VOICE RECOGNITION ACCURACY:
WHAT IS ACCEPTABLE?

by

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E. F. Roland

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and
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This work was performed by the authors at the Naval Postgraduate School. Professor Poock has been investigating the potential for VOICE recognition/input into both Navy and Army systems (Navy Document Number N00039WRDX017 and Army MIPR TB-024). E. F. Roland has also performed work as a contractor to NPS for Professor Poock under "Research and Development Study of the Feasibility of Using Computer Voice Entry" under NPS Contract N00228-82-C-6418.

Individual reports have been prepared for each sponsor on studies pertinent to their work. The enclosed work was not required by either sponsor nor funded by either sponsor specifically. We did this work in our spare time as we felt it was very important. Because we feel the topic is very generic to both Army and Navy, we have prepared the report for both.
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<td>A research experiment was conducted to investigate how accurate a voice recognition system must be for daily production use. Specifically, the purpose of the research was to establish the percentage accuracy level at which a user becomes frustrated and decides not to use a voice recognition device. The experiment consisted of controlling the perceived recognition accuracy of a voice recognition system and then collecting data through the use of a</td>
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questionnaire from the experimental users on the acceptability of the equipment. The experiment was not totally successful for a variety of reasons. This paper will discuss the research methodology, review the data collected, and suggest possible alternatives to the experimental design to overcome the problem areas encountered.
ABSTRACT

A research experiment was conducted to investigate how accurate a voice recognition system must be for daily production use. Specifically, the purpose of the research was to establish the percentage accuracy level at which a user becomes frustrated and decides not to use a voice recognition device. The experiment consisted of controlling the perceived recognition accuracy of a voice recognition system and then collecting data through the use of a questionnaire from the experimental users on the acceptability of the equipment. The experiment was not totally successful for a variety of reasons. This paper will discuss the research methodology, review the data collected, and suggest possible alternatives to the experimental design to overcome the problem areas encountered.
I. INTRODUCTION

Within the last ten years voice recognition technology has grown from a laboratory research endeavor to a useful and economic, computer human interface tool. The equipment available today is relatively inexpensive, compact, and accurate as evidenced by numerous applications, both industrial and military, which successfully use this input methodology. Improvements in the technology are still being made. Three major areas for continued research in voice input to computers are as follows.

1. User independence
2. Continuous speech
3. Vocabulary capability of 10,000 to 12,000 words

The literature indicates that the solution or at least incremental breakthroughs to these three research areas are just a few years away. Hopefully, the goal of manufacturers and researchers is to develop and produce systems with all or some of the properties listed above which have the best accuracy rate possible. A question arises with this goal in mind. At what accuracy rate should the system be made available to users? If an accuracy rate of 95% is acceptable why not use those systems while new and better algorithms are being developed? Conversely, if 95% accuracy rate is not acceptable and will give voice recognition a bad reputation among management personnel and users it should be held back until an acceptable rate can be achieved. A measure of where this accuracy threshold is could be of
great use to researchers and system manufacturers. Therefore, the question investigated was how poor must a voice recognition system be before the user becomes frustrated with the error rate and will choose not to use the system.

A required accuracy rate will depend on the task for which the system is intended to be used. For example, if voice recognition is to be used for the input of guidance parameters and launch sequence commands in a computerized missile delivery system, anything less than 99+% accuracy would be unacceptable even under the high stress situations most likely existing during the input process. On the other hand, there are numerous tasks which can be labeled as non-critical where voice recognition errors can be tolerated and in fact now occur frequently using more conventional input methods such as a keyboard. A typical task in this category would be information retrieval such as a stock broker obtaining stock information for a client, or an airline reservationist retrieving flight information for a customer. Neither of these tasks are particularly critical in nature. If an occasional error is made during the input process it is easily corrected and the process repeated without any damage to the system or loss in revenue, profit or system efficiency.

An experiment was developed to study the user acceptability question with the objective of determining a user required accuracy rate. A VET/2 voice recognition unit manufactured by Scott Instrument Inc. of Denton, Texas was used in conjunction with a Basic software program created on an Apple II Plus microcomputer. The experiment's subjects were asked to read an ordered list of words into the voice recognition unit and observe whether the word was recognized properly. This same ordered list of words was stored in
computer memory. Each subject was led to believe the system was in a recognition mode, but in fact, the software program waited for a verbal input and then drew a random number to determine if the spoken input should be displayed as correct recognition, misrecognition or nonrecognition. If the random number determined it was to be a correct recognition the next word on the ordered list was displayed. If a misrecognition was to occur an alternate word was displayed, and a question mark was displayed if the random number determined a nonrecognition was to appear. In other words, the program can be viewed as a voice actuated system where any verbal response would trigger the recognizer, but a random number would determine the output, not the recognition algorithms. As long as the subjects continued to read the ordered list of words, it appeared as if word recognition was being accomplished. By varying the random number test the subject's perceived accuracy rate could be controlled. The errors were recorded, and each subject was asked to complete a questionnaire. The questions were designed to indicate when a frustration level was reached due to recognition inaccuracy.

The experiment did not lead to the desired goals or results. This paper will cover the experiment and why the actual results were different than predicted. First, the report will describe the computer software program which was created to vary the perceived recognition rate during the experiment. Next, the experimental design will be discussed. The entire design was not implemented because preliminary data analysis indicated the desired results were not being obtained. The method used to implement the experimental design will also be discussed. The third section of the report will cover the preliminary data analysis and summary of user responses to the experiment.
Finally, conclusions will be drawn as to why the experiment did not resolve the question at hand, and recommendations will be presented for future research concerning the question of "How good should voice recognition equipment be?".
II. PROGRAM SOFTWARE DESCRIPTION

Two computer software programs were written for use in this experiment. The first program was used to create three databases consisting of words to be used for the planned experimental design. Since this program was used only as an aid for the database preparation, it will not be discussed. A copy of the program and the databases of words are attached in Appendix A and Appendix B respectively. The second program created was used to alter the perceived recognition accuracy of the Scott Instrument VET/2 recognizer. It was written in Applesoft Basic and is included as Appendix C. The following description explains the program logic using the program line numbers for reference.

Line 10 dimensions a character array called W$(200,2). During the experiment, this array held the 200 vocabulary words used for the experiment. W$(I,1) held the word which was to be spoken, and W$(I,2) held a sound alike word. The use of this sound alike word will be explained later. The array F$(3) held the name of the three word databases which were available for use. These databases were named:

1. COMPUTER, designed to be used by users of a text editor on the IBM 3033 computer at the Naval Postgraduate School,
2. STOCK, designed to be used by stockbrokers, and
3. AIRLINE, designed to be used by airline reservationists or travel agents.

The array P(4) held the four different probabilities associated with the planned recognition rates of 99%, 95%, 90%, and 85%.
Line 20 sets the variable D$ to a control D which is used for file manipulation on the Apple computer.

Lines 30 and 40 are data assignment statements for the F$ and P arrays.

Line 45 assigns to the character variable M$ a series of five blank spaces. M$ is used for print control or print spacing.

Line 50 is an output statement asking the user what database is to be used.

Line 60 accepts as an input the number of the desired database. This number is placed in the variable A.

Line 70 opens the correct database file.

Line 80 sets the read device to the appropriate database file.

Line 90 reads in the 200 word vocabulary and their sound alikes into the W$ array.

Line 100 closes the input database file.

Line 105 asks for a random number generator seed and places the integer response into the variable called IS.

Line 110 asks for an algorithm number, which in effect is the array index of the desired accuracy rate. The question in line 110 was stated in such a manner so that experiment participants would assume different word recognition algorithms were being tested.

Line 120 places the algorithm number in the variable B, and if B is less than zero, the program is stopped.

Lines 130 through 160 call the Scott instrument voice recognition subroutines used to load the voice patterns into
memory, and initialize the recognition unit. The voice patterns, although not used for recognition purposes, were necessary for the proper operation of the recognition unit.

Line 170 prints a header announcing the practice session of 10 words. During this practice session the use of voice recognition equipment was explained to the experiment participant. The explanation given to each participant will be described in detail later.

Lines 180 through 200 create a program loop. The variable I is used as an indexing variable. This indexing variable is first set to 1, and the first word of the vocabulary database is printed on the Apple computer display. This display is used as a prompt to the experiment's participants for the word they are to speak. After the word is displayed the program is transferred to the recognizer's subroutine which will accept a verbal input. After the recognizer accepts the voice input the subroutine returns control to this main program. After the acceptance of the voice response an artificial delay is created by the "FOR Z ..." statement. This delay was necessary to provide a capability of stopping program execution if the participant made an error which could lead them to believe the program was not actually recognizing their voice. The delay provided the time for the experimenter to stop the program before the "recognized" word was displayed. After the delay a subroutine, which will be described later, is called to determine whether a correct response, a sound alike mistake, a random mistake, or a nonrecognition response should be displayed to the participant. After the response is displayed the index variable, I, is checked to determine if the test practice session is over.
Line 210 sets a series of counters to zero. These counters keep track of the number of non recognitions presented to the participant (Q), the number of sound alike misrecognitions presented (S), and the number of nonsense misrecognition responses (N). The variable T is calculated at the end of each participant's pass through the 200 word vocabulary list and holds the accuracy rate actually presented to the subject.

Lines 220 through 250 comprise another program loop. The logic is similar to lines 180 through 220 except the entire 200 word vocabulary is sequentially displayed.

Lines 260, 270 and 280 respectively display statements thanking the participants, calculating the actual accuracy rate presented, and displaying the accuracy rate and all counters in a coded form.

Line 290 sends control of the program back to the question asking which algorithm should be used (Line 110), and the program is ready for the next participant.

Line 300 is the first line of the subroutine which will calculate whether the response which is to be shown to the participant is a correct recognition response or one of the three possible error responses. A random number is drawn. If the random number is greater than the accuracy rate which is presently being simulated the program will branch to the statements necessary to calculate the type of error which should be presented.

Line 310 is executed if a correctly recognized response is to be displayed. The print statement will first print the variable containing the blank spaces, and then the correctly recognized word. This was done so the recognized word was displayed further to the right on the Apple screen.
than the word which was output as a prompt. Transfer then is passed to statement 400.

Lines 320 through 340 are used to determine the type of error that should be displayed given that the present word is to be perceived as an error by the participant. A random number is drawn, and if it is less than .33 the error is considered a sound alike error and control is passed to line 390. If the random number, R, is between .33 and .66, it is considered a random or nonsense error and control is passed to line 360. Finally, if the random number is greater than .66, it is considered a nonrecognition. Therefore, the three types of errors are equally likely. In previous voice recognition studies, Poock (1980), Poock (1981), and Jay (1981), error rates of about 1.8% have been consistently experienced with a Threshold Technology Inc., Delran New Jersey, model 600 voice recognizer. In these studies nonrecognitions consisted of 31% to 35% of the total recorded errors. There were no statistics available on the percentage of misrecognitions which could be considered sound alikes or non-intuitive confusing misrecognitions. For this reason it was assumed that misrecognitions should be equally divided between the sound alike possibilities and the random error possibilities. Therefore, all three error types were programmed to occur with equally likely probabilities.

Line 350 is executed if a nonrecognition is to occur. It again prints the variable, MS, which contains blanks and then a question mark, ?, representing the Scott Instrument convention for a non-recognition. The counter for non-recognitions is increased by one and the program is then transferred to line 400.

Line 360 through 380 determine a random word response for
the random misrecognition case. A random number is drawn and converted into a random integer between 1 and 200. Next it is checked to ascertain that the random integer generated is not the word which is to be misrecognized. If this check had not been made, a misrecognition could have been recorded but the participant would have in fact seen the correct response. The randomly selected word is printed on the display in the same manner as a properly recognized word, and the nonsense word counter is incremented. Again control is then passed to statement 400.

Line 390 is executed if the random number, R, indicates that this incorrect recognition should be a sound alike and the second word in the W$ array is printed out. These words have been selected in such away that an average user would conclude that it was an understandable or likely recognition error. The sound alike counter is incremented.

Line 400 is the last line of the subroutine. Again a loop is added to produce a delay. The index used in the program loop consisting of statements 220 through 260 is incremented. A blank line is displayed for readablity and the subroutine returns to the main program to print the next word in the 200 word vocabulary list.

The next section will describe how this program was used, and the reaction of the experiment's participants as to the believability that a voice recognizer was being tested.
III. EXPERIMENTAL DESIGN

It has already been mentioned that three databases were formed for the research experiment. The plan was to run three groups of 100 people each through one of the databases. In other words, 100 stockbrokers or investment counselors would say the 200 words associated with their profession, and then rate the acceptability of the equipment. Likewise, 100 airline reservationists or travel agents were to use the airline reservationist word list, and 100 students would use the 200 words associated with the IBM 3033 text editor program.

A word list of 200 words was used for two reasons. First it was decided that going through a list of 100 words went too fast, and the subjects would not get a good feeling for the accuracy rate. Using 300 words was definitely out of the question because of the time involved in conducting the experiment for the number of planned subjects, and because of a possible boredom factor which could complicate the subjects perception of the system. The median seemed like a reasonable choice. The vocabulary size of 200 words also satisfied a second criteria. That was the desire to get user frustration information at a more accurate level than every 1 percentage point. At least the 200 words would give ratings at every one half percentage point.

During the experiment it became apparent that a frustration level was not being achieved or at least measured. Therefore, after the first fourth of the experiment some preliminary data analysis was done, and the results showed that little was being learned about user accuracy needs. It was decided to stop the experiment and report on what had been done to date. A total of 78
subjects participated in the test. The intent of this section of the paper is to explain how the subjects were introduced to the experiment and how they reacted to the recognition system. This section will also discuss the design of the questionnaire.

The subjects were students, staff and faculty members at The Naval Postgraduate School in Monterey, California. They were all volunteers and between the ages of 25 and 49. The entire explanation and experiment took between 10 and 15 minutes per subject.

When a subject arrived at the experiment site, it was explained that some new user independent voice recognition algorithms were being tested. The Scott Instrument voice recognition device was covered to preclude the subjects from getting the wrong impression of its capability. The algorithm number was entered into the system in front of the subject as the idea of different algorithms was being explained.

Some of the subjects had used voice recognition equipment on previous voice experiments. These students needed little practice, but still went through the ten practice words. The practice words were used as the teaching device for those subjects who had not used the equipment before. The need to speak a phrase as a continuous flow of speech was explained, as was the explanation of the meaning of a question mark (?) when it appeared on the display. If the subject showed an interest in the machine's capability during the practice session, their questions were postponed until after they had answered the questionnaire.

The subjects were asked to ignore all the errors (if any) which occurred during their practice session. It was explained that some artificial intelligence algorithms were
being employed and the system was selecting characteristics of their voice for use in the main portion of the experiment.

As the subjects were going through the 200 word list, the experiment was stopped each time an error occurred. The error was pointed out to the subject and a short explanation was given as to what that error would do if the true text editor was employed. The idea for stopping the program was two fold. First it was noticed during preliminary program testing that some people started to read the words on the display and weren't watching the recognized word displayed. In other words, the experiment bored them and they weren't always aware of the errors. At first this had been solved by placing the recognized word directly under the prompt word. Unfortunately this solution caused another problem. The subjects who participated in the preliminary testing started to say the recognized word instead of the following prompt word which had a devastating effect on the user's confidence that the system was recognizing their voice. Therefore, the recognized word was placed to the right of the prompt word, and each error was pointed out to the subject. The second reason for stopping the program was to delay the subject in completing the experiment. It was hoped that the idea of an error slowing them down would transfer to their perception of how the system would work in a real environment. The plan was to slow them down thus creating a frustration level which was to be measured.

There were numerous times even with the precautions taken where the subject read the wrong word, or started to make a comment without the microphone being turned off. This led to a recognition which in the majority of cases was correct, when the spoken utterance was obviously incorrect. The experimenter's finger was always kept lightly on the Apple
computer's space bar. By depressing the bar the microphone and voice recognition system were deactivated. The majority of the time, the experimenter depressed the space bar soon enough to avoid a correct recognition of an incorrect voice input. This was the major reason for the delay loop explained earlier in the program software description. If the space bar was not depressed soon enough, and the correct response appeared on the display, the subject was told that the software program had been developed to do its own data collection automatically. Furthermore, it was explained that the experiment was interested in only recognizer errors not the human errors which will always occur with a voice system. Therefore, it was explained, that pressing the space bar was an automatic override, and no matter what was said the automatic data collection routine would count it as a correct recognition. This explanation seemed to satisfy everyone, who encountered the situation.

After the subject had completed the 200 words, he or she was asked to fill out a two page questionnaire. This questionnaire is attached as Appendix D. Questions 3, 4 and 5 created the data which was of most importance to the experiment and was the measurement of user acceptability. The sets of response alternatives, for these three questions, were taken from an Army Research Institute publication on questionnaire construction (1976). The responses have been tested and shown to have mean scaling factors at least one standard deviation away from each other while maintaining the parallel wording. Question 9, concerning the part of the country the subject grew up in, had nothing to do with the experiment that was being conducted, but was included to make the experiment about testing user independent algorithms more believable to the participants. The remaining questions are self explanatory.
and will be reviewed in detail when discussing the analysis of the data collected.

After the questionnaire was completed the subject was free to ask questions about the system. They were led to believe that all algorithms had been created at the School, and that the technology was not commercially ready because of the extremely large amount of core needed to run the system. This was done to insure that the believability in the system would not decrease as students talked about the experiment. On the other hand, it was not the intent of the experiment to lead the subjects to believe that voice recognition capabilities were beyond the present state of the art.

The experiment was a total success as far as the believability of the system was concerned. There were a couple of instances when the random number generator cooperated fully. For example, a subject asked a question which triggered a response and the random number generator created a nonrecognition. In another case a word was misrecognized in the test sequence and the same word was misrecognized during the experiment, both times the misrecognition was the sound alike word. There were subjects who tried to analyze the system and hypothesized why the system did not recognize them correctly. One subject was convinced that any word with an "S" sound would not be recognized properly because he tended to slur his "S" sound. There were only two subjects out of the 78 tested who mentioned the fact that they doubted the system was recognizing their voice. This fact was noted on their questionnaire after they left the laboratory area.
IV. DATA ANALYSIS

Appendix E and F present the data collected. Appendix E contains the raw data collected, while Appendix F has the data in the ranked form. All of the data analysis used nonparametric statistics methodologies based on ranks.

The first column of data in Appendix E contains the total number of errors the user observed. This number is the sum of nonrecognitions and both types of misrecognitions. The second column contains the total number of misrecognitions which is the sum of the sound alike errors and nonsense errors which were observed by the subject. Columns 3, 4, and 5 are the individual error totals for nonrecognitions, sound alike misrecognitions, and random misrecognitions, respectively. Column 6 is the age of the subject, and column 7 is the average number of hours the subject spends using a computer terminal each day. The average number of hours spent at a terminal were considered important for the stock brokers and airline reservationists, but had little meaning for the students who became the only participants in the experiment. Therefore, this data will not be used in the analysis, but is presented for completeness.

The next two columns, column 8 and 9, are the answers to the questions on whether the subject had ever seen or used voice recognition equipment. These answers are coded with a 1 representing an answer of "yes", and a 2 representing a "no" response. Columns 10, 11, and 12 are the responses to the questions dealing with user acceptability. These are also coded, from a 1 meaning a poor acceptability response to 5 for a high acceptability response. Column 13 is the sum of the responses to the three questions. Since the questions each had parallel wording the sum of the answers
for the individual questions was used for the data analysis. This method gave a more accurate numeration of the acceptability level for each subject.

Column 14 and 15 are the data collected on the subject's perception of his or her own typing ability in terms of speed and accuracy respectively. These data fields are also numeric codes for the response given on the questionnaire. A value of 1 represents a poor rating, a 2 an average rating while a 3 represents a very good rating in the speed and accuracy capability of each subject. Column 16 is the response to the question of whether the subject ever had a typing course. The same response convention was used for the two previous yes-no questions.

The second to the last column, column 17, tabulates the data collected representing the geographic region where the subject grew up. The codes have the following meaning.

1 - South
2 - East
3 - Midwest
4 - Foreign
5 - West
6 - All over or not specified

Finally the last column, column 18, is the subject's number of years experience with computers and computer terminals.

As it was already mentioned Appendix F contains the ranked data. The data are organized in the same manner as previously described for the raw data except some of the columns are the ranks of the data collected. There were numerous ties and the rank value assigned was the average of the ranks that would have been assigned to them had there been no ties. All of the recognition error counts were
ranked, as were the age data, total acceptability rating data, and the subject experience data.

The first set of analysis used Spearman's rank correlation coefficient (Conover, 1980) as a test statistic to determine if there was any negative correlation between the number of errors presented to a subject and that subject's acceptability rating. It had been hypothesized that as the number of errors increased the user acceptability would decrease. Therefore, the null hypothesis was that the number of errors and user acceptability are mutually independent or had no correlation. The alternative hypothesis was that these two variables are negatively correlated. The following tabulates Spearman's correlation coefficient calculated on the ranked data between these two variables.

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<td>All errors</td>
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<td>Total misrecognition</td>
<td>-0.249</td>
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<tr>
<td>Non recognitions</td>
<td>-0.250</td>
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<tr>
<td>Sound alikes</td>
<td>-0.215</td>
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<td>Random misrecognition</td>
<td>-0.201</td>
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At a significance level of 0.025 the null hypothesis can be rejected for the first three values. It appears as if the desired negative correlation is present, but the correlation is very slight as indicated by the value of the correlation coefficient. The hypothesis of mutual independence can not be rejected between the sound alike errors and user acceptability, and the random errors and the acceptability variable.

Figure 1 is a graph of the numeric user acceptability totals versus total user perceived errors. It shows that although there is evidence of a negative correlation there is little information existing as to where or at what error
level the acceptability values start to decrease. In fact the real problem is exemplified by observing the average response values for various groups of subjects. Table 1 contains, for various groups of subjects, the averages of the total values for the three acceptability questions along with the standard deviation. There is very little difference between the groups. Even the group that observed more than a 15% error rate still rated the system in the "like it" and "would use it" category. A Kruskal-Wallis test was done to determine if these groups of subjects had the identical mean response values. This hypothesis could not be rejected at the .05 or .1 significance level. The test statistic value, T, was calculated at 6.78 and the chi-square distribution quantile for the four degrees of freedom at the .05 level is 9.488 and at the .1 level is 7.779. Therefore, even though a small negative correlation is detected in the data, very little information can be gained as to where a distinct drop occurs in user acceptability values.

Two other Spearman's Rho correlation coefficient tests were done. First a correlation possibility was investigated between the ranked values of age and the ranked values of acceptability. The hypothesis that age and acceptability values were not correlated could not be rejected. Spearman's correlation coefficient was calculated at .03. The same test was done to check the data for mutual independence among the ranked values for years of experience and the ranked values of the acceptability totals. Again the independence hypothesis could not be rejected with a correlation coefficient of -.02.

In addition to the Kruskal-Wallis test previously mentioned, a series of similar tests were completed in order to determine if there were any differences in the mean
acceptability responses among different groups of individuals. Table 2 summarizes these tests. None of the hypotheses that all the mean acceptability responses were identical could be rejected. In other words no statistical differences could be found among the various groups tested.

The only test which suggested a possible difference was the test between the groups divided by geography. This was interesting because numerous people approached the experiment asking for example, if this machine understood "Louisianian". They knew they had a distinct southern accent, and if it recognized them they were very surprised. This could account for the relatively high Kruskal-Wallis statistic even though the groups could not statistically be shown to have different means.

In conclusion, there is really very little information present in the data collected. For this reason the experiment was cut short before the time was spent at business establishments. It is hypothesized that there are at least two basic flaws in the experimental design. First the experiment was working with an advanced technology. Some of the people who were tested were not aware that voice recognition existed. In fact, numerous people answered on the questionnaire that they had seen voice recognition to computers on "Star-Trek". With an attitude like that any recognition capability was impressive. If this is true it would be expected that there might have been a larger difference between the group acceptability averages between those who had seen voice recognition equipment before and those who had not. Since this did not occur we can only assume that the group which had seen voice recognition before knew about its user dependence limitations and were equally impressed with the user independence capabilities being demonstrated.

20
The second problem area involves the lack of a task which needed to be accomplished within the experimental framework. Reading a list of words and pointing out the errors did not create the frustrating situations which are going to exist when you encounter a recognition error while trying to accomplish a task. Although it was hoped that stopping the experiment each time an error occurred would provide this feeling, it did not totally simulate the frustration associated with task completion. Furthermore, subjects who had never seen or used voice recognition equipment had a difficult time visualizing how the equipment would actually be used. Although an explanation was given to each subject at the beginning of the experiment, it appears as if the concept was not totally understood by everyone. This was evidenced by some of the questions asked by the subjects after the experiment was finished. If there had been a realistic job or goal, this problem could be alleviated.
Figure 1

Graph of Raw Data
<table>
<thead>
<tr>
<th>% Error Rate Groups</th>
<th># of subjects in group</th>
<th>Average</th>
<th>Standard Deviation</th>
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</thead>
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<tr>
<td>0.0 - 1.5</td>
<td>19</td>
<td>4.40</td>
<td>4.46</td>
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<tr>
<td>2.0 - 5.0</td>
<td>13</td>
<td>4.41</td>
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<td>5.5 - 10.0</td>
<td>23</td>
<td>3.96</td>
<td>4.08</td>
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<td>10.5 - 14.5</td>
<td>16</td>
<td>3.71</td>
<td>3.93</td>
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<td>15.0 - 21.0</td>
<td>7</td>
<td>3.90</td>
<td>4.02</td>
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**TABLE 1.**

Acceptability Response Summary
<table>
<thead>
<tr>
<th>GROUP</th>
<th>TEST STATISTIC</th>
<th>CHI-SQUARE = .05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seen Voice equipment-not seen voice equipment</td>
<td>1.18</td>
<td>3.84</td>
</tr>
<tr>
<td>Used Voice equipment-not used voice equipment</td>
<td>3.65</td>
<td>3.84</td>
</tr>
<tr>
<td>Slow, intermediate, fast speed typist</td>
<td>2.14</td>
<td>5.99</td>
</tr>
<tr>
<td>Poor, fair, very good typing accuracy</td>
<td>4.38</td>
<td>5.99</td>
</tr>
<tr>
<td>Typing course-no typing course</td>
<td>0.12</td>
<td>3.84</td>
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<tr>
<td>Part of country raised in</td>
<td>10.15</td>
<td>11.07</td>
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</table>

**TABLE 2.**

Results of Kruskal-Wallis Tests
V. RECOMMENDATIONS AND CONCLUSIONS

The data collected in this experiment do not help answer the question of how good a voice recognition system must be to maintain user acceptability. The following recommendations are provided for future research efforts and experiments.

1. Introduce the subjects to voice recognition equipment before the start of the experiment.

2. Demonstrate the equipment within an appropriate work environment. In other words, demonstrate the use of the equipment to accomplish a suitable job within their individual areas of expertise.

3. Have the subjects train the equipment. Don't present a system which is obviously years ahead of currently available technology.

4. Set up a series of tasks which are suitable for voice recognition input which can be accomplished within the test environment. It appears that it is important that the job is very realistic in nature.

5. Consider the following method to vary the recognition accuracy for the experiment. Use a recognition system which has the capability to easily access not only the word which was recognized, but the runner up word. Then by the use of a random process determine whether the recognition unit should output the first or runner up word. If the recognition system used has a fairly good accuracy rate, the first choice word should be the correct word. Therefore, by
randomly selecting the second word you are randomly selecting errors from the recognition unit. It is possible that the recognition unit will make a mistake and the recognized word will be incorrect. If the random draw determines a correct response is to be given, the first word will be output to the system but in this case it is an error. This error was not expected; therefore, although the actual accuracy rate of the system will not be under the experimenters control the overall error rate should be very close to the percentage of times the runner up word is chosen. If a 100% accurate system was used this percentage of runner up choices would be equal to the error rate observed. Since a 100% accurate system does not exist it appears as if close will have to do.

The Interstate Electronics Corporation machine is suitable for this type of task. The only problem involved with this recommendation is that it will be impossible to observe error rates much less than the underlying error rate associated with the equipment chosen for use in the experiment.

Since there was evidence of the hypothesized negative correlation, it is possible that the frustration measurement will fulfill the needs of follow on experiments. This question of frustration measurement should be investigated further before undertaking the next phase of experimentation to answer the question about acceptable accuracy rates for voice recognition equipment.
BIBLIOGRAPHY


APPENDIX A

LIST 1,9000

10 D$ = "": REM D$ CONTAINS A CNTRL D
20 I$ = "": REM I$ CONTAINS A CNTRL I
30 DIM F$(3):F$(1) = "COMPUTER";F$(2) = "STOCK";F$(3) = "AIRLINE"
40 DIM W$(200, 2)

50 PRINT "DO YOU WANT TO:": PRINT "1. CREATE A NEW FILE": PRINT "2. UPDATE A FILE": PRINT "3. PRINTOUT A FILE": PRINT "4. STOP"
60 INPUT A

70 ON A GOTO 1000, 2000, 3000, 4000
1000 B$ = "CREATE"
1010 GOSUB 6000

1020 PRINT D$;"OPEN ";F$(A);", V001": PRINT D$;"CLOSE"
1030 I$ = 1: J = 1
1040 GOSUB 5000
1050 GOTO 50
2000 B$ = "UPDATE"
2010 GOSUB 6000

2020 ONERR GOTO 2050
2030 PRINT D$;"OPEN ";F$(A);", V001"
2040 PRINT D$;"READ ";F$(A)
2050 FOR I$ = 1 TO 200: FOR J$ = 1 TO 2: INPUT W$(I, J$): NEXT J$: NEXT I$
2060 PRINT D$;"CLOSE"
2070 PRINT "DO YOU WANT TO:": PRINT "1. CHANGE INDIVIDUAL WORDS": PRINT "2. ADD TO THE LIST OF WORDS": PRINT "3. STOP"

2080 INPUT AA
2090 ON AA GOTO 2100, 2200, 2300
2100 PRINT "WHAT WORD NUMBER DO YOU WANT TO CHANGE": PRINT "IF YOU WANT TO STOP INPUT A -1"
2110 INPUT I$: IF I$ = 0 THEN GOTO 2170
2120 PRINT "DO YOU WANT TO CHANGE": PRINT "1. THE WORD": PRINT "2. THE WORD LIST AND SOUND ALIKES"
2130 INPUT J
2140 PRINT I$, J
2150 INPUT W$(I$, J)
2160 GOTO 2100

2170 I$ = 201: GOSUB 5070
2180 GOTO 2070
2200 PRINT "WHAT WORD NUMBER DO YOU WANT TO START AT?"
2210 INPUT I$: J$ = 1
2220 GOSUB 5000
2230 GOTO 2070
2300 GOTO 50

3000 B$ = "PRINTOUT"
3010 GOSUB 6000
3020 ONERR GOTO 3050
3030 PRINT D$;"OPEN ";F$(A);", V001"
3040 PRINT D$;"READ ";F$(A)
3050 FOR I$ = 1 TO 200: FOR J$ = 1 TO 2: INPUT W$(I$, J$): NEXT J$: NEXT I$
3060 PRINT D$;"CLOSE"
3070 PRINT "DO YOU WANT": PRINT "1. JUST THE WORD LIST": PRINT "2. WORD LIST AND SOUND ALIKES": PRINT "3. STOP"
3080 INPUT J
3085 ON J GOTO 3090, 3090, 3400
DO YOU HAVE OKI-IMAGE LOADED AND WANT A HARDCOPY? (Y OR N)

IF Y$ = "N" THEN GOTO 3170

PRINT D$; "PR# 2"
PRINT I$, "SON"

ON J GOTO 3200, 3300, 3400

FOR I = 1 TO 200: PRINT I, W$(I, J): NEXT I
PRINT D$; "PR# 0": GOTO 3070
FOR I = 1 TO 200: PRINT I, W$(I, J - 1), W$(I, J): NEXT I
PRINT D$; "PR# 0": GOTO 3070
GOTO 50
STOP:
END

IF I > 200 THEN GOTO 5065
PRINT I, J
INPUT W$(I, J)
IF W$(I, J) = "END" THEN GOTO 5065
J = J + 1
IF J = 2 THEN GOTO 5010
I = I + 1: J = 1: GOTO 5000
GOSUB 5070: RETURN
PRINT D$; "OPEN ": F$(A); ", V001"
PRINT D$; "WRITE ": F$(A)
FOR K = 1 TO I - 1: FOR J = 1 TO 2: PRINT W$(K, J): NEXT J: NEXT K
PRINT D$; "CLOSE": RETURN
PRINT "WHAT FILE DO YOU WANT TO ": B$: PRINT "1. COMPUTER": PRINT "2.
STOCK": PRINT "3. AIRLINE"
INPUT A: RETURN
Airline Vocabulary

1. Allentown
2. Abilene
3. Albuquerque
4. East Hampton
5. Washington Dulles
6. Columbus Ohio
7. Akron
8. Ohara Field
9. Cleveland
10. Cedar Rapids
11. Corpus Christi
12. San Juan
13. Boston
14. Rapid City
15. Daytona Beach
16. Goose Bay
17. Dayton
18. Utica
19. Denver
20. Lewiston
21. Detroit
22. Montpelier
23. Charleston
24. Monterey
25. Franklin
26. Bangor
27. Fargo
28. Manitowoc
29. New York
30. San Jose
31. Fort Collins
32. Laramie
33. Kona
34. San Diego
35. Freeport
36. Missoula
37. Oklahoma City
38. Colorado Springs
39. Pittsburgh
40. Duluth
41. Louisville
42. St Petersburg
43. Honolulu
44. Kirksville
45. Columbia
46. Columbus Georgia
47. Roanoke
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194. Penta Gorda
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196. Danville
197. Mankato
198. Hattiesburg
199. Lampico
200. Clinton

Idaho Falls
Harrison
Wichita Falls
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Sacramento
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Pueblo
Grand Canyon
Atlantic City
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Princeton
Waterville
Laramie
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Council Bluffs
Guadalahara
Danville
Walla Walla
Sarasota
Poza Rica
Mankato
Tillsa
Victoria
Newburg
Tupelo
Lake Charles
Fayetteville
Pueblo
Clarksburg
Punta Gorda
Appleton
Computer vocabulary

1. Login
2. Alter
3. Backward
4. Command
5. Cursor Column
6. Findup
7. Left
8. Nfind
9. Put-D
10. Query
11. Reset
12. Set Autosave
13. Set File Mode
14. Set Line Character Off
15. Set Number
16. Set Reserved
17. Set Synonym
18. Set Verify
19. Stack
20. Delete Line
21. Assign
22. Five
23. Six
24. Seven
25. Eight
26. Nine
27. Ten
28. Alpha
29. Bravo
30. Charlie
31. Logoff
32. Bottom
33. Cmsg
34. C-Repalce
35. Find
36. Join Cursor
37. Msg
38. Next
39. Purge
40. Replace
41. Set Arbitrary Character
42. Set Filler
43. Set Line Character On
44. Set Nulls
45. Set Record Format
46. Set Stream
47. Set Variable Blank
48. Split
49. Uppercase
50. Duplicate Line
51. Access
52. Filedef
53. Global
54. Listfile
55. Start

Logoff
Add
Bottom
Compress
Cursor File
Forward
Load
Nfind-up
Parse
Quit
Restore
Set Case
Set File Name
Set Logical Record Length
Set Pack
Set Scale
Set Tableline
Set Wrap
Status
Duplicate Line
Access
Four
Sixty
Seventy
Eighty
Ninety
Send
Papa
Romeo
Whiskey
Login
Backward
Command
Cursor Column
Findup
Join
Macro
Nfind
Put-D
Reset
Set Autosave
Set File Mode
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Set Number
Set Reserved
Set Synonym
Set Verify
Stack
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Assign
Fetch
Cobol
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State
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57 One
58 Two
59 Three
60 Four
61 Profile
62 Cancel
63 Cms
64 Cp
65 Expand
66 File
67 Join Column
68 Modify
69 Power-Input
70 Renumber
71 Selective Change
72 Set Current Line
73 Set Image
74 Set Message Mode
75 Set Prefix
76 Set Span
77 Set Text
78 Sort
79 Type
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82 Quebec
83 Romeo
84 Sierra
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86 Uniform
87 Victor
88 Whiskey
89 Yankee
90 Zulu
91 No Profile
92 C-Append
93 C-Locate
94 C-Copy
95 Duplicate
96 Expand
97 File
98 Join
99 Move
100 Preserve
101 Repeat
102 Set APL
103 Set Escape
104 Set Implicitly Cms
105 Set Nondisplayable Characters
106 Set Range
107 Set Stay
108 Set Truncate Column
109 Sos
110 Up
111 Kilo
112 Echo
113 Echo
114 Thirty
115 Five
116 No Profile
117 C-Append
118 Cmsg
119 C-Replace
120 Emsg
121 Find
122 Join Cursor
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138 Tango
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140 Romeo
141 Nine
142 Preserve
143 X-ray
144 Charlie
145 Move
146 Profile
147 Cancel
148 Cms
149 Cp
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153 Join Column
154 Msg
155 Purge
156 Replace
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158 Set Filler
159 Set Line Character On
160 Set Nulls
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163 Set Variable Blank
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Texaco
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Ala Moana
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Honda
Allis Chalmers
American Hospital
Ashland Oil
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Boise Cascade
Canadian Pacific
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Chrysler
Coca Cola
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113 Union Oil of California
114 TRW
115 Citicorp
116 Revlon
117 Woolworth
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120 Fotomat
121 San Diego Gas
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125 Avon
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127 Allied Corp.
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129 Beckman Instruments
130 Big Three
131 Boston Edison
132 Brooklyn Union Gas
133 Bulova
134 Campbell Soup
135 Carolina Power & Light
136 Carpenter Technology
137 AMF
138 Becton Dickinson
139 Carolina Freight Carriers
140 Central Maine Power
141 Clark Oil & Refining
142 Coldwell Banker
143 Colonial Store
144 Commonwealth Edison
145 Central & South West
146 Consolidated Foods
147 Continental Can
148 Colt Industries
149 Clark Equipment
150 Central Soya
151 Continental Oil
152 Copper Range
153 Consolidated Freightway
154 Continental Air Lines
155 Corning
156 Cummins Engine
157 Cooper Laboratories
158 Cyprus Mines
159 Del Monte Corp
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161 Detroit Edison
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Holiday Inn
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International Paper
Jonathan Logan
Kimberly Clark
Lone Star Industries
Kaiser Steel
Fieldcrest
General Dynamics
Hilton
Ford Motor
Hershey
Host
International Harvester
Johnson & Johnson
Lenox
Lone Star Gas
Federal Mogul
Kennecott Copper
APPENDIX C

LILIST 1,9000

10 DIM W$(200,2), F$(3), P(4)
20 D$ = "" ; REM CONTAINS A CONTROL-D
30 F$(1) = "COMPUTER" ; F$(2) = "STOCK" ; F$(3) = "AIRLINE"
40 P(1) = .99 ; P(2) = .95 ; P(3) = .90 ; P(4) = .85
45 M$ = "" ; REM CONTAINS _A_ CONTROL-D
50 PRINT "WHAT WORD DATABASE DO YOU WANT TO USE?" ; PRINT "1. COMPUTER"
   "2. STOCK" ; PRINT "3. AIRLINE"
60 INPUT A
70 PRINT D$ ; "OPEN " ; F$(A) ; "", V001"
80 PRINT D$ ; "READ " ; F$(A)
90 FOR I = 1 TO 200 : FOR J = 1 TO 2 : INPUT W$(I, J) : NEXT J : NEXT I
100 PRINT D$ ; "CLOSE "
105 PRINT "INPUT A SEED" : INPUT IS
110 PRINT "WHAT ALGORITHM DO YOU WANT TO USE?"
120 INPUT B : IF B < 0 THEN STOP
130 GOSUB 40000
140 CALL JTABLE + 15
150 VOC$ = "CLASSIC.VOC"
160 GOSUB 40100
170 PRINT "FIRST SOME PRACTICE WORDS"
180 I = 1
190 PRINT I, W$(I, 1) : GOSUB 40400 : FOR Z = 1 TO 150 : NEXT Z : GOSUB 300
200 IF I < 11 THEN GOTO 190
210 Q = 0 : S = 0 : N = 0 : T = 0
220 PRINT "WE WILL NOW START THE EXPERIMENT"
230 I = 1
240 PRINT I, W$(I, 1) : GOSUB 40400 : FOR Z = 1 TO 150 : NEXT Z : GOSUB 300
250 IF I < 201 THEN GOTO 240
260 PRINT "THANK YOU FOR PARTICIPATING IN THE EXPERIMENT"
270 T = (200 - Q - S - N) / .2
280 PRINT B ; T ; "" ; Q ; "" ; S ; "" ; N
290 GOTO 110
300 IF RND (IS) ) P(B) THEN GOTO 320
310 PRINT M$ ; W$(I, 1) : GOTO 400
320 R = RND (IS)
330 IF R < .33 THEN GOTO 390
340 IF R < .66 THEN GOTO 360
350 PRINT M$ ; "" ; Q = Q + 1 : GOTO 400
360 U = INT ( RND (IS) * 200 ) + 1
370 IF U = I THEN GOTO 360
380 PRINT M$ ; W$(U, 1) ; N = N + 1 : GOTO 400
390 PRINT M$ ; W$(I, 2) ; S = S + 1
400 FOR Z = 1 TO 150 : NEXT Z : I = I + 1 : PRINT : RETURN
Appendix D

Code # ______________________

CATEGORY [ ] AIRLINE
[ ] STOCK BROKER Age ______
[ ] COMPUTER

TIME SPENT AT A COMPUTER TERMINAL A DAY _____________ hrs.

1. Have you used voice recognition equipment before ☐ YES ☐ NO

2. Have you seen voice recognition equipment used before ☐ YES ☐ NO

3. Considering that you know how many typing errors you normally make, and considering the number of errors you saw the voice system make, how well do you like the voice system.

Really Dislike Don't Neutral: If I have it, fine If I don't have it, fine
Dislike Like Neutral: If I have it, fine If I don't have it, fine
Like Really

4. Is the accuracy of the voice recognition system adequate enough to make you want to use it in your daily job?

Very Inadequate Slightly Inadequate Neutral Slightly Adequate Very Adequate

5. Comparing voice input to manual typing input, is voice input:

Undoubtedly Worse Moderately Worse The Same Moderately Better Undoubtedly Better
6. Do you consider yourself a slow, intermediate, or fast typist?

Slow    Intermediate    Fast

7. How accurately do you think you type?

Poor    Fair    Quite Well

8. Did you ever take a typing course?

Yes    No

9. What part of the country, (USA) did you grow up in?

________________________

10. How many years experience have you had in typing information into computers?

_________________________years.

11. Please tell the experimenter how much and what type of educational background you have.
| C | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
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| 25 | 13 | 16 | 12 | 8 | 23 | 22 | 1 | 5 | 5 | 5 | 15 | 2 | 2 | 1 | 1 | 1 |
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## Appendix F: Ranked Data

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Voice recognition 1982 accuracy.