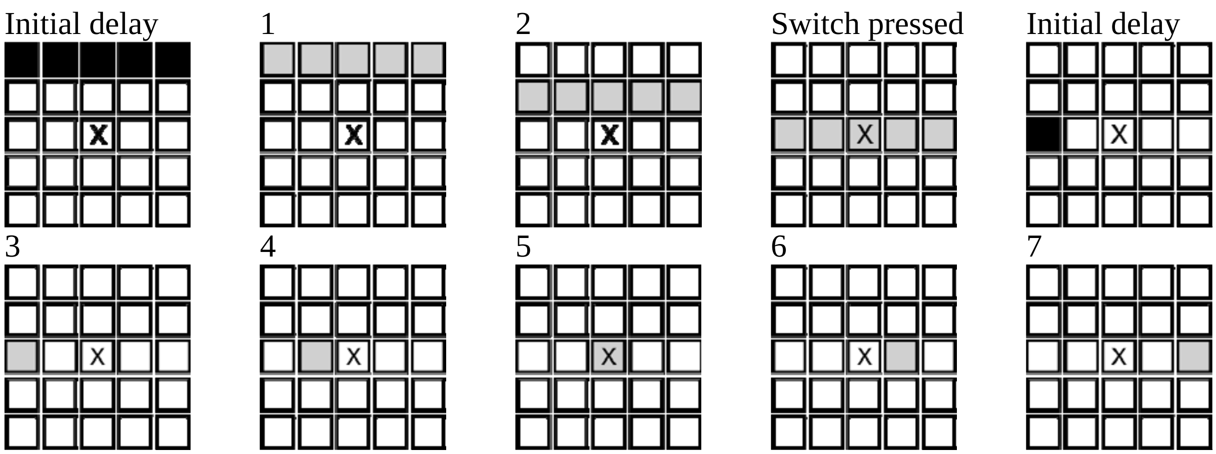
In this case, the system starts over with row-scanning at the top of the matrix once the end of the column is reached.

First row:
$D_{n,col}$ = [scan rate] * [position of row i in matrix - 1] + [scan rate] * [number of columns] + I + K
$D_{n,col} = K + I + (R) * (c_i)$





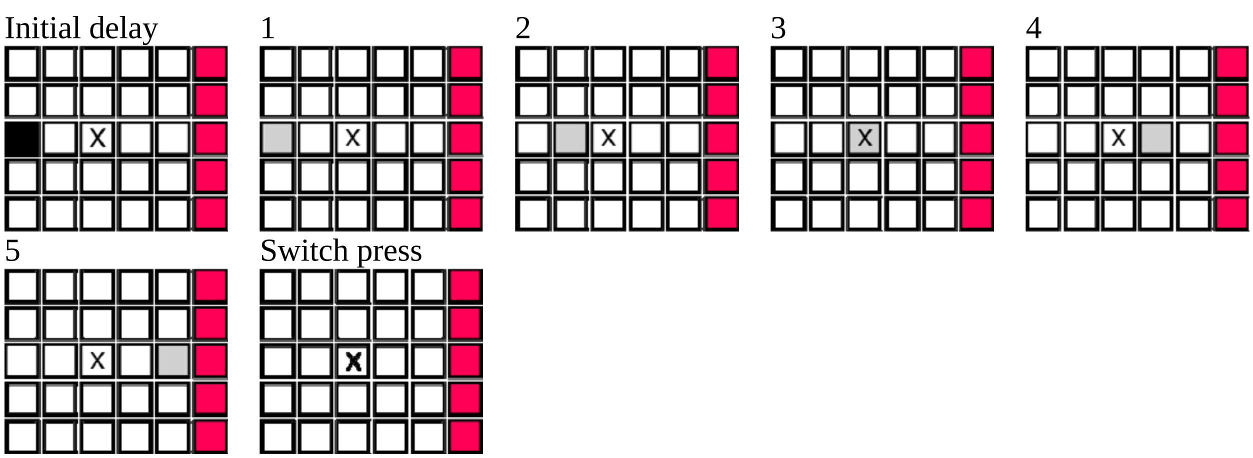
Not first row:
$D_{n,col}$ = [scan rate] * [position of row i in matrix - 1] + [scan rate] * [number of columns] + 2I + K
$D_{n,col} = I + (R) * (i - 1) + K + I + (R) * (c_i) = 2I + K + R * (c_i + i - 1)$



QUESTION-Loop count of 1, item to re-scan row at end of row

In this case, once the end of the row is reached the user must press the switch to initiate another scan through the row. If the user does not press the switch, then row-scanning is initiated.

$D_{n,col}$ = [scan rate] * [number of columns - 1] + [switch press time] + [initial delay]
$D_{n,col} = (R) * (c_i - 1) + K + I$



Question: Is the initial delay added in each time the first column is highlighted? Or is it only added in the first time the first row is highlighted? We can check this by putting in a ridiculously large initial delay and letting the scan wrap around. Here, we're assuming the initial delay is added each time, which makes sense to me.

SELECTING THE ROW BEFORE THE TARGET ROW

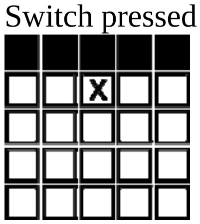
In this case, the user presses the switch too soon and selects the row before the target row (2 <= i <= r). The time penalty depends on the method used to abort the row scan. In this situation, it's impossible to select the row before the first row, so i >= 2.

FIXED LOOP COUNT

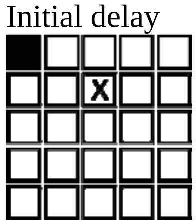
Here the user must wait for the system to scan through row *i-1* a fixed number of times before re-scanning. It is assumed that row scanning resumes at the first row after the system scans the columns of row *i-1* the fixed amount.

Select first row when target is in second row (i = 2)
$D_{e,row}$ = [position of row *i* in matrix - 1] * [scan rate] + [switch press time] + [number of columns in row i] * [scan rate] * [loop count] + [initial delay]
$D_{e,row} = (i - 2)(R) + (K) + (c_{i-1})(R)(L) + I = K + I + (c_{i-1})(R)(L)$

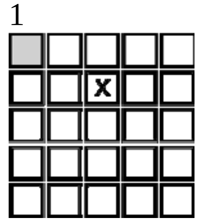
Switch pressed



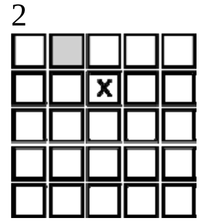
Initial delay



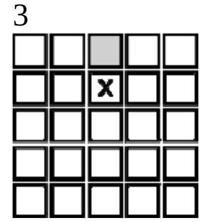
1



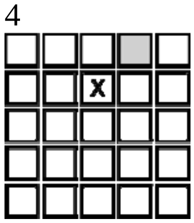
2



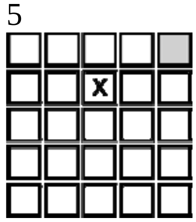
3



4

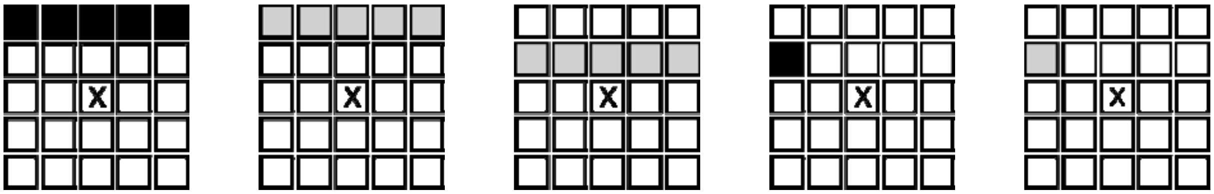


5

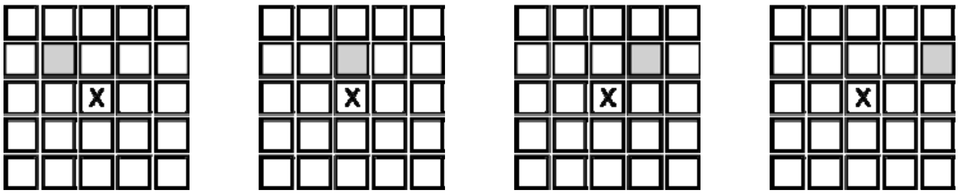


Select something other than first row, target not in second row (3 <= i <= r)
$D_{e,row}$ = [position of row *i* in matrix - 1] * [scan rate] + [switch press time] + [number of columns in row i] * [scan rate] * [loop count] + [initial delay] * 2
$D_{e,row} = (i - 2)(R) + (K) + (c_{i-1})(R)(L) + 2I$

Initial delay 1 Switch pressed Initial delay 2



3 4 5 6



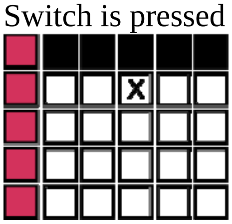
Question: Is the initial delay added in each time the first column is highlighted? Or is it only added in the first time the first row is highlighted? We can check this by putting in a ridiculously large initial delay and letting the scan wrap around. **Here, we're assuming the initial delay is NOT added each time**.

A "STOP SCANNING" ITEM AT BEGINNING OF ROW

Here the user selects the wrong row and then immediately selects an item to abort scanning through the row.

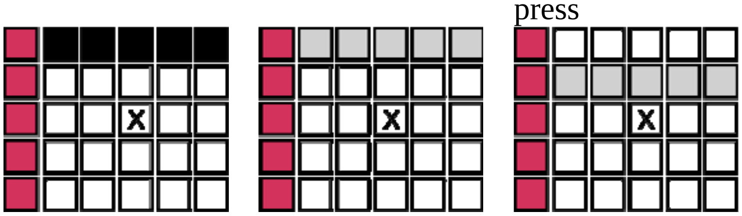
Select first row when target is in second row (i = 2)
$D_{e,row}$ = [position of row *i-1* in matrix - 1] * [scan rate] + [double switch press]
$D_{e,row} = (i - 2)(R) + P_2 = P_2$

Switch is pressed twice



Select something other than first row, target not in second row (3 <= i < r)
$D_{e,row}$ = [position of row *i-1* in matrix - 1] * [scan rate] + [double switch press] + [initial delay]
$D_{e,row} = (i - 2)(R) + P_2 + I$

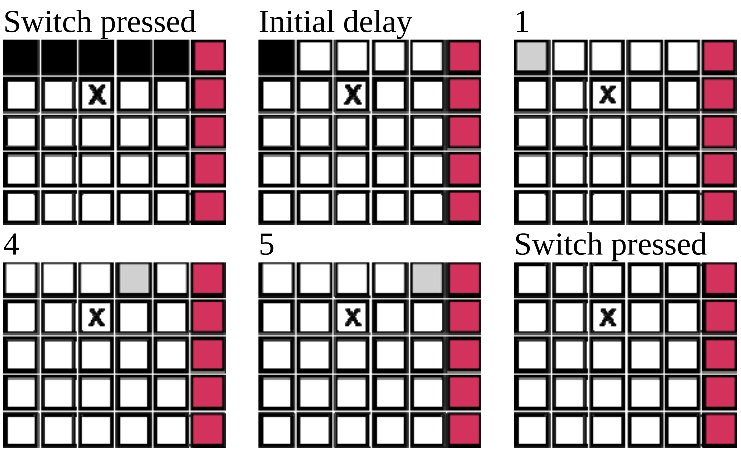
Initial delay 1 Double switch press



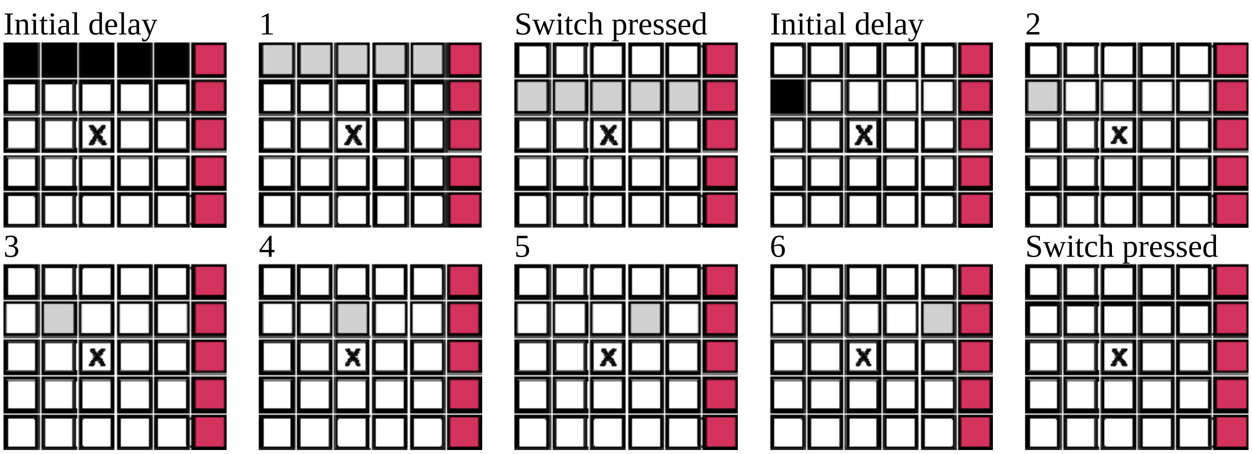
A “STOP SCANNING” ITEM AT END OF ROW

Here the user selects the wrong row and then selects an item to abort scanning through the row at the end of the first scan through the row.

User selects first row when target is in second row (i = 2)
$D_{e,row}$ = [position of row *i-1* in matrix - 1] * [scan rate] + [scan rate] * [number of columns - 1] + 2 * [switch press time] + [initial delay]
$D_{e,row} = (i - 2)(R) + (R) * (c_{i-1} - 1) + 2K + I = (R) * (c_{i-1} - 1) + 2K + I$



User selects row other than first row, target not in second row (3 <= i <= r)
$D_{e,row}$ = [position of row *i-1* in matrix - 1] * [scan rate] + [scan rate] * [number of columns - 1] + 2 * [switch press time] + 2 * [initial delay]
$D_{e,row} = (i - 2)(R) + (R) * (c_{i-1} - 1) + 2K + 2I$



SELECTING AN INCORRECT ITEM

Here the user selects some item i-1, x to reinitiate scanning. Most often, x is 1 (i.e., the first item in the wrong row).

$D_{e,row} = T_{i-1,x}$

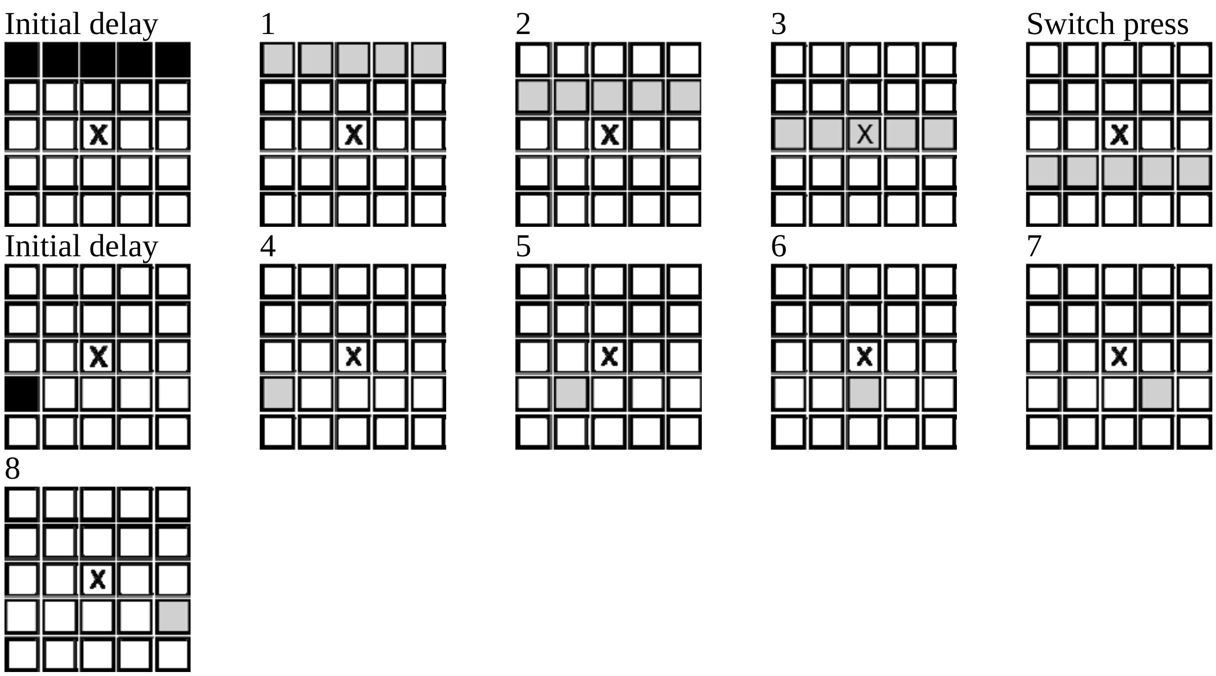
SELECTING THE ROW AFTER THE TARGET ROW

In this case, the user presses the switch too late and selects the row after the target row. The time penalty depends on the method used to abort the row scan. Any row in the matrix can be selected. If the target row is the last row in the matrix (i = r) then the person selects the first row in the matrix after it wraps around.

FIXED LOOP COUNT

Here the user must wait for the system to scan through row *i+1* a fixed number of times before re-scanning. . It is assumed that row scanning resumes at the first row after the system scans the columns of row *i+1* the fixed amount.

$D_{l,row}$ = [position of row *i* in matrix + 1] * [scan rate] + [switch press time] + [number of columns in row i+1] * [scan rate] * [loop count] + 2 * [initial delay]
$D_{l,row} = (i)(R) + (K) + (c_{i+1})(R)(L) + 2I$



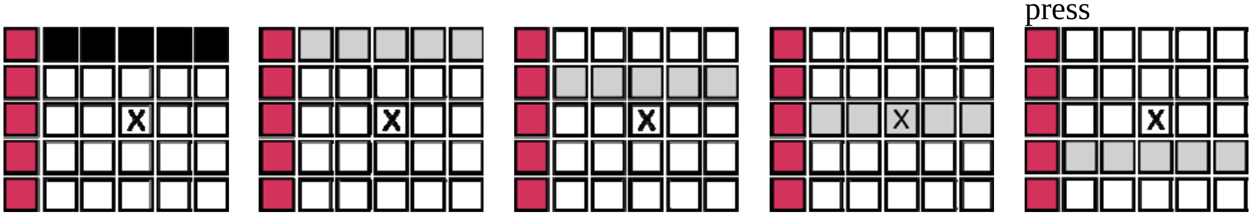
Question: Is the initial delay added in each time the first column is highlighted? Or is it only added in the first time the first row is highlighted? We can check this by putting in a ridiculously large initial delay and letting the scan wrap around. **Here, we're assuming the initial delay is NOT added each time**.

A “STOP SCANNING” ITEM AT BEGINNING OF ROW

Here the user selects the wrong row and then immediately selects an item to abort scanning through the row.

$D_{l,row}$ = [position of row *i+1* in matrix - 1] * [scan rate] + [double switch press] + [initial delay]
$D_{l,row} = (i)(R) + P_2 + I$

Initial delay | 1 | 2 | 3 | Double switch press

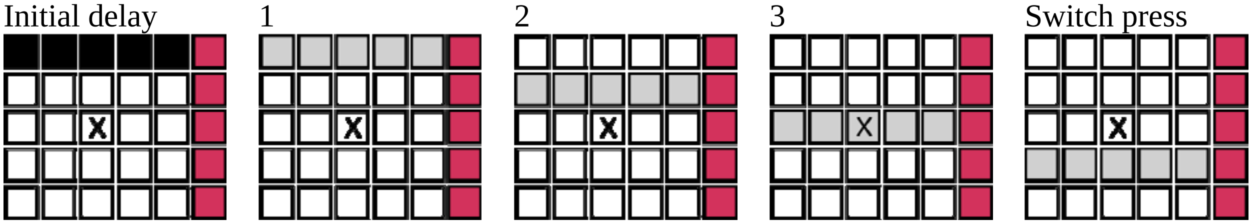


A “STOP SCANNING” ITEM AT END OF ROW

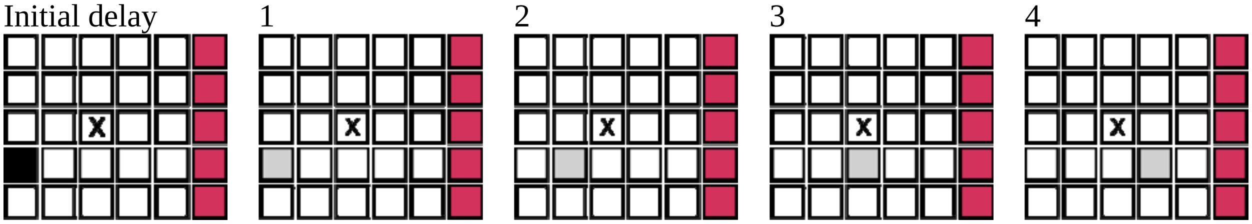
Here the user selects the wrong row and then selects an item to abort scanning through the row at the end of the first scan through the row.

$D_{l,row}$ = [position of row *i+1* in matrix - 1] * [scan rate] + [scan rate] * [number of columns - 1] + [switch press time] + [initial delay] * 2
$D_{l,row} = (i)(R) + (R)(c_{i+1} - 1) + 2K + 2I$

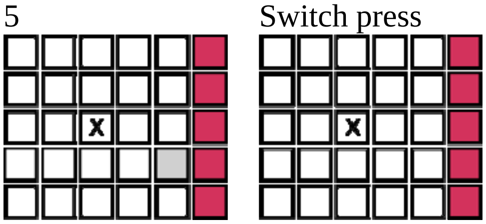
Initial delay | 1 | 2 | 3 | Switch press



Initial delay | 1 | 2 | 3 | 4



5 | Switch press



SELECTING AN INCORRECT ITEM

Here the user selects some item i+1, x to reinitiate scanning. Most often, x is 1 (i.e., the first item in the wrong row).

$D_{l,row} = T_{i+1,x}$

SELECTING THE WRONG COLUMN

Unlike selecting the wrong row, selecting the wrong column actually inserts a character into the document. The time penalty for selecting the wrong column, then, depends on whether or not the user notices the error, and whether or not the person chooses to correct the error.

The time penalty can be calculated based on the number of additional keystrokes the error causes:

- Zero additional keystrokes ($D_{l,col} = D_{e,col} = 0$)
  - User doesn't notice error
  - User notices error, doesn't erase, skips correct character
- One additional keystroke ($D_{l,col} = D_{e,col}$ = time for incorrect keystroke)
  - User notices error, doesn't erase, selects correct character
- Two additional keystrokes ($D_{l,col} = D_{e,col}$ = time for backspace key + time for incorrect keystroke)
  - User notices error, erases incorrect character, selects correct character

Inserted by Bob:

P_d = Probability of detecting error-determined by looking at sentence test data (#errors fixed / # errors)

P_f = Probability of fixing error – probability is 1.0 - participants were asked to fix all errors before start of sentence test.

P_{fc}= Probability of fixing error by selecting correct character – determined from data

P_{fbk}= Probability of fixing error by deleting char (backspace) and selecting correct character- determined from data

Since $P_f = 1.0$, user must fix error so $P_{fbk} + P_{fc} = 1.0$.

$$D_{l,col} = D_{e,col} = P_d * ((P_{fc} * T_{avg}) + (P_{fbk} * (T_{bk} + T_{avg})))$$

$$D_{l,col} = D_{e,col} =$$
$$((1.0 - P_d) * 0.0) + (P_d * (((1.0 - P_f) * 0.0) + (P_f * ((P_{fc} * T_{avg}) + (P_{fbk} * (T_{bk} + T_{avg}))))))$$
$$= (P_d * (P_f * ((P_{fc} * T_{avg}) + (P_{fbk} * (T_{bk} + T_{avg}))))))$$

$$T_{bk\text{-}fix} = (P_{fbk} * (T_{bk} + T_{avg}))$$
$$T_{cc\text{-}fix} = (P_{fc} * T_{avg})$$
$$T_{fix} = P_f * (T_{bk\text{-}fix} + T_{cc\text{-}fix})$$

An easier way to integrate incorrect column selections is to increase the number of selections per word.

D.1.5 Average selection time

We have the following variables:

- P_c = Probability of error-free selection
- P_n = Probability of not pressing switch
- P_e = Probability of pressing switch too early
- P_l = Probability of pressing switch too late
- $\underline{T}$ = average number of seconds per selection when no errors occur
- $\underline{D_{n,row}}$ = average penalty per selection when switch not pressed on target row
- $\underline{D_{e,row}}$ = average penalty per selection when switch is pressed before target row
- $\underline{D_{l,row}}$ = average penalty per selection when switch is pressed after target row
- $\underline{D_{n,col}}$ = average penalty per selection when switch not pressed on target column
- $\underline{D_{e,col}}$ = average penalty per selection when switch is pressed before target column
- $\underline{D_{l,col}}$ = average penalty per selection when switch is pressed after target column

$\underline{ST} = (P_c)(T) + (P_n)(T+D_{n,row}) + (P_n)(T+D_{n,col}) + (P_e)(T+D_{e,row}) + (P_e)(T+D_{e,col}) + (P_l)(T+D_{l,col}) + (P_l)(T+D_{l,row})$

Since $P_c + P_n + P_e + P_l = 1$, we can simplify to:

$\underline{ST} = T + (P_n)(D_{n,row}) + (P_n)(D_{n,col}) + (P_e)(D_{e,row}) + (P_e)(D_{e,col}) + (P_l)(D_{l,col}) + (P_l)(D_{l,row})$

D.1.6 Average text entry rate

We have the following variables:

- $\underline{SPW}$ = average number of selections per word
- $\underline{ST}$ = average number of seconds per selection
- $\underline{TER}$ = average text entry rate (in words per minute)

$\underline{TER}$ = (selections / second) * (60 seconds / 1 minute) * (words / selection)
$\underline{TER} = (1/\underline{ST}) * (60) * (1/\underline{SPW})$

IDA

```
textEntryRate[i] = ( (correctLetters[i] / meanSentenceTime[i]) * 60 *
```

```
                    1000) / charsPerSentence;
```

WHAT ABOUT WORD AND CHARACTER PREDICTION?

Word prediction/completion and character prediction does several things:

- It definitely increases the size of the matrix
- It potentially adds time for the user to look at the dynamically changing items
- It potentially decreases the average scan length by putting targets closer to the origin
- It potentially decreases the average number of selections per word

As long as we write our equations in terms of average number of selections per word, we shouldn't have to explicitly consider word prediction/completion or character prediction. What we can do, however, is determine whether the decreased number of selections per word is worth the cost of increasing the size of the matrix.

DATA FROM LESHER, 1998

Lesher's 1998 article calculated the average number of scan steps per selection and the effects of character- and word-level prediction. Unfortunately, they only report the relative savings, not the actual number of scan steps.

Lesher's simulations made the following assumptions:

- 7x7 scanning matrix: 26 letters; space key; 10 numerals; 9 punctuation marks and symbols; return key; shift key; backspace key
- Automatic spacing after punctuation
- Automatic capitalization after a period

Matrices used by Lesher:

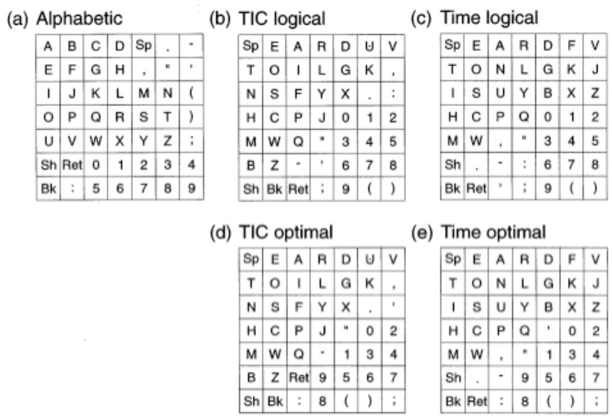


Figure 3. Five possible baseline matrix arrangements: (a) an alphabetic layout; (b) the TIC configuration proposed by Foulds et al. (1975), supplemented with a logical arrangement of punctuation marks and symbols; (c) the Time layout using a logical arrangement of characters; (d) the TIC arrangement with optimal positioning of the remaining characters; and (e) the Time configuration with optimal positioning of all characters.

Layout 3c was used to generate all baseline measures.

All their data was reported in terms of "switch count":
We remind the reader that during single-switch scanning, the switch count includes both the number of physical switch activations and the number of scan periods associated with the automated progression from one group to the next.

Lesher also considered three ways of accessing the prediction list(s):

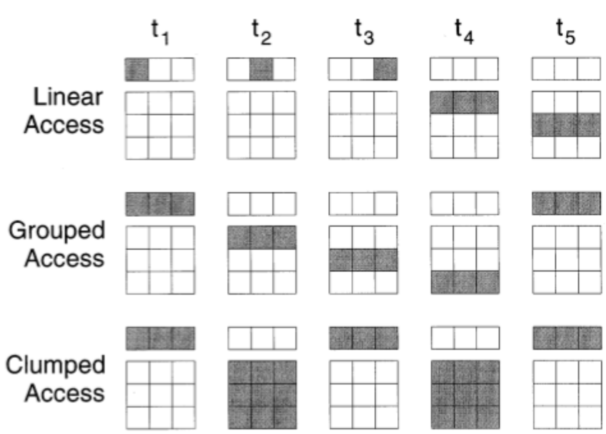


Figure 2. The three access methods that can be applied to a scanning matrix with an associated prediction list: linear, grouped, and clumped.

Lesher also looked at combining character- and word-level prediction:

A broad set of preliminary studies was performed to determine the viability of the various schemes for combining character and word prediction. Access order, access method, list size, *and delay sizes were independently varied for character and words lists, resulting in hundreds of configurations. These initial experiments revealed that nearly all of the access order and access method combinations produced savings worse than those reported for either character prediction or word prediction alone. The only promising configuration employed a grouped access word list, followed by a linear access character list, followed by the static character matrix.*

In general, he found that:

The application of a list-optimized character matrix and single-character prediction delays, either individually or in tandem, enhances performance under every configuration, although the gain is more profound for character lists. Since these methods add little or no complexity to a predictive scanning system, but provide sizable switch savings, we speculate that they could provide substantial improvements in text production rates for augmented communicators already using prediction lists. The practical advantage of techniques employing both character and word prediction, however, is less clear.

Default matrix

Sp	E	A	R	D	F	V
T	O	N	L	G	K	J
I	S	U	Y	B	X	Z
H	C	P	Q			
M	W	,				
Sh	.					
BkSp	Ret					

Matrix with initial delay

	Sp	E	A	R	D	F	V
	T	O	N	L	G	K	J
	I	S	U	Y	B	X	Z
	H	C	P	Q			
	M	W	,				
	Sh	.					
	BkSp	Ret					

Matrix with “stop scanning” item at front of each row

Stop	Sp	E	A	R	D	F	V
Stop	T	O	N	L	G	K	J
Stop	I	S	U	Y	B	X	Z
Stop	H	C	P	Q			
Stop	M	W	,				
Stop	Sh	.					
Stop	BkSp	Ret					

Matrix with “stop scanning” item at end of each row

Sp	E	A	R	D	F	V	Stop
T	O	N	L	G	K	J	Stop
I	S	U	Y	B	X	Z	Stop
H	C	P	Q				Stop
M	W	,					Stop
Sh	.						Stop
BkSp	Ret						Stop

Matrix with “reverse scan” item at start of each row

Rev	Sp	E	A	R	D	F	V
Rev	T	O	N	L	G	K	J
Rev	I	S	U	Y	B	X	Z
Rev	H	C	P	Q			
Rev	M	W	,				
Rev	Sh	.					
Rev	BkSp	Ret					

Matrix with “stop scanning” item at front of each row

Stop	Sp	E	A	R	D	F	V
Stop	T	O	N	L	G	K	J
Stop	I	S	U	Y	B	X	Z
Stop	H	C	P	Q			
Stop	M	W	,				
Stop	Sh	.					
Stop	BkSp	Ret					

Matrix with “stop scanning” item at end of each row

Sp	E	A	R	D	F	V	Stop
T	O	N	L	G	K	J	Stop
I	S	U	Y	B	X	Z	Stop
H	C	P	Q				Stop
M	W	,					Stop
Sh	.						Stop
BkSp	Ret						Stop

Matrix with “reverse scan” item at start of each row

Rev	Sp	E	A	R	D	F	V
Rev	T	O	N	L	G	K	J
Rev	I	S	U	Y	B	X	Z
Rev	H	C	P	Q			
Rev	M	W	,				
Rev	Sh	.					
Rev	BkSp	Ret					

Matrix with “keep scanning” item at end of each row

Sp	E	A	R	D	F	V	Re-scan
T	O	N	L	G	K	J	Re-scan
I	S	U	Y	B	X	Z	Re-scan
H	C	P	Q				Re-scan
M	W	,					Re-scan
Sh	.						Re-scan
BkSp	Ret						Re-scan

Matrix with “stop scanning” item at front of each row with initial delay

	Stop	Sp	E	A	R	D	F	V
	Stop	T	O	N	L	G	K	J
	Stop	I	S	U	Y	B	X	Z
	Stop	H	C	P	Q			
	Stop	M	W	,				
	Stop	Sh	.					
	Stop	BkSp	Ret					

Matrix with “stop scanning” item at end of each row with initial delay

	Sp	E	A	R	D	F	V	Stop
	T	O	N	L	G	K	J	Stop
	I	S	U	Y	B	X	Z	Stop
	H	C	P	Q				Stop
	M	W	,					Stop
	Sh	.						Stop
	BkSp	Ret						Stop

Matrix with “reverse scan” item at start of each row and initial delay

	Rev	Sp	E	A	R	D	F	V
	Rev	T	O	N	L	G	K	J
	Rev	I	S	U	Y	B	X	Z
	Rev	H	C	P	Q			
	Rev	M	W	,				
	Rev	Sh	.					
	Rev	BkSp	Ret					

Matrix with “stop scanning” item at front of each row and initial delay

	Stop	Sp	E	A	R	D	F	V
	Stop	T	O	N	L	G	K	J
	Stop	I	S	U	Y	B	X	Z
	Stop	H	C	P	Q			

	Stop	M	W	,				
	Stop	Sh	.					
	Stop	BkSp	Ret					

Matrix with “stop scanning” item at end of each row and initial delay

	Sp	E	A	R	D	F	V	Stop
	T	O	N	L	G	K	J	Stop
	I	S	U	Y	B	X	Z	Stop
	H	C	P	Q				Stop
	M	W	,					Stop
	Sh	.						Stop
	BkSp	Ret						Stop

Matrix with “reverse scan” item at start of each row and initial delay

	Rev	Sp	E	A	R	D	F	V
	Rev	T	O	N	L	G	K	J
	Rev	I	S	U	Y	B	X	Z
	Rev	H	C	P	Q			
	Rev	M	W	,				
	Rev	Sh	.					
	Rev	BkSp	Ret					

Matrix with “re-scan row” item at end of each row and initial delay

	Sp	E	A	R	D	F	V	Re-scan
	T	O	N	L	G	K	J	Re-scan
	I	S	U	Y	B	X	Z	Re-scan
	H	C	P	Q				Re-scan
	M	W	,					Re-scan
	Sh	.						Re-scan
	BkSp	Ret						Re-scan

Matrix with “stop scan” item or “reverse scan” item at beginning of each row, “re-scan row” item at end of each row, and initial delay

	Stop/Rev	Sp	E	A	R	D	F	V	Re-scan
	Stop/Rev	T	O	N	L	G	K	J	Re-scan
	Stop/Rev	I	S	U	Y	B	X	Z	Re-scan
	Stop/Rev	H	C	P	Q				Re-scan
	Stop/Rev	M	W	,					Re-scan
	Stop/Rev	Sh	.						Re-scan

	Stop/Rev	BkSp	Ret						Re-scan

Wacky idea: instead of using an initial delay, shift the matrix by one row and column so that the most frequently used items are in the second row and column and the least frequently used items are in the first row and column. This way, you get an initial delay without having to use a real initial delay.

Z	Ret	BkSp				
J	Sp	E	A	R	D	F
V	T	O	N	L	G	K
	I	S	U	Y	B	X
	H	C	P	Q		
	M	W	,			
	Sh	.				

Making Decisions

SETTING SCAN RATE (R)

Things we can measure in IDA:

Switch press down time	P_d	seconds	
Switch press hold time	P_h	seconds	
Switch press up time	P_u	seconds	
Switch press recovery time	P_r	seconds	
Single switch press	P_1	seconds	$P_1 = K$
Double switch press	P_2	seconds	$P_2 = P_d+P_h+P_u+P_r+K$
Triple switch press	P_3	seconds	$P_3 = 2(P_d+P_h+P_u+P_r)+K$

From this, we can calculate K based on the specific scanning system being used:

- Register selection as soon as a switch down is registered ($K = P_d$)
- Register a selection after the switch is held down for a set time ($K = P_d + P_h$)
- Register a selection as soon as a switch up is registered ($K = P_d + P_h + P_u$)
- Register repeat selections if the switch is held down ($K_1 = P_d$; $K_2 = P_d + P_h$)

Then we can use K and the .65 rule to set scan rate:

$R = K / .65$

SETTING INITIAL DELAY (I)

The point of the initial delay is to allow recovery time between switch presses. We need an initial delay if the time required to recover from a switch press and then generate a second switch press is greater than R.

If a switch press is registered as soon as the switch is down (i.e., right after P_d), then what we want is:

$P_h+P_u+P_r+K < R + I$

We can use this to set initial delay:
$I = P_h+P_u+P_r+K - R$

CHOOSING BETWEEN A LOOP COUNT, STOP SCAN ITEM, RE-SCAN ITEM AND REVERSE SCAN ITEM

A stop scan, re-scan or reverse scan item increases the size of each row, which increases:

- the scan length (# of scans, S_{ij}, to reach each item) of each item in matrix
- the number of switch hits (potentially)

But it does not change the number of matrix selections per word, so we should be able to make comparisons between choices based on average number of selections per word. In other words, we don't have to simulate letter-by-letter text entry.

The following combinations can be used:

- Loop count
- Stop scan at beginning of each row
- Stop scan at end of each row
- Re-scan at end of each row
- Reverse scan at beginning of each row
- Stop scan at beginning of each row and Re-scan at end of each row
- Reverse scan at beginning of each row and Re-scan at end of each row

For each combination, we can calculate:

average penalty per selection when switch not pressed on target row	$D_{n,row}$		
average penalty per selection when switch is pressed before target row	$D_{e,row}$		
average penalty per selection when switch is pressed after target row	$D_{l,row}$		
average penalty per selection when switch not pressed on target column	$D_{n,col}$		

In IDA, we can measure:

Probability of error-free selection	P_c		
Probability of not pressing switch	P_n		
Probability of pressing switch too early	P_e		
Probability of pressing switch too late	P_l		

We can then choose the combination of settings that minimizes:
ST = $(P_c)(T) + (P_n)(T+D_{n,row}) + (P_n)(T+D_{n,col}) + (P_e)(T+D_{e,row}) + (P_e)(T+D_{e,col}) + (P_e)(T+D_{e,row}) + (P_l)(T+D_{l,col}) + (P_l)(T+D_{l,row})$

CHOOSING WHETHER TO USE CHARACTER- OR WORD-LEVEL PREDICTION

Using character-prediction adds another row to the matrix, which increases the scan length (S_{ij}) of each item in the matrix but decreases selections per word (SPW).

Using word-prediction adds another row to the matrix, which increases the scan length (S_{ij}) of each item in the matrix but decreases selections per word (SPW).

Using character- or word-prediction may change the probability of making an error.

We have the following options:

- No character- or word-prediction (no extra rows in matrix)
- Character prediction (one extra row in matrix)
- Word prediction (one extra row in matrix)
- Both character- and word-prediction (two extra rows in matrix)

For each combination, we can calculate:

average penalty per selection when switch not pressed on target row	$D_{n,row}$		
average penalty per selection when switch is pressed before target row	$D_{e,row}$		
average penalty per selection when switch is pressed after target row	$D_{l,row}$		
average penalty per selection when switch not pressed on target column	$D_{n,col}$		

In IDA, we can activate character- and/or word-prediction and measure:

Probability of error-free selection	P'_c		
Probability of not pressing switch	P'_n		
Probability of pressing switch too early	P'_e		
Probability of pressing switch too late	P'_l		

For each condition, we can then calculate
ST = $(P'_c)(T) + (P'_n)(T+D_{n,row}) + (P'_n)(T+D_{n,col}) + (P'_e)(T+D_{e,row}) + (P'_e)(T+D_{e,col}) + (P'_e)(T+D_{e,row}) + (P'_l)(T+D_{l,col}) + (P'_l)(T+D_{l,row})$

In IDA, we can't measure SPW for the actual text the user will be typing. The accuracy of our decision will therefore depend on how accurately we estimate SPW with and without prediction. Can we use estimates from Lesher?

We want to choose the combination of settings that minimizes:
TER = (1/ST) * (60) * (1/SPW)

APPENDIX E : SMS OUTPUT XML FILE FORMAT


```
<?xml version="1.0" ?>
<ScanCalculations>
 <TestCode>RMank-Base</TestCode>
 <TrialNumber>1</TrialNumber>
 <MatrixName>Alphabetic5x6</MatrixName>
 <InputSettings>
 <ScanRate>1.2</ScanRate>
 <InitialDelay>0.0</InitialDelay>
 <LoopCount>1.0</LoopCount>
 <NumOfRows>5.0</NumOfRows>
 <NumOfCols>6.0</NumOfCols>
 <ReverseScan>false</ReverseScan>
 <OptimalScan>false</OptimalScan>
 <BeginRowStopScan>false</BeginRowStopScan>
 <EndRowStopScan>true</EndRowStopScan>
 <ContinueScanAtRowEnd>false</ContinueScanAtRowEnd>
 <ErrorFreeSelection>0.5159</ErrorFreeSelection>
 <NoSwitchPress>0.3503</NoSwitchPress>
 <NoSwitchPressInTargRow>0.0</NoSwitchPressInTargRow>
 <SwitchPressBeforeTargetRow>0.0191</SwitchPressBeforeTargetRow>
 <SwitchPressBeforeTargetRow>0.0573</SwitchPressBeforeTargetRow>
 <SwitchPressBeforeTargetCol>0.0131</SwitchPressBeforeTargetCol>
 <SwitchPressBeforeTargetCol>0.0127</SwitchPressBeforeTargetCol>
 <DetectingError>1.0</DetectingError>
 <FixingError>0.2667</FixingError>
 <CorrectCharFix>0.0</CorrectCharFix>
 <BackspaceWithCorrectChar>0.2667</BackspaceWithCorrectChar>
 <IncorrectSelectToExitScan>0.0</IncorrectSelectToExitScan>
 <SwitchHitsPerChar>2.0</SwitchHitsPerChar>
 <HoldTimeToRegisterSelection>1.37</HoldTimeToRegisterSelection>
 <DownTime>0.7</DownTime>
 <HoldTime>0.34</HoldTime>
 <UpTime>0.34</UpTime>
 <RecoveryTime>0.15</RecoveryTime>
 <SelectionsPerWord>5.0</SelectionsPerWord>
 <NumberOfScanGroups>2.0</NumberOfScanGroups>
 </InputSettings>
 <Calculations>
 <WrongRowAvgPenalty>6.0</WrongRowAvgPenalty>
 <BeforeRowAvgPenalty>9.190985</BeforeRowAvgPenalty>
 <AfterRowAvgPenalty>12.187643</AfterRowAvgPenalty>
 <WrongColAvgPenalty>10.830694</WrongColAvgPenalty>
 <BeforeColAvgPenalty>0.53966206</BeforeColAvgPenalty>
 <AfterColAvgPenalty>0.53966206</AfterColAvgPenalty>
```

<AvgSelectTimeWithoutError>7.5871005</AvgSelectTimeWithoutError>
<AfterRowSelectAvgPenalty>4.7199993</AfterRowSelectAvgPenalty>
<BeforeRowSelectAvgPenalty>4.7000003</BeforeRowSelectAvgPenalty>
<AvgSelectionTime>10.336971</AvgSelectionTime>
<AvgTextEntryRate>1.1608816</AvgTextEntryRate>
</Calculations>
<SwitchPressTimes>
<Single>1.37</Single>
<Double>2.9</Double>
<Triple>4.43</Triple>
</SwitchPressTimes>
</ScanCalculations>

APPENDIX F : SETUP AND PROTOCOL

Significance. If the Scanning Model software can accurately calculate the Text Entry Rate (TER) of a participant using that person's scan settings and error tendencies, when compared to their actual TER rate as calculated by the IDA Sentence test; the Scanning Model software accuracy will be validated. Various input /scan settings can be manipulated within the Scanning Model that will result in scenarios that produce predicted TERs. These predicted TERs will be tested for accuracy by having the test participants perform the IDA Sentence tests again using the associated input/scan settings (scenarios). The observed TER will be compared to the Scanning Model's TER prediction. If TER predicted by the model is accurate under the various scenarios, the Scanning Model software can be used as a tool to determine the configuration that achieves the maximum TER rate for a participant based upon their individual tendencies.

Setting. Testing will occur at each participant's home, office or a "neutral" site, such as UCP of Pittsburgh or TRCIL. The number of participants will be 4-6. One or more users can participate simultaneously.

Test Length. 1 session lasting approximately 2 hours.

Computer Support. The study requires a computer with IDA, Morae recorder software, and the Scanning Model software installed. Also required are the onscreen keyboard software WiVik and Reach Interface Author. The user's switch will be plugged into the computer.

Software Readiness. Algorithms for Scanning Model and row-column error collection have been implemented; testing so far is successful. Error correction data collection algorithm is being completed.

State of the System at Test Start. IDA program will be open. No other folders will be open (not that it matters, but just to be consistent).

Input Devices. Participants will use their own switch as an interface to the computer when possible. A switch will be provided to accommodate the participant's needs if necessary. The switch will plug into a device that interprets switch clicks as mouse clicks and passes the input to the IDA and on-screen keyboard software. The investigator will attempt to match them with the most practical hardware available.

Basic Design. The study is designed to assess the accuracy of the Scanning Model software (SMS) in relation to its ability to predict the Text Entry Rate (TER) of individuals who use single switch row-column scanning to communicate. Part 1 of the study uses the IDA Switch Activation test to determine the switch press times of the participant. In Part 2 of the study, the Sentence test in IDA will be used to determine the TER, the type and frequency of row-column selection errors, the error and correction frequency, as well as the methods of error correction and their frequency. Third party onscreen keyboard software (WiVik or Reach Interface Author) will be used by the participant to perform the sentence test. The test participant's switch press times, scan settings, error types, error frequencies, and correction methods obtained from Parts 1 and 2 of the study will be input into the SMS in Part 3. The model will be run under various configurations (reverse scan, stop scan at start row button, stop scan at end of row button, continue scan) and scan settings (scan rate, initial delay, loop count, keyboard layout) to calculate text entry rates. The configurations will be determined by examining the test results and Morae recording to ascertain configurations most likely to impact the participants TER. These configurations will then be implemented in Part 4 of the study. In Part 4 the user will again perform the IDA Sentence test. This time, with the aforementioned scanning configurations used to calculate text entry rates by the Scanning Model.

Basic Design. Part 1. Switch press time acquisition. The participant will perform an IDA Switch Activation test using their own switch. The test will consist of 10 single click trials and 10 double click trials.

Basic Design. Part 2. Scanning TER, errors, error correction methods, and their frequencies. The participant will perform IDA Sentence tests and attempt to transcribe the sentence presented at the top of the screen by selecting each character from an onscreen keyboard matrix with their switch. The matrix layout can be alphabetic or frequency-based. The onscreen keyboard will be Reach Interface Author. The matrix choice and participant's scan settings are to be configured prior to the start of each test. The will be two series of tests. Each test will present 2 sentences to the participant. Morae Recorder software will be used to record all screen activity during the Sentence tests.

Basic Design. Part 3. Intermediate Data Analysis and Calculations. The output XML files and onscreen results for the IDA tests performed in Parts 1 & 2 are examined to determine the switch press times, error types and correction methods as well as their respective frequencies. This information is used to configure the SMS in respect to switch press times, the error types, and correction probabilities of the test participant. Text entry rates will be calculated under various scanning configurations. These configurations will be used in Part 4.

Basic Design. Part 4. Scanning TER with updated configuration. The participant will perform IDA Sentence tests and attempt to transcribe the sentence presented at the top of the screen by selecting each character from an onscreen keyboard matrix with their switch. The matrix layout can be alphabetic or frequency-based. The onscreen keyboard will be either Wivik or Reach Interface Author. The matrix choice and participant's scan settings are to be configured prior to the start of each test; specifically, the matrix layout and configuration as determined after intermediate data analysis in Part 4. The will be two series of tests. Each test will present 2 sentences. . Morae Recorder software will be used to record all screen activity during the Sentence tests. Morae will be used to go back through the sentence test after the session to see if performance in Part 4 matches performance in Part 2.

Pre-Test Data.

1) Complete the consent form.
2) Complete the participant information form **<participant name>-Info.doc** This form contains demographic info about school/work status, education, type of disability, age, AAC device type, length of AAC use, scan rate, matrix layout. Participant name for the naming of the file will be written as first initial of the first name and followed by the participant's last name.
3) Complete the participant address form **<participant name>-Address.doc**.

Pre-Test Setup.

1) Determine the scan settings regularly used by the participant and enter them in the Settings section of the Settings and Results Data form **<participant name>-Data.doc**. These settings can be obtained from the participant's communication device. If these are unavailable default settings will be used (.65 rule for scan rate, initial delay 1 sec., freq based layout, loop count of 1).
2) Open the IDA application and create a new client file. Open the file **Template-Model.ida**. Enter the participants name by accessing the Tools menu and then the Edit Client Information. Use the Save As selection to save the file as **<participant name>-Model.ida**
3) Open the template file **Model-Data.xml** in Wordpad**.** This file is the input configuration file for the Scanning Model software. Set the TrialNumber field to 1 and the TestCode field to **<participant name>-base.** The file is to be saved as **<participant name>-base.xml.**
4) Open the spreadsheet template file **Model-Data.xls.** The file is to be saved as **<participant name>-data.xls.**
5) Mute Sound.
6) Set Wivik configuration.
7) Open the on-screen keyboard application (Reach Interface Author) and set the scan settings to those acquired from the participants communication device.
    a) Select the **Scanning** menu and choose **Single Switch Scanning.**
    b) Select the **Scanning** menu and choose **Prompts and Timing.**
    c) Select the **Keyboard** button to set row/column settings.
        i) Set the amount of time the 1st row is offered to the participant's initial delay time.
        ii) Set the amount of time all other rows are offered to the participant's scan rate time.
        iii) Set the amount of time the 1st key/column is offered in the selected row to the participant's initial delay time.
        iv) Set the amount of time all other keys/columns are offered to the participant's scan rate time.
        v) Disable the prompt to remain in a row.
    d) Select the **General** button to set time settings.
        i) Set the scan pattern repeat rate to the participants loop count.
        ii) Disable the Undo feature and the Reverse prompt feature by clicking on the text describing the feature.
        iii) Click the OK button to save the settings.

e) Select the **Options** menu and choose **Settings**
   i) Select **Word Prediction** and the sub-topic **Punctuation**
   ii) Disable Auto Punctuation and Auto Spacing by un-checking them.
   iii) Select **Word Prediction** and the button **Dictionary Manager.**
   iv) Close all dictionary icons by clicking on them.

f) Use the keyboard sequence Ctrl + Alt + h to hide/show the Reach button bar.

Part 1

Part 1. The purpose of this test section is to determine the switch press times of the participant. The required switch press times are the down, hold, up, and recovery. The single switch press time will also be acquired.

1) Setup: Switch Activation test, set Number of Trials to 10, Selection Method is set to Double Click. Set max time per trial to 15 seconds. All other settings will remain at default values. Save settings.
2) Run the practice test of Switch Activation Test 1.
3) Run the Switch Activation Test. There will be 10 single-click trials and 10 double-click trials.
4) View the report of the Switch Activation test
5) Enter results into the Part 1 section of the Settings and Results Data form **<participant name> Data.doc**.

Part 1. Data Collected.

The IDA Switch test results consist of *Press time, Release Time, Double Click Interval, and Total Time*. Results are the average times for all 20 trials and are located in the "All Trials" row of the *Results Summary Table*. The *Double Click Interval* mean is located in a separated section located at the bottom of the results screen. The test results will be noted and used as input parameters to the Scanning Model software. The following table shows the data mapping.

Switch Press Times

IDA Switch Test Results	**SMS Input Parameters**
Press Time	Switch Press Down Time

(Release Time/2)	Switch Press Hold Time
(Release Time/2)	Switch Press Up Time
(Click Interval - Release Time)	Switch Press Recovery Time
Total Time	Register Selection Hold Time

Part 2

Part 2

Part 2. The purpose of this test section is to determine (a) Text Entry Rate (TER), (b) types of errors, (c) number of errors, and (d) error correction methods of a participant using a single switch for row-column scanning.

1) Setup:
   a) Sentence Test 1 – Test Name is set to "Base Sentence Test 1", Case Sensitive is set Off (unchecked), Input Device is set to on-screen keyboard, Number of trials is set to 2, Sentence List is set to "Test 1", Max time trial is set to 360 seconds. All other settings will remain at default values.
   b) Sentence Test 2 – Test Name is set to "Base Sentence Test 2", Case Sensitive is set Off (unchecked), Input Device is set to on-screen keyboard, Number of trials is set to 2, Sentence List is set to "Test 2", Max time trial is set to 360 seconds. All other settings will remain at default values.
   c) On-screen Keyboard (Wivik, Reach Interface Author) - the Scan Rate is set to the participant's normal scan rate, if unknown the .65 rule will be used to determine a scan rate.
2) Start recording in Morae Recorder
   a) Press Ctrl+F9 or use button in Recorder app
   b) If Logitech camera panel pops up, close it.
   c) Verify that little video camera icon shows up in lower right of display
3) Run the Sentence practice test (Test 1).
4) Run the two Sentence tests.
   a) Run the first test (Test 1). There will be 2 trials. The maximum time per trial is 360 seconds.
   b) Run the second test (Test 2). There will be 2 trials. The maximum time per trial is 360 seconds.
5) Stop recording in Morae Recorder
   a) Press Ctrl+F9 or use button in Recorder app

b) Save the file as **<participant name>-Base.**

6) View the report of the Sentence tests.
   a) Sentence Test 1 - Select and copy the error test results from the Notes area of the IDA test reports screen. This data is pasted into the Sentence Test 1 section of the Excel spreadsheet.
   b) Sentence Test 2 - Select and copy the error test results from the Notes area of the IDA test reports screen. This data is pasted into the Sentence Test 2 section of the Excel spreadsheet.
7) Verify that average results were calculated for both tests.
8) Enter results into the Part 2 section of the Settings and Results Data form **<participant name> Data.doc**.

Part 2. Data Collected.

The TER (words/minute), types of errors, number of errors, total number of error corrections, number of error corrections using backspace with correct character, number of error corrections by only typing correct character. This data will be used to calculate the probability of each type of error correction occurring.

Part 3.

Part 3. Intermediate Data Analysis and Calculation. The purpose of this section is to examine the results from Parts 1 & 2 of the study and use this data as input into the Scanning Model software. Text entry rates will be calculated under various scanning configurations in the Scanning Model software.

2) Enter data into Scanning Model software input configuration (XML) file.
   a) Enter scan settings used for Part 2 into XML file (scan rate, initial delay, loop count).
   b) Enter switch settings from Part 1 for the switch used throughout study.
   c) Enter error probabilities calculated from results of Part 2.
   d) Enter scanning matrix data. This includes size, configuration, characters, and character frequencies (should be 5x6 matrix and either frequency-based or alphabetic layout).
3) Run Scanning Model software
   a) Calculate baseline TER in model using baseline scan setting used by the participant in Parts 1 & 2. Test Code field of model should be unique and reflect baseline (participants lastname and the word base i.e. RMank-Base). The output file will be named using the Test Code field.
   b) Determine configurations (3) to be used as input parameters to Scanning Model software.
      i) The configurations will be determined by examining the test results and Morae recording to ascertain configurations most likely to impact the participants TER based upon their type, frequency, and correction methods for errors.
      ii) The following parameters can be modified/enabled to augment the scanning configuration:
         1. **Scan Rate –** could be modified when very few or an extreme amount of errors occurs
         2. **Initial Delay –** could be modified when many scanning errors occur when target is in the first row or column of the matrix
         3. **Loop Count –** could be modified if the targeted column in a row is often missed
         4. **Matrix layout** (frequency vs. alphabetic) – could be modified when targets are missed because the of lack of letter location awareness (freq->alpha) or to acquire improved TER because of letter position (alpha->freq).
         5. **Abort Scan Methods**
            *** End of row Stop scanning option –** Used with loop count > 1 and wrong row selected often.

* **Beginning of row Stop scanning option**– Used with loop count > 1 and wrong row selected often.

*** End of row Continue scanning option**– Used with loop count = 1 and wrong row selected often.

6. **Reverse scan** through columns in a row

c) Calculate predicted TERs under various scan configurations.
   i) Calculate TER in model using 1st configuration. Test Code field of model should be unique and represent configuration (participants initials and the word i.e. RMank-Config1). The output file will be named using the Test Code field.
   ii) Calculate TER in model using 2nd configuration. Test Code field of model should be unique and represent configuration (participants initials and the word i.e. RMank-Config2). The output file will be named using the Test Code field.
   iii) Calculate TER in model using 3rd configuration. Test Code field of model should be unique and represent configuration (participants initials and the word i.e. RMank-Config3). The output file will be named using the Test Code field.

4) Enter results into the Part 3 section of the Settings and Results Data form **<participant name> Data.doc** for each Scanning Model configuration results (Base, InitDelay, Stop at End, Continue at End).

Part 4

Part 4. The purpose of this test section is to primarily determine (a) Text Entry Rate (TER). The (b) number of errors and (c) error correction methods are of interest to determine if they are consistent across trials.. The various scanning configurations used to calculate TER in Part 3 will be implemented by modifying the settings and configuration of the on-screen keyboard software. The TER results of Part 3 will be compared to the TER calculated by the Scanning Model software in Part 4 (for the same configurations).

1) Setup:
   a) Sentence Test 1 – Test Name is set to "Config 1 Sentence Test", Adapt Settings is set Off (unchecked), Case Sensitive is set Off (unchecked), Input Device is set to on-screen keyboard, Number of trials is set to 2, Sentence List is set to "Test 1", Max time trial is set to 360 seconds. All other settings will remain at default values.
   b) Sentence Test 2 – Test Name is set to "Config 2 Sentence Test", Adapt Settings is set Off (unchecked), Case Sensitive is set Off (unchecked), Input Device is set to on-screen keyboard, Number of trials is set to 2, Sentence List is set to "Test 1", Max time trial is set to 360 seconds. All other settings will remain at default values.
   c) Sentence Test 3 – Test Name is set to "Config 3 Sentence Test", Adapt Settings is set Off (unchecked), Case Sensitive is set Off (unchecked), Input Device is set to on-screen keyboard, Number of trials is set to 2, Sentence List is set to "Test 1", Max time trial is set to 360 seconds. All other settings will remain at default values.

d) On-screen Keyboard (Reach Interface Author or Wivik) - the Scan settings and on-screen keyboard configuration will be set to the scanning configuration used in the model calculations of Part 3. Follow Pre-test Setup directions to enable various scanning configurations (General and Keyboard buttons in the Prompts and timing settings).

2) Start recording in Morae Recorder
   a) Press Ctrl+F9 or use button in Recorder app
   b) If Logitech camera panel pops up, close it.
   c) Verify that little video camera icon shows up in lower right of display
3) Config 1 Sentence Test
   a) Configure on-screen keyboard (Reach/Wivik) for configuration 1 settings.
   b) Run the Sentence practice test.
   c) Run the first test (Test 1). There will be 2 trials. The maximum time per trial is 360 seconds.
4) Config 2 Sentence Test
   a) Configure on-screen keyboard (Reach/Wivik) for configuration 2 settings.
   b) Run the Sentence practice test.
   c) Run the second test (Test 2). There will be 2 trials. The maximum time per trial is 360 seconds.
5) Config 3 Sentence Test 3
   a) Configure on-screen keyboard (Reach/Wivik) for configuration 3 settings.
   b) Run the Sentence practice test.
   c) Run the third test (Test 3). There will be 2 trials. The maximum time per trial is 360 seconds.
6) Stop recording in Morae Recorder
   a) Press Ctrl+F9 or use button in Recorder app
   b) Save the file as **<participant name>-Config.**
7) Enter results into the Part 4 section of the Settings and Results Data form **<participant name> Data.doc** for each Scanning Model configuration results.

Part 4. Data Collected.

The TER (words/minute) for each sentence test run under the three different scan/matrix configurations. Error types and correction methods.

APPENDIX G : CONSENT FORM

RST Department of Rehabilitation Science and Technology

School of Health and Rehabilitation Sciences • University of Pittsburgh

Forbes Tower, Suite 5044
Pittsburgh, PA 15260
412.383.6596
Fax: 412.383.6597
TDD 412.383.6598

www.shrs.pitt.edu/rst

CONSENT TO ACT AS A PARTICIPANT IN A RESEARCH STUDY

TITLE: Assessment of Alternative Computer Access Devices

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Telephone: 412-383-6593

SOURCE OF SUPPORT: National Institutes of Health

 Participant's Initials __________

Why is this research being done?

You are being asked to participate in a research study to develop software that automatically configures alternative computer access technology to meet a user's unique needs. In this research study, we will record your actions (keystrokes, mouse movements, switch presses and eye movements) while you use alternative computer access technology to perform a series of tasks on a computer. We will use this information to develop and evaluate methods for configuring devices based on user performance.

Who is being asked to take part in this research study?

You are being invited to take part in this research study because you are between 21 to 65 years of age. People invited into this study can be male or female, and may or may not have a physical, perceptual or cognitive impairment that interferes with their ability to access a computer. The study is being performed on a total of 50 individuals here at the University of Pittsburgh.

What procedures will be performed for research purposes?

If you decide to take part in this research study, you will undergo the following procedures that are not part of your standard medical care:

Screening Procedures:

Procedures to determine if you are eligible to take part in a research study are called "screening procedures". For this research study, the screening procedures include:

1. Talking to you about your current computing habits. We will be particularly interested in how often you use the computer and whether you can access a computer without assistance.

Training Procedures:

If you qualify to take part in this research study, you will undergo the following training procedures:

1. A training session to familiarize you with the alternative computer access technology and computer tasks that will be used with this study. At the end of the training session, you will be asked to use the alternative computer access technology to perform a series of tasks.

Experimental Procedures:

If you qualify to take part in this research study, you will undergo the following experimental procedure:

1. You will be given a series of tasks to perform, one at a time, using alternative computer access technology. While you perform the tasks, we will record keystrokes and mouse movements and use an eye tracking system to monitor your visual attention. We will also record data about your hand and finger movements and the electrical activity in your brain. This will require you to wear an accelerometer on your wrist, three electrodes on your index finger, and a "swim cap" with many electrodes embedded in it.

<u>Monitoring/Follow-up Procedures:</u>

Procedures performed to evaluate the safety and effectiveness of the experimental procedures are called "monitoring" or "follow-up" procedures. For this research study, the monitoring/follow-up procedures include:

1. Between trials, you will be asked if you are experiencing any fatigue or discomfort.

You are free to go home after the trials are completed.

The entire session is expected to last no longer than two hours:

- Screening Procedures: 15 minutes
- Training Procedures: 30 minutes
- Experimental Procedures: 1 hour and 15 minutes

What are the possible risks, side effects, and discomforts of this research study?

The possible risks of this research study are the same associated with normal computer use. These include the possibility that you might become fatigued or uncomfortable from sitting down in front of the computer and typing for too long.

What are possible benefits from taking part in this study?

You will likely receive no direct benefit from taking part in this research study.

If I agree to take part in this research study, will I be told of any new risks that may be found during the course of the study?

You will be promptly notified if any new information develops during the conduct of this research study that may cause you to change your mind about continuing to participate.

Will my insurance provider or I be charged for the costs of any procedures performed as part of this research study?

Neither you, nor your insurance provider, will be charged for the costs of any of the procedures performed for the purpose of this research study (i.e., the Screening Procedures, Training Procedures, Experimental Procedures, or Monitoring/Follow-up Procedures described above).

Will I be paid if I take part in this research study?

You will be paid $75 for taking part in this study.

Who will pay if I am injured as a result of taking part in this study?

University of Pittsburgh researchers and their associates who provide services at UPMC (UPMC) recognize the importance of your voluntary participation in their research studies. These individuals and their staffs will make reasonable efforts to minimize, control, and treat any injuries that may arise as a result of this research. If you believe that you are injured as a result of the research procedures being performed, please contact immediately the Principal Investigator or one of the co-investigators listed on the first page of this form. Emergency medical treatment for injuries solely and directly related to your participation in this research study will be provided to you by the hospitals of UPMC. It is possible that UPMC may bill your insurance provider for the costs of this emergency treatment, but none of these costs will be charged directly to you. If your research-related injury requires medical care beyond this emergency treatment, you will be responsible for the costs of this follow-up care unless otherwise specifically stated below. There is no plan for monetary compensation. You do not, however, waive any legal rights by signing this form.

Who will know about my participation in this research study?

All records related to your involvement in this research study will be stored in a locked file cabinet. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. Only the researchers listed on the first page of this form and their staff will have access to your research records. Your research records will be destroyed when such is approved by the sponsor of this study or, as per University policy, at 5 years following study completion, whichever should occur last.

Any information about you obtained from this research will be kept as confidential (private) as possible. You will not be identified by name in any publication of research results unless you sign a separate form giving your permission (release). In unusual cases, your research records may be released in response to an order from a court of law. It is also possible that authorized representatives of the Food and Drug Administration, the study sponsor (National Science

Foundation), and/or the University Research Conduct and Compliance Office may inspect your research records.

The fact that you are participating in a research study and that you are undergoing certain research procedures (but not the results of the procedures) may also be made known to individuals involved in insurance billing and/or other administrative activities associated with the conduct of the study.

Will this research study involve the use or disclosure of my identifiable medical information?

No identifiable medical information will be used or disclosed.

Is my participation in this research study voluntary?

Your participation in this research study is completely voluntary. You do not have to take part in this research study and, should you change your mind, you can withdraw from the study at any time. Your current and future care at a UPMC facility and any other benefits for which you qualify will be the same whether you participate in this study or not.

May I withdraw, at a future date, my consent for participation in this research study?

You may withdraw, at any time, your consent for participation in this research study. To formally withdraw your consent for participation in this research study you should provide a written and dated notice of this decision to the principal investigator of this research study at the address listed on the first page of this form.

Your decision to withdraw your consent for participation in this research study will have no effect on your current or future relationship with the University of Pittsburgh. Your decision to withdraw your consent for participation in this research study will have no effect on your current or future medical care at a UPMC hospital or affiliated health care provider or your current or future relationship with a health care insurance provider.

If I agree to take part in this research study, can I be removed from the study without my consent?

It is possible that you may be removed from the research study by the researchers. Subjects will be removed from this study if they have not completed the session within two and one-half hours or if they appear to be experiencing excessive fatigue or discomfort.

Conflict of Interest

One or more of the investigators conducting this research has a financial interest in or a patent for the development of this software. This means that it is possible that the results of this study could lead to personal profit for the individual investigator(s) and/or the University of Pittsburgh. This

Participant's Initials __________

project has been carefully reviewed to ensure that your well-being holds more importance than any study results. Any questions you might have about this will be answered fully by Dr. Simpson (412-383-6593) or by the Human Subject Protection Advocate of the University of Pittsburgh (866-212-2668).

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VOLUNTARY CONSENT

The above information has been explained to me and all of my current questions have been answered. I understand that I am encouraged to ask questions about any aspect of this research study during the course of this study, and that such future questions will be answered by a qualified individual or by the investigator(s) listed on the first page of this consent document at the telephone number(s) given. I understand that I may always request that my questions, concerns or complaints be addressed by a listed investigator.

I understand that I may contact the Human Subjects Protection Advocate of the IRB Office, University of Pittsburgh (1-866-212-2668) to discuss problems, concerns, and questions; obtain information; offer input; or discuss situations in the event that the research team is unavailable.

By signing this form, I agree to participate in this research study. A copy of this consent form will be given to me.

____________________ ____________________ __________

Participant's Signature | Printed Name of Participant | Date

CERTIFICATION of INFORMED CONSENT

I certify that I have explained the nature and purpose of this research study to the above-named individual(s), and I have discussed the potential benefits and possible risks of study participation. Any questions the individual(s) have about this study have been answered, and we will always be available to address future questions as they arise."

____________________ ____________________

Printed Name of Person Obtaining Consent | Role in Research Study

____________________ __________

Signature of Person Obtaining Consent | Date

APPENDIX H : QUESTIONNAIRE

Participant Code: ____________

Interviewer: ____________

Date: ____________

Please answer the following questions. All of your answers will be treated confidentially. Any published document regarding these answers will not identify individuals with their answers.
If there is a question you do not wish to answer, please just leave it blank and go on to the next question.

Participant Information

This first section asks for some basic information about you.

1. Gender
☐ Male
☐ 2 Female

2. Age: ___________

3. What is your highest level of education?

☐1 No formal education
☐2 Less than high school graduate
☐3 High school graduate/GED
☐4 Vocational training
☐5 Some college/Associate's degree
☐6 Bachelor's degree (BA, BS)
☐7 Master's degree (or other post-graduate training)
☐8 Doctoral degree (PhD, MD, EdD, DDS, JD, etc.)

4. Is English your primary language?

☐1 Yes
☐2 No
If "No", what is your primary language? ______________________

5. Are you a veteran?

☐1 Yes
☐2 No

6. Do you consider yourself Hispanic or Latino?

☐1 Yes
☐2 No

7. How would you describe your primary racial group?

1 No primary group
2 White Caucasian
3 Black/African American
4 Asian
5 American Indian/Alaska Native
6 Native Hawaiian/Pacific Islander
7 Multi-racial
8 Other (please specify) ______________________________

8. What is your primary occupational status? (Check one)

1 Work full-time
2 Work part-time
3 Student
4 Homemaker
5 Retired
6 Volunteer worker
7 Seeking employment, laid off, etc.
8 Other (please specify) ______________________________

9. **Do you currently work for pay?**

1 Yes, full-time
2 Yes, part-time
3 No
If "Yes", what is your primary occupation? ____________________

10. Do you currently attend school or other formal training?

1 Yes, full-time
2 Yes, part-time
3 No
If "Yes", what is your primary field of study? ____________________

Health Information

11. In general, would you say your health is:

1	2	3	4	5
Poor	Fair	Good	Very good	Excellent

12. **Do you now have any health problem that requires you to use special equipment, such as a cane, a wheelchair, a special bed, or a special telephone?**

- 1 Yes
- 2 No
- 3 Don't know/not sure

If yes, please describe the special equipment:

____

____

13. **For each of the following conditions please indicate if you have ever had that condition in your life, have the condition now at this time, or never had the condition. Check one box for each condition.**

Condition	In your lifetime, but not now 1	Now 2	Never 3
a. Amputation			
b. Arthritis			
c. Asthma or Bronchitis			
d. Cancer (other than skin cancer)			
e. Cerebral Palsy			
f. Diabetes			
g. Epilepsy			
h. Heart Disease			
i. Hearing Impairment			
j. Hypertension			
k. Multiple Sclerosis			
l. Muscular Dystrophy			
m. Post Polio Syndrome			
n. Spina Bifida			
o. Spinal Cord Injury			
p. Stroke			
q. Traumatic Brain Injury/Closed Head Injury			
r. Vision Impairment			
s. Upper extremity impairment (e.g., reaching, grasping, holding things, using computer mouse, etc.)			
t. Other significant illnesses (please list)			

AAC Device and Computer Use

14. How long have you been using a communication device?

- 1 Less than 6 months
- 2 About 1 year
- 3 2-3 years
- 4 3-5 years
- 5 5-10 years
- 6 10 or more years

15. How long have you been using your current communication device?

- 1 Less than 6 months
- 2 About 1 year
- 3 2-3 years
- 4 3-5 years
- 5 5-10 years
- 6 10 or more years

16. How long have you been single switch scanning?

- 1 Less than 6 months
- 2 About 1 year
- 3 2-3 years
- 4 3-5 years
- 5 5-10 years
- 6 10 or more years

17. What is the make and model of your current communication device (i.e. Dynavox MT4)?

____

____

18. How often do you use your communication device to communicate with other people?

I use my device to communicate:

Not often				Always
1	2	3	4	5

19. Have you ever had any training to use your communication device?

1 Yes
2 No
If "Yes", what kind? ______________________

20. Have you ever had any custom pages to use your communication device?

1 Yes
2 No
If "Yes", who created them? ______________________

21. Do you ever have difficulties reading information on the screen of your communication device? If yes, please describe.

____

____

______

22. Do you ever have difficulties reading information on a computer screen? If yes, please describe.

____

____

______

23. What type of screen layout do you use for typing on your communication device?

1 Alphabetic
2 Frequency Based
3 Other
If "Other", what type?

____

24. What is the current scan rate of your communication device.

____

25. Where is your switch normally positioned for use with your communication device?

____

____

____

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