Help Me Speak

Ganesh Arumugam[1] **Stephen Flaherty**[2] **Mansoor Pervaiz**[2] **Zhichun Ye**[1]

[1]College of Computer and Information Sciences
Northeastern University
{arumugam.g,ye.zhic}@husky.neu.edu

[2]College of Computer and Information Sciences
Bouve' College of Health Sciences
Northeastern University
{sflaher1,mansoor}@ccs.neu.edu

INTRODUCTION

People with speech impairments have a hard time communicating with the general public. For Dysarthria (a class of neurological speech motor disorder), in the early stages of the condition, patients are able to communicate because other people can understand them (though with some difficulty). However, as the impairment progresses the communication becomes labored and eventually the patients reduce the communication attempts. As a result, the social network of the patients shrinks considerably. So much so, that only the caregivers of the patients are able to understand them for a very limited set of utterances. This reduces the self-reliance and autonomy of these patients [1].

However, this problem becomes exacerbated for subjects with motor impairments. Patients with Parkinson's disease (PD), Amyotrophic Lateral Sclerosis (ALS), Multiple Sclerosis (MS) and brain injuries such as stroke or trauma, not only suffer from speech impairment but also motor control impairments. This slows the communication process and prevents them from using any normal motion-controlled device which can enhance communication such as a personal computer [2].

As a result, users with visual, cognitive and motor impairments face many challenges in trying to use typical computer systems and software, and can struggle with assistive technologies [3]. The standard speech recognition software products such as Dragon Naturally Speaking (www.nuance.com) or Windows Speech Recognition (www.microsoft.com), are not viable solutions for these users, as research has shown their accuracy on subjects with even mild dysarthria was less than 70% [4]. The impaired speech of dysarthric patients is not well interpreted by these programs and there are no currently available products designed for dysarthric speakers. Other methods that employ speech recognition on subject with moderate or severe dysarthria require extensive training sessions for users and still produced only mixed results, with minimal lasting improvements in the accuracy of recognition [5].

DESIGN

The goal of this project is to provide a simple voice-activated email application for dysarthric speakers. It allows users to complete basic email tasks such as create, read, reply and delete an email. The email content will be sent as a voice attachment. The system relies on a sparse design featuring large buttons and labels supporting the most basic functions. The requirements of the system are shown in Table 1.

Table 1 System requirements

Functional requirements

1. The system should not require the use of hands as a form of input.
2. The system should visually have large and easy to see components.
3. The system should be customizable for each user.

Non-functional requirements

4. The system should be platform independent and reliable.
5. The proposed product's hardware requirements for visual display, keyboard layout, workstation layout, environment, display with reflections, display colors and non-keyboard input
6. The efficiency of the system can be measured in terms of response time and task performance.
7. Large button/text size and contrasting colors
8. Function within the social organization and infrastructure of the care homes.
9. Operate in a standard power and light environment with broadband internet access.

The final design was driven by the needs, abilities and wants of our target users. Each screen/page of the web browser-based design has a limited number of options and contrasting colors to reduce the visual and cognitive demands on the user [7]. One of our key functional requirements was that the system should visually have large and easy to see components. We also specified a non-functional requirement focusing on button/text size and color contrasts in visual displays. The system responds to vocal commands from the user by employing pattern recognition to compare speech from the user to previously recorded versions of each command and the user does not need to use their hands as a form of input. Each user records their own voice for the commands, allowing the system to accommodate the idiosyncrasies of individual speech pattern [7], meeting our final critical functional requirement-that the system should be customizable for each user.

As mentioned in our non-functional requirements, the system is based on web browser technology and is platform independent. It is reliable and can be installed on any computer which has internet access. It doesn't require any particular hardware such as a special designed mouse or keyboard since the system is based on voice command. The social organization and infrastructure of the care facilities are important for supporting the target user of the system because the user will require help to set up and maintain the system. The operating environment of the facilities will also need to provide suitable power and light for the user to successfully interact with the system. The efficiency of our system can be measured in terms of response time and performance issue.

The heuristic evaluations from Team 6 were very helpful in refining the final design. They discovered a number of consistency and navigation issues that would have hampered user testing. Some issues are conglomerates of several comments from the reviewing team. Items with similar or related themes were addressed together.

Catastrophe/Major Issues identified

- Indicate to user which menu they are in. Some of the screens look similar so it may not be clear which part of the application a user is in.
  Solution: Add audio cues and labels to areas to help user avoid getting lost. We have to be careful to distinguish these labels from the active buttons. We do not want users to think they can select the label as a command- which would not make sense as the label tells them where they currently are. We employed audio cues on the main pages to let the user know where they are. We used very short descriptive messages as we did not want to overwhelm them with information. We also wanted to avoid annoying our users with an abundance of messages every time they move between screens. We chose not to add extra labels in many places to reduce the cognitive load and visual demands on the user [7].
- Broken link in the help page. Cannot navigate to the Home screen.
  Solution: repair the link.
- Voice activation on the help screen.
  Solution: This was our plan all along. For the demo we did not have voice recognition ready.
- Background color and button controls on the Help page are different than the other pages.
  Solution: fix the CSS file. We had ended up with 2 CSS files for the demo due to some last minute issues that we could not resolve in time. All CSS style elements will be consolidated in one file to improve layout consistency.
- Help page too long. Need navigation elements or individual help links from current page where user currently at.
  Solution: Help page will be voice activated to allow scrolling and navigation, something that was not ready in time for the prototype. We added individual help buttons on some of the screens. We have to assess the functionality gain with the cost of adding new buttons with our users since our goal is to keep the screens as simple as possible [7]. The help page formatting was also brought in line to match the rest of the application.

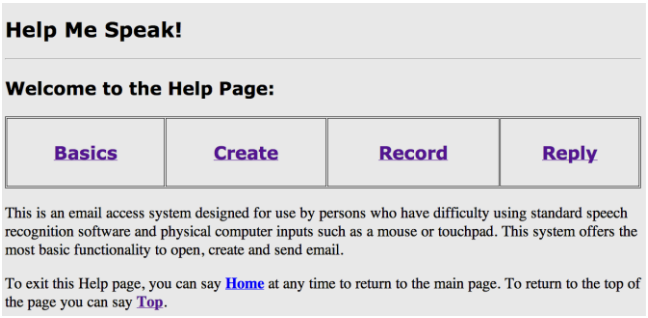

Figure 1 Help page before heuristic evaluation

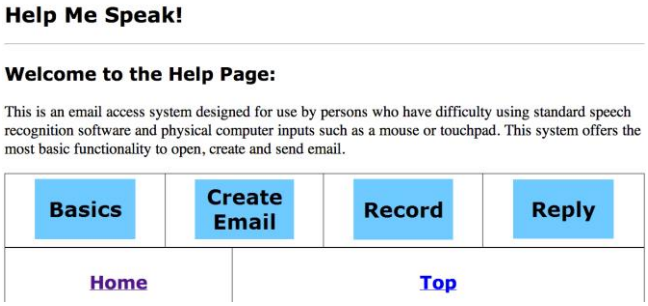

Figure 2 Help page after heuristic evaluation

- No way to stop recording message before 2 minutes.
  Solution: the system was intended to allow the user to stop speaking for 10 seconds to discontinue recording. It would have been too difficult to allow a voice command to stop recording as we would have to extract and recognize that command while recording the message and distinguish this intent from what the user is saying in the message. Part of the user training will be to instruct them on this method of stopping a recording.
- Reducing the number of confirmation screens
  Solution: Ongoing design decisions here. We want to keep the system simple with the fewest commands, but we also don't want users to feel lost or unsure of what is happening. User testing should help us with input from our users about the need for confirmations [7].
- Doesn't contain a setting page.
  Solution: Add the setting page and put a button at the home screen. Use a different color to represent it as a clickable button which allow caregivers to help users to record their commands.

Here you can train the system for your voice. Record each command at least five times. The more you train for each command the better the system will perform

Back

Commands		
Create Email	0	Record Stop
Inbox	0	Record Stop
Help	0	Record Stop
Quit	0	Record Stop
Yes	0	Record Stop

Figure 3 Setting page

Minor/Cosmetic issues

- Using animation or images for buttons and controls.
  Solution: We wanted to have buttons with a clear label as to the function of the button. Adding images would require the user to remember what the image stands for and the action it performs. The user would also have to associate a command with the image. To reduce cognitive load on our users, each button is labeled with the voice command required. We elect not to use image icons in the final design.
- Popup to alert user of incorrect command
  Solution: This is part of the intended design. If the user says a command that is not recognized, there will be an alert to let them know and ask them to repeat the command. To reduce commands needed and complexity, the proposed design for the popup would be to close after 5 to 10 seconds and return the user to the current workspace. This way the use does not have to say an additional command. We will evaluate this with the user testing.
- Allow sorting of rows in email.
  Solution: no action. Creating a sort option would introduce a whole new range of commands for the users and increase the complexity. Our users want a simple system to send and open emails. It takes them a great deal of time to navigate through current systems. We will stay with a more simple approach.
- Show greater distinction between rows or buttons with different sizes, colors or backgrounds.
  Solution: Evaluate in user testing to see if this is what our users want. Changing colors might add to the cognitive load as the user will have to remember what the color indicates.
- Table changes size when navigating in emails.

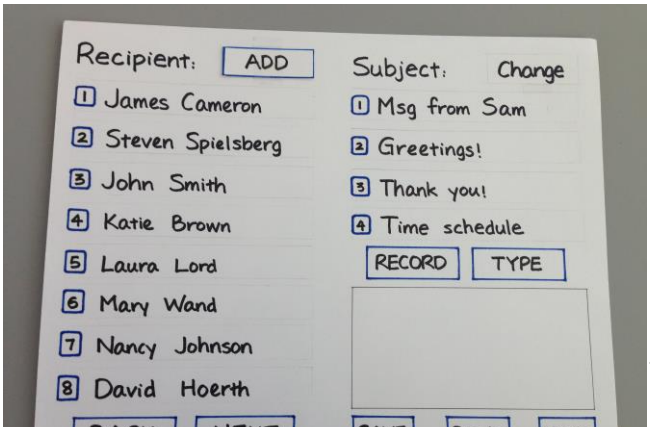

Figure 4 New Email Screen in our paper prototype

Solution: Examine the code and retest to look for reason behind the sizing discrepancy. Correct as needed.

Design Process

The design process for this project was very enlightening for us. We charged into the early stages of development with very clear ideas about what we wanted to provide for our users. We envisioned a comprehensive system that would allow users to open email, video conferencing programs, word processing software and pictures/videos on their computer by just using their voice to issue commands. We imagined that our users would be able to seamlessly navigate among these different applications and increase their level of social interaction and connections with friends and family. We also sought to create a system to aid our users in speaking, especially around those who are not familiar with their individual speech patterns. We imagined that this would allow them to engage in more public activity with others and to communicate more effectively.

We were in for a rude awakening. From our first interactions with users on, we discovered that our ambitious design was simply off target for a variety of reasons. Our users have significant visual impairments and many have cognitive challenges, and these issues made our original goal of an interface packed with features impractical. Many of our users would grow tired from the need to process large amounts of information, and a screen full of buttons and text only made this worse [7]. We also found that users did not want assistance with speaking in the form of amplifiers or computer generated speech. They were passionate about using their own voices as much as they could to communicate. This passion could be viewed as an act of defiance against their health conditions. It felt to us that they did not want to admit or accept that they could no longer speak themselves, and that allowing a device to speak for them would be "giving in". Despite the process of speaking presenting a significant physical and mental challenge for them, they were going to keep doing it as long they could.

The capabilities of our users and their desire to user their own voices forced us to rethink our approach. We elected to step back on our plan and simply focus on an email application. Users expressed a strong desire to send and view emails, but they struggled with their current systems. They needed a simple system that could help them quickly create and send emails.

Since our target users struggle with their current systems which usually require multiple steps to achieve a very basic task, we decided to minimize the number of page switching and integrate more than one function into a single page in our paper prototype (Figure 4). We thought it would

Num	Contact Name
1	Martin Smith
2	Laura Rees
3	Dave Wong
4	Susan Lord
5	Rachel Hoerth
6	Julie Paul
7	Williams Anthonio

Figure 5a Select a Recipient Screen

improve the user experience. However, in our user tests, most users were confused by the cluttered layout. They did not know where to start and most of them were confused by the "next" button in our create email page. This led us to change our design scheme. We split the process into a sequence of three screens and remove the options of updating the subject of the outgoing email and the ability to type in a message (figure 5a-c).

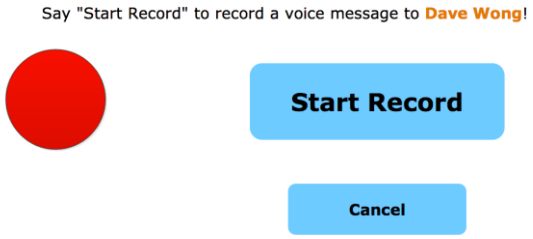

Figure 5b Record a Message Screen

We also changed a lot on our home screen. We replaced the "Drafts" and "Sent email" button with "Help" and "Quit" buttons because in our user tests we found that our target users don't understand what "drafts" mean and none of them really review their drafts and sent emails. Moreover, they confused "Sent Email" with "Send New Email". We also changed the words on the "new email" button to "create email" since they thought the word "new email" meant "the new coming email".

IMPLEMENTATION

The implementation of HelpMeSpeak used a combination of standard web technology for the user facing components. HTML, CSS, and Javascript were employed to create the web interface and "buttons" for the functions. We choose a web browser based interface to afford ease of installation and cross platform compatibility. The user needs only to run an up to date web browser on their system. We had originally considered a Java based approach, but this would have necessitated a more complicated set up and installation. The web platform also gives the greatest opportunity for scaling the project beyond our initial user population.

Since the primary target user will use his/her voice to activate features and functions, the buttons are mostly to show the options available on each screen. They are responsive and could be clicked with a mouse if the user has the motor skills to do so. The large button size is designed for visually impaired users. In prototyping and interviews, our users expressed difficulty in seeing what was on their screen when using standard solutions for people with disabilities. We sought to create a very simple layout with large, clearly readable features.

The voice recognition component was implemented in Python. It is not a true speech recognition system, rather we are using a pattern matching approach that compares the commands spoken by the user to previously recorded versions of the commands. The system is matching the audio profile with stored version of the command recorded by the same user. We took this approach because natural language processing is a challenging area and though there are commercial products that perform well (such as Dragon Naturally Speaking) for most users, our target population of

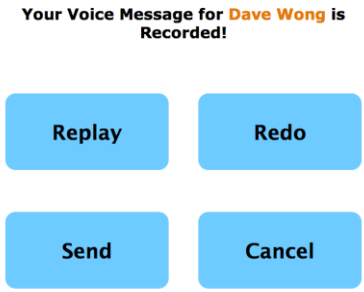

Figure 6c Send Message Screen

dysarthric speakers is not able to use off the shelf solutions. Standard systems cannot interpret their impaired speech patterns, as several of our users noted to us during testing. They also have difficulty performing the lengthy training component required by many speech recognition programs, the quickly grow tired from the sheer effort of speaking and the cognitive demands of the training phase. Our solution is to record a set of simple one- to three-word commands for each user and use them for the pattern matching. There is no need for the system to learn their vocal characteristics. If a user's speech pattern changes over time or due to disease processes, the commands can simply be re-recorded.

EVALUATION METHOD

Our goal was develop a set of evaluation criteria to test whether our system meets the following critical functional and non-functional requirements that we have chosen from the full list in Table 1.

Functional requirements: (F)

1. The system should not require the use of hands as a form of input.
2. The system should visually have large and easy to see components.
3. The system should be customizable for each user.

Non-functional requirements: (N)

1. The product for dysarthria people should be platform independent and reliable.
2. The efficiency of our product can be measured in terms of response time and performance issue.
3. Large button/text size and contrasting colors in visual displays.

Metrics for success:

1. Whether user able to perform basic tasks by using voice command (create email, open inbox, etc.). We will know whether our system recognize the command and perform the correct action. Measure number of incorrect commands. It should be less 5 in the whole process. (F1, F2, F3, N1, N3)
2. Response time of system: assess response speed of the system. There should be minimal delay or lag time processing commands. Measure with stopwatch/timer. With our users needs anything greater than 5 seconds would be problematic. (N2)
3. System robustness. Does the system work properly on the user's computers? Measure and assess startup time, responsiveness and system related errors. There should be no system errors and start time ought to be comparable to other web based applications loading on the same machine. We could record time to open Gmail or yahoo mail as a comparison. (N1, N2)
4. System setup. Measure time needed to install and test system to ensure it is functioning properly. It should be less than 5 minutes. (N1)
5. User comprehension. Does the user understand the commands and additional system functionality, such as how to navigate between pages? Measure number of incorrect actions and commands. It should be less than 5. (F1, F2, N3)
6. Time to complete create email task. Measure how long it will take for the user to create and send an email. Goal should be less than 10 minutes. Compare against time required by same user on different software. (F1, F2, F3, N1, N2, N3)
7. Time to complete open inbox and read email task. Measure how long it will take for the user to create and send an email. Goal should be less than 10 minutes. Compare against time required by same user on different software. (F1, F2, F3, N1, N2, N3)
8. Time to complete reply an email task. Measure how long it will take for the user to create and send an email. Goal should be less than 5 minutes. Compare against time required by same user on different software. (F1, F2, F3, N1, N2, N3)

Briefing:
This system is a new email system that allows you to use voice commands. The system is already trained for your voice. In this email application you will record your voice instead of typing or dictating a message to someone else. The voice message that you record will be sent to the recipient for them to listen to. We have added some email addresses in your address book and you already have some emails in your inbox. This will allow you to test the email application and tell us if it is better than your current method of accessing [7].

Task Scenarios:

1. Create an email to Dave Wong.
2. Read the email from Dave Wong from your inbox.
3. Reply the email from Dave Wong.

Post Testing Questions:
Overall System Functionality:
1. Please rate your satisfaction with this application on a scale from 1 (not satisfied at all) to 10 (very satisfied).
2. Please rate the ease of use for this application on a scale from 1 (very difficult) to 10 (very easy).
3. What did you like most about this application?
4. What did you like least?
5. What features were missing that you would like to see added?
6. What features would you remove?

Specific Functionality:
1. Would you prefer to have icons on the buttons, text labels or both?
2. Does this system provide useful feedback for your actions?
3. Would you prefer a help button on every screen?
4. Were the commands easy to understand? How could they be improved?
5. Is this system better than your current email technology? Why?
6. Does this system function in a similar fashion to the email system you currently use?
7. Do you find the audio cues helpful?

Last question:
Is there anything else you would like to say that you haven't had a chance to?

Target users:
We choose our test users from the residents at The Boston Home (www.thebostonhome.org). Our project's target users are speech impaired adults who developed Dysarthria at some point in their life and are unable to use standard computer systems due to motor impairments. One member of the project team (MP) has been working at The Boston Home in conjunction with other projects and this connection was instrumental in gaining approvals to test our system onsite and interact with our desired user population. The speech pathologist at The Boston Home, SP was very helpful and identified people whom we can interview for our project. He was keenly interested in the project and also offered us assistance for arranging future visits for our team. We have tested our system with 3 target users.

Our first patient was A. She is a female in her 40s and has severe motor impairment, with her hands are balled into a fist all the time. She also has significant speech impairment. She uses the computer in her room with standard speech recognition software (Dragon Naturally Speaking).

However, due to her speech impairment it is difficult for her to effectively use the Dragon speech recognition software. She also uses an iPad (www.apple.com) with a touchscreen, though with a lot of difficulty. She uses the computer to send emails, list her food in a word processor and Skype.

Our second patient was B. She is in her 50s, is severely motor impaired and cannot use her hands at all for any sort of input control to the computer. She only uses voice (as an input) to interact with her computer. She uses Windows speech recognition to control the computer. She was also dysarthric with a strong Boston accent which makes it difficult for the speech recognition to work for her. However, she has been trained to pronounce some of the words differently (the words where the speech recognition fails). She uses the computer to email her husband, son and daughter. She employs the web browser to surf the internet and even has a Facebook account. It often takes her more than 30 minutes to write one email.

Our third patient was C. He is in his early 40s. He has been using a personalized speech recognition system which was developed for him by his brother-in-law. He uses the computer to control his TV, to browse the web and to access his emails. He has heavily accented speech and severe motor impairments. He cannot move his hands at all.

Analysis process:
During our post user-testing analysis, three of our team members met to perform a systematic assessment of the testing sessions to create an affinity diagram, shown in Figure 6:

1 Reiterated the notes and wrote down individual points on yellow post-its.

2 Viewed the user testing videos and found the points which were missing in the notes and wrote down individual points on yellow post-its.

3 Divided all the post-its into groups based on the relevant sub-headings like customizable, less time, easy to use, navigation, and commands.

4 Assigned a blue post-it to each sub-group of yellow and give a new heading to it.

5 Start with the longest column and divide it into blue posts. The blue posts stress the importance on design relevance.

6 Create temporary green labels to group the common blue posts that reflects broad categories like ease of use.

7 Assigned a pink post-it group of blue post-its.

8 Divided the pink post-its into groups of 2-6 blue columns.

9 Assigned each pink post-it group with a green post-it.

EVALUATION RESULTS

Top level "green label" consists of:

1. Voice Navigation
2. Ease of Use
3. Customizable

Voice Navigation
One of the functional requirements is that the system should not require the use of hands as a form of input. With the help of voice navigation we are able to meet this requirement. The target users were able to use their own voice to invoke the commands and to complete the task we gave them without using the mouse or other physically controlled input. The users confirmed during follow-up

Figure 6 Affinity Diagram

questioning that they want to use their own voice to invoke commands, and they preferred the system providing them with audio feedback as well [7]. Our affinity diagram reflects this, with pink labels mentioning audio feedback, and blue label mentioning audio feedback for system navigation. Some of the observations we made during user testing indicate audio feedback should be slow and clear. And the system should produce an audio form of any error message to the user. These points were noted on yellow labels in our affinity diagram. Some of the system constraints were challenged in this type of interaction where the user voice should be recognized and the system responds efficiently. One of the non-functional requirements was that the efficiency of our system can be measured in terms of response time and performance issue. This heavily depends on the voice navigation part of our application. Since if the system does not provide any audio feedback to the user when errors in voice recognition occur, then the user will be forced to use other forms of inputs.

Problem 1
All the text in the email should be read aloud. The system should provide error messages in audio format. The confirmation messages should also be delivered audibly.

Reason 1
Since our target users were visually impaired and they could not read even small messages shown on the screen. Since audio cues were helping them in other major parts of the system, they expected it throughout the system.

Solution 1
We have provided voice navigation for the most prominent parts of the system. We need to implement the same concept across all parts of the system and make the system completely voice navigable.

Problem 2
Some users think the audio cues are not as detailed as they expect. They want the audio feedback to be more detailed about the options.

Reason 2
The reason is similar to reason #1, since some of our target users are suffering from poor memory, they want the audio options as a part of the audio feedback that can act as a reminder.

Solution 2
We need to discuss and finalize the content in the audio cues. We don't want to have a long audio cue since it may become annoying. But we need to prepare audio content with useful information.

Ease of use
The system is built for the target users having visual impairment in addition to their speech and motor impairments. So we iterated over the critical design area of font size and color. The final prototype version testing with our end users produced some good feedback for the system. They felt they had fewer screens to send an email and the fonts were clear and easily distinguishable. One of the design principles we followed in the system development was "less is more". One of our functional requirements was that the system should visually have large and easy to see components. So we reduced the complexity of the system to complete the simple tasks in a faster way. This helped us achieve a faster time for finishing a particular task. Some of the other feedback incorporated into the system was in the naming of the buttons. We had named the buttons based on their functionality. A non-functional requirement for the system was large button/text size and contrasting color in visual displays. So every button in the system was made larger and had bigger font to meet this non-functional requirement. The pink labels in our affinity diagram represent the requirements of the system being efficient, easy to navigate. Items related to having content easier to visually navigate are grouped to form the green label "ease of use" section of the diagram. The blue labels from our affinity diagram indicate the system's ease of use and highlights the users' preferences for ease of navigation in our system. Our user testing successfully demonstrated that our users were able to easily navigate our system to complete the particular task provided.

Problem 3
Some people asked for a "help" button to be placed on each page.

Reason 3
Our target users could not remember all the available commands in each page. As new users, they may get confused about some buttons and don't know what a particular button does. They want to refer to the help page to see the available functions in the corresponding page.

Solution 3
We can include a "Help" button on each page, but that necessitates a redesign of most layouts since adding a button might make the page cluttered. We still need to see whether it is really useful to have the "Help" button on each page.

Customizable
One of our most important functional requirements was that the system should be customizable for every user based on the speech impairment and voice strength. We have provided a settings page for each user where we record their voice for every command shown on the system. This provides the customization every user expects from the system, as depicted by green labels in the affinity diagram. The pink and blue labels indicate the user's desire for the system being customizable to their needs and this was shown in the results of our user testing. Additionally, several yellow labels suggested the fact that the system should provide alternate commands and text.

Feedback
The buttons should have numbers along with the text.

Reason
Our target users could not speak every word used by our system, even when it was a single word, since they had trouble in pronouncing some of the required words.

Solution
We can include the numbers on every button and provide it to the user. The font size for the numbers could be the same as used for Address book in the system.

Conclusion

We were able to develop a prototype email application that successfully meets the needs of Dysarthic speakers. Though not fully functional, our system was shown to give these challenging users access to email by the use of voice commands only.

Reflections and future work
We would have a designer on the team to have a more aesthetically pleasing interface (while maintaining usability for our target users). Though our design is predicated on our user abilities and needs, we should still strive for the best looking and most functional system possible.

After getting the user feedback on the paper prototypes, we would not just jump to the low-fidelity prototype. Instead we would update the paper prototype and do more user testing with the paper versions to get more feedback from our actual test users before moving to coding. We would also do more field-testing with the low fidelity prototype to gather another round of feedback from either our experts or test users.

While developing the low-fidelity prototypes we had difficulty in finalizing color schemes. We were unsure of the interaction of our user's visual impairments on our choice of color. There were some color schemes which could be more appealing than the ones we actually used. But the problem was that we were not sure if our users would be able to comprehend the interface or suffered from color-blindness. We would have liked to create a few different color schemes and button layout options using a simple graphic design tool and get feedback from our target users on an optimal combination.

We had the same test users perform the paper prototype and the final prototype evaluation. We would like to add more people who did not use the paper prototype and get them to use it too during user evaluation. A broader sample of test users will provide us with more diverse feedback and help us improve the design.

We would like to create extensive logs set up for each screen and then give it to our users. We would instruct them to use it for a week and then analyze the logs to understand which screens are still confusing or difficult to navigate through and identify any common problem areas across users.

TEAM CONTRIBUTION
Introduction: Steve

Design: Steve & Zhichun

Implementation: Steve

Evaluation Method: Zhichun & Mansoor

Evaluation Results: Ganesh

Reflections: Mansoor

Conversation to CHI Format: Mansoor & Zhichun

Revision: Zhichun & Mansoor

Final Review: Steve

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APPENDIX
Briefing:
This system is a new email system that allows you to use voice commands. The system is already trained for your voice. In this email application you will record your voice instead of typing or dictating a message to someone else. The voice message that you record will be sent to the recipient for them to listen to. We have added some email addresses in your address book and you already have some emails in your inbox. This will allow you to test the email application and tell us if it is better than your current method of accessing [7]