Toward Private and Independent Accessible Write-In Voting: A Multimodal Prediction Approach

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Abstract. The overall objective of this research is to design a multimodal system to write-in a candidate's name that addresses the issues of time, privacy, and accessibility. In order to determine if these issues were met, the design is analyzed and compared against alternate methods of writing-in a candidate's name. An experiment was performed to assess two aspects of the multimodal system: speech interaction and switch interaction. The research intends to capture and analyze the efficiency and effectiveness of writing-in a candidate's name anonymously through multimodal interactions. Though the essence of this research embodies universal of design for everyone everywhere, the design and experiments put forth in this paper will focus on the U.S. voting population.

Keywords: Accessibility · Universally usable interfaces · Electronic voting systems · Multimodal interaction · Text prediction

1 Introduction

The design of ballots is the foundation of successful election operations. Today, a properly designed ballot interface is one of the key aspects to running a successful election; an interface that enables all voters to have independent access to the ballot. As technology for electronic voting systems continues to develop, there is an increased need for universal design in these systems [1, 2]. A universal design ensures that systems are as usable as possible by as many people as possible regardless of age, ability or situation [3]. By focusing on the needs of the voter, the design of electronic voting systems can satisfy the aforementioned usable criteria. With ballot privacy

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constantly being a major concern in the design of voting systems, it is often difficult to implement voting technology that incorporates a private, yet universal, design. Some developers today address this issue through the design of their electronic voting systems [4]; however, these electronic voting systems have yet to integrate universal design into the writing-in of a candidate's name.

The objective of this research is to develop a system in which a person, regardless of ability or disability, can efficiently, anonymously, independently, and effectively spell a candidate's name through multimodal interaction. The research conducted captures and analyzes the efficiency and effectiveness of writing-in a candidate's name anonymously through multimodal interactions. Broadly speaking, the purpose of this research is to design a method to write-in a candidate's name that addresses the issues of time, privacy, and accessibility.

2 Background

The Help America Vote Act (HAVA) of 2002 was created [9] as a result of the major issues faced in the 2000 United States Presidential Election. HAVA aimed to prevent these problems, such as interpreting voter intent, from happening in future elections. The Voluntary Voting System Guidelines (VVSG), which expand access for individuals with disabilities to vote privately and independently [5], is a byproduct of HAVA. The VVSG addresses the advancement of technology and provides requirements for voting systems to be tested to ensure functionality, security, and accessibility [4]. The VVSG states that all voters must have access to the voting process without discrimination, and that the voting process must be accessible to individuals with disabilities, including non-visual accessibility. It also states that voting systems should be independently accessible to as many voters as possible, which further emphasizes the need for a universal design. A universally designed system requires no special adaptation or additional cost to be usable by as many people as possible thus is accessible to people with disabilities [6–9].

In United States' elections, voters have the option to vote for a person who is not listed on the ballot by writing that person's name in a dedicated space on the ballot. Because election law is not mandated federally, laws pertaining to writing-in a candidate vary across all states [5]. Most, but not all states allow write-in candidates for general elections. Similarly, some states require people to pre-register as a write-in candidate for an election, while others do not. Some states do not allow candidates to be written-in at all [5]. Election write-ins can introduce a host of challenges that often result in turmoil. The 2010 general election in Alaska was the basis of one such controversy [10]. Joe Miller and Lisa Murkowski were candidates for U.S. Senate in the election on November second. Murkowski was registered as a write-in candidate, and upon completion of the vote tallies, was declared the winner of the race. Murkowski obtained more than 97 percent of the write-in votes; 11 percent more votes than Joe Miller [10]. Miller, however, filed a lawsuit, claiming that write-in votes were not counted properly according to Alaska state law. Miller's argument was that elections officials accounted for voter *intent*, from which certain ballots, like those shown in Fig. 1, were counted as votes for Murkowski. By designing a usable ballot interface, voters can feel certain about their votes being casted as intended, and election officials are able to feel confident about interpreting voters' intent.

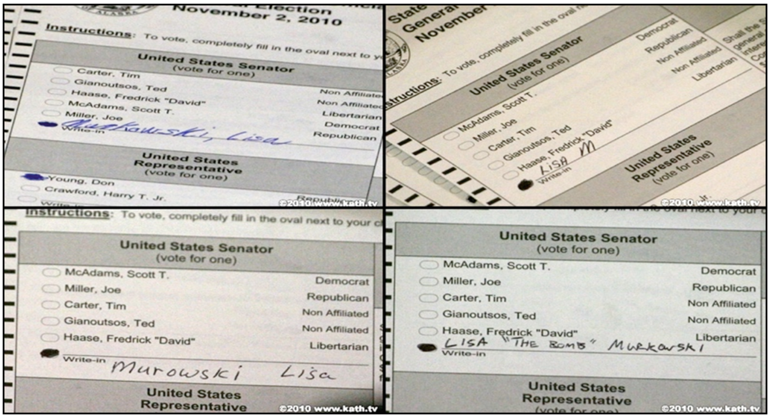

Fig. 1. Ballot variations for write-in candidate, lisa murkowski

2.1 Accessible Write-In Voting

Due Electronic voting systems that employ the use of a touchscreen often feature a virtual keyboard for voters to input the write-in candidate's name. When the VVSG was released, many voting system manufacturers opted to utilize the audio ballot – reading the on-screen content aloud via headphones – to meet the accessibility standard for writing-in candidate's names. For the write-in option, traditional audio ballots present the alphabet to the voter in a linear fashion from A to Z, one letter at a time, wrapping around to start over from "A" when the end is reached. The voter then spells the candidate's name, letter by letter, by making a selection when the desired letter is heard through the headphones. The presentation style of the alphabet and manner in which voters make selections vary between voting system designs.

The presentation style of voting system designs is to traverse the alphabet via automatic scanning or voter input. With automatic scanning, the system's audio will prompt the voter with a letter and pause to give the voter time to select the letter. If the voter does not make a selection, the system continues automatically to the next sequential letter. When automatic scanning is not used, the voting system will only continue to the next letter when the voter chooses to do so. In this case, the voter has options to select the letter, or to skip the letter.

Traditional voting systems implement a wide range of techniques for voters to make letter selections when writing-in a candidate in conjunction with audio ballots. The systems can provide the voter with a button to select a letter, e.g., buttons for selecting and skipping letters; buttons for selecting, skipping, and returning to the previous letter; a button to select and a rotary dial to scroll through the letters; or touchscreen guides for selecting and skipping letters.

The research discussed here builds on the Prime III voting system prototype [11], which features multimodal inputs (physical and speech) with automatic scanning. Using these methods, enhanced with a clustering and prediction model, it is hypothesized that voters will have a more efficient, effective, and satisfactory accessible write-in experience.

3 System Design

3.1 Cluster Selection

For each letter of the candidate's name, the clusters are presented to the voter for selection. The voter begins by making the proper selections, through a microphone or switch button, to spell the candidate's name. The system first prompts the voter with the alphabet clusters. Once the voter selects the desired cluster, containing the first letter of the intended candidate's last name, the system then prompts the voter with the letters contained in that cluster. The voter then chooses a letter, and the system moves on to get the next letter of the desired candidate's name. Once letters have been selected, the name prediction can begin. If the voter does not intend to write-in one of the names suggested, s/he continues the process of selecting clusters, then letters, until the correct name is suggested, or the name has been spelled in full.

As can be seen from Table 1, the alphabet is broken down into five standard clusters; four clusters of five letters, and one cluster of six letters. When selecting the first letter of each of the candidate's names, the voter is first prompted to choose from one of the five standard clusters. The first cluster presented to the voter is chosen at random, with the prompts for the remaining clusters following in alphabetical order, in a round robin fashion. This method for presenting a randomly selected initial cluster increases voter privacy by preventing selection detection via eavesdropping bystanders.

Table 1. Standard letter clusters

Cluster Letters
A, B, C, D, E
F, G, H, I, J
K, L, M, N, O
P, Q, R, S, T
U, V, W, X, Y, Z

The purpose of this randomization is to secure ballot anonymity by ensuring that bystanders would not be able to decipher for whom the voter voted. The initial cluster is chosen using a weighted random; each cluster may not have an equal chance of being chosen first. The weights for the clusters depend on the letter position of the name being spelled and the names in the database. Once the first letter has been selected, the system is able to present a common letter cluster prior to the presentation of the five standard letter cluster prompts. This common letter cluster consists of the three most common next letters, given the letters previously selected by the voter. The most common letter cluster is a special cluster that is dependent on the presence of database name matches to the letters already selected. For example, suppose the voter is spelling the intended candidate's last name, and has selected 'C' as the first letter. Based on the records in the database, the three most frequent letters that follow 'C' as the first letter are presented in this "most common letter" cluster.

The most common letter cluster expedites the selection process since the voter is able to make selections at this point, rather than potentially traversing each of the standard letter clusters. If the next letter of the name is not in the most common letter cluster, the voter is then prompted to select one of the standard clusters.

Figure 2 demonstrates the process of presenting cluster prompts to the voter. Once the voter selects the correct cluster containing the next letter of the desired candidate's name, s/he is prompted to choose from those letters: if the voter selects the cluster of letters {A, B, C, D, E}, s/he is prompted to choose from those letters within that cluster; if the voter selects the cluster of the most common letters, for example, {R, A, E}, s/he is prompted to choose a letter from that common letter cluster. Once the desired letter is chosen, the system moves on to the set of prompts for the voter to select the next letter of the write-in candidate's name.

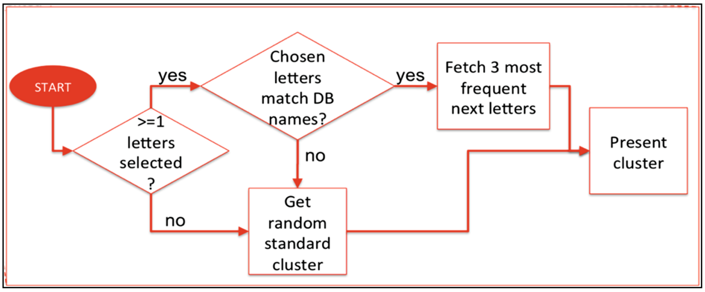

Fig. 2. Auditory write-in cluster prompt algorithm

3.2 Name Prediction

The prediction system for writing in a candidate's name is made possible through the use of a local database of names. The database contains two types of names; common names and names that have the highest probability of being written-in. The high probability names stored are based on pre-registered write-in candidates and other highly popular write-in names (e.g. Mickey Mouse). The database also contains a table of the top 1000 ranked surnames, a table containing the top 1000 ranked male names and the top 1000 ranked female names from the 1990 United States Census [12, 13]. Because there is a single database table for given names, the Census rankings of each name needed to be altered to form a single ranking scheme for both male and female names. This new ranking scheme, combining male and female names into a single list, was based on the percent frequency of name popularity rather than the sole rank.

In order to effectively reduce the amount of time a voter spends to write-in a candidate's name, this system utilizes a name prediction method built on the name database. The names suggested are fetched from the name database depending on the letters already chosen by the voter. If one of the predicted names is correct, the voter does not need to go through the entire spelling process. There are various aspects in the timing of the name predictions. A visual summary of the name prediction operation is shown in Fig. 3.

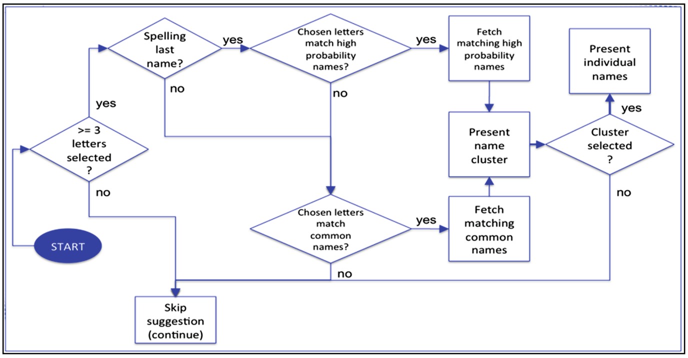

Fig. 3. Auditory write-in prediction algorithms

4 Experiment

4.1 Experiment Design

As previously stated, the clustering and predictive write-in system served as the experimental system; a linear spelling write-in system served as the control system. The interface of the experimental system was as described in Sect. 3. The database created for the experimental system included pre-registered (highly probable) write-in candidates from the 2010 general election U.S. Senate race in Alaska, in addition to the census names. The linear system was modeled after the write-in methods used in the DRE systems described in Sect. 2, and uses neither clustering nor prediction during the write-in process. To write-in a name using the linear system, participants were presented each letter of the alphabet sequentially, beginning with the letter 'A', selecting one at a time until the spelling is complete. This linear system was used for the comparison of results of the experiment.

The experiment was designed to randomly divide the participants into two groups. The participants in the first group interacted with the systems via speech input (herein referred to as the "speech group"); the participants in the second group interacted with the systems via switch input (herein referred to as the "switch group"). Participants in both groups were prompted to make selections via speakers (for observation). Speech group participants made selections via microphone; switch group participants interacted with the system via a 2-button switch – pressing the right button moved to the next prompt, while pressing the left button made selections. Within each group, two tasks were completed on both the experimental and linear systems.

4.2 Tasks

System prompts can only be interrupted when using the switch input method, and not using the speech input method. Therefore, completing the evaluation tasks via the speech input method on the linear control system would overburden the study participants. Instead, the corresponding tasks were simulated under a best-case scenario for the speech input group in order to evaluate the efficiency of the control system vs. the experimental system.

4.3 Participants

There were 40 participants in this study; all were recruited from Auburn University. The demographic results indicated that the age range for the participants was 19 to 27, with an average 20.2 years of age. There were 34 males to participate in this study, making up 85% of the participants. Three of the participants listed that they had disabilities; one indicated dyslexia, another indicated loss of hearing in one ear, and another indicated poor vision.

5 Results and Discussion

The performance metrics evaluated during the experiment in this study were effectiveness and efficiency. The effectiveness is determined by analyzing the accuracy of task completion. Efficiency is determined by measuring the task completion time. User satisfaction was measured based on the participants' response from the post-experiment questionnaire. The following sections report on the findings for each of the usability metrics individually.

5.1 Effectiveness

In this study, the effectiveness was measured discretely as success and failure. A task was deemed successful if the participant completed the spelling of a name correctly. If a participant was unable to complete the spelling, or if upon completion the name spelled was incorrect, the task was declared a failure. As previously stated, one of the expected outcomes of the experiment was that the participants would be able to accurately complete the given tasks using both input methods. 93.75 percent of the tasks were completed successfully on the experimental system, including participants in both the speech and switch groups. Zero participants failed multiple tasks. Of the five failed tasks, one task ended before the spelling of the name was complete; four were incorrectly spelled name submissions.

5.2 Efficiency

An expected outcome of the experiment was that the experimental system would be more efficient than the linear system. The results of this investigation are reported in this section. The experimental procedure for participants in the speech group differed from that of the switch group. Therefore, efficiency data for each of the two groups was analyzed separately. Tables 2 and 3 are discussed in the reporting of both groups.

Speech Interaction. The average time-to-task for Task A (user-chosen names) on the experimental system was 5.19 m; the average time-to-task for the same names on the linear system was 8.12 m (see Table 2). A total of 21 user chosen names were spelled during the study. 81 percent of the names chosen had a record in the database; 88 percent of those names were suggested to the participants. Of the names suggested, the participants selected 87 percent (see Table 3).

Table 2. Analysis summary for user chosen names for speech and switch interactions

Interaction Type	Measure	Experimental System	Linear System
Speech	Average Time-to-Task	5.19 mins (std. dev. 1.99)	8.12 mins (std. dev. 2.07)
Switch	Average Time-to-Task	3.51 mins (std. dev. 0.97)	4.90 mins (std. dev. 1.58)

Table 3. Common name records, speech and switch interaction selection percentage

Measure	Speech	Switch
Number of User Chosen Names Spelled	21	19
Names with Database Records	80.95%	73.68%
Intended Names Suggested to Participant	88.24%	92.86%
Suggested Names Selected by Participant	86.67%	100%

Figure 3 provides a more in-depth comparison of both systems used in the speech group. The shortest surname chosen was “Doe” (three letters); the longest surnames spelled were “Johnson” and “Patrick” (seven letters). The surname length with the fastest time-to-task was the three-letter group on the experimental system, at 2.83 m. The surname length with the slowest time-to-task was the seven-letter group on the linear system, at 11.00 m. The smallest difference in time-to-task between the two systems was the three-letter group, with a time difference of 0.85 m. The largest difference was the six-letter group, with a time difference of 4.02 m. The time-to-task

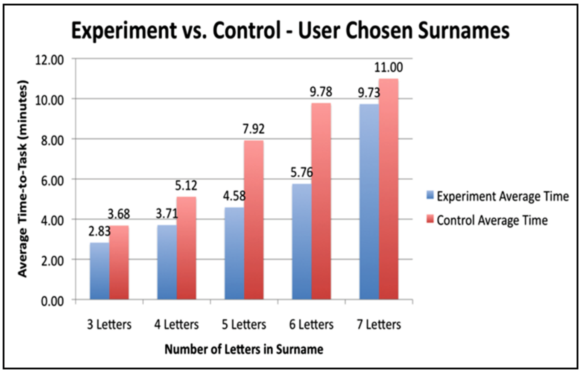

Fig. 4. Time-to-task by name length for user chosen names for speech interaction

data was evaluated statistically via the Wilcoxon Rank Sum test, showing that the experimental system is faster than the linear system ($p < 0.0001$) (Fig. 4).

Switch Interaction. The average time-to-task for Task A (user-chosen names) on the experimental system was 3.51 m; the average time-to task for the same names on the linear system was 4.9 m (see Table 2). Of the 19 surnames chosen in the switch input group, there were records in the database for 74 percent of these names; 93 percent of the names with database records were suggested to the participants. When names were suggested, 100 percent of the participants selected the name (see Table 3). Figure 5 provides a more in-depth comparison of both systems used in the switch group. The shortest surname chosen was "Doe" (three letters); the longest surnames spelled were "Newton" and "Dawkin" (six letters). There were four, four-letter surnames spelled, averaging 2.94 on the experimental system and 3.61 on the linear system. Averaging 3.34 and 5.18 on the experimental and linear systems, respectively, were 12 five-letter surnames. The time-to-task data was evaluated statistically via the paired t-test, showing that the experimental system is between 1.4 and 2.5 m faster than the linear system (95% confidence). The results of the t-test ($p < 0.0001$) suggest that the experimental system is faster than the linear system. Figure 4 depicts a summary of the statistical analysis of the time-to-task for the speech interaction method.

5.3 User Satisfaction

The post-questionnaire was used to gain knowledge of the participants' opinion of the system designs used in this experiment. Since only the participants in the switch group performed tasks on the linear system, user satisfaction data on the linear system was not collected from the participants in the speech group (Table 4). The Signed Rank Wilcoxon test shows that, for statements one through five, there was not enough evidence to show a difference between the two systems ($p > 0.05$). However, in response to the usability statement, results suggest that the linear system was more usable than the experimental system ($p = 0.03$). In addition, Table 4 shows the results of a combined analysis of the questionnaire responses. Overall, there was insufficient evidence to show a significant difference in the user satisfaction between the two systems ($p = 0.17$) (Fig. 5).

Table 4. Switch interaction method – experiment vs. control user satisfaction analysis

User Satisfaction Statement	Wilcoxon p-value
1. This method is easy to use.	0.5547
2. It was easy to understand the instructions.	0.0781
3. It was easy to correct my spelling mistakes.	0.9375
4. I feel that I made selections privately.	1.000
5. This method should be used for voting during elections.	0.3828
6. Usable	0.0313
Overall User Perception	0.1698

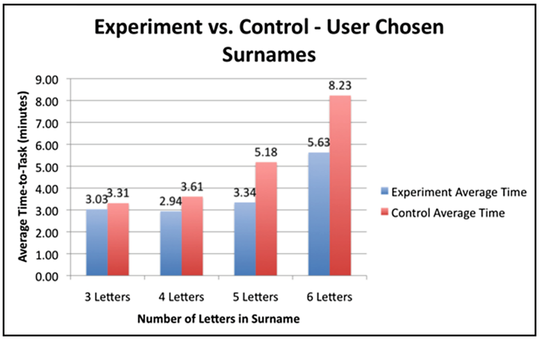

Fig. 5. Switch interaction- user chosen summary by name

6 Conclusion

The ultimate goal of electronic voting systems today should be to allow anyone to vote privately and independently. The VVSG provides useful and necessary guidelines to ensure that all eligible citizens have the same access when voting, regardless of a person's disability. The primary objective of this research was to embrace these guidelines by developing a universal design in which a person can efficiently, anonymously, and independently write-in a candidate's name during an election. The method designed allows voters to spell a candidate's name discretely through multimodal interaction. This method uses a clustering and predictive approach in order for the voter to get through the voting process of writing-in a candidate's name quickly and accurately.

The objective of this research was evaluated by analyzing different methods of writing-in a candidate's name. The evaluation measures were the time taken to complete write-in tasks, accuracy of the task completion, and user perception of the write-in method used. Analysis of these three measures led to the determination of the predictive system's efficiency, effectiveness, and user satisfaction. The evaluation results suggest that the system is effective, given that 94 percent of all tasks were completed, efficient, with statistically significant evidence showing that voters can write-in names faster with the predictive system than with the linear systems in use today, and provides user satisfaction, with statistical significance that the overall user perception of the system is significantly above a mid-range neutral ranking. Overall, the results of the experiment show that the designed system is an effective and efficient solution to writing-in a candidate's name.

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