Abstract

Certain degenerative motor function disabilities such as ALS can hinder a user's ability to use a standard mechanical keyboard. These users are left with limited communication and data input methods. Eye tracking is the most viable option left for these users as the movement of eyes is generally preserved in all but extreme cases. We propose a new soft keyboard layout specifically designed to be used with eye tracking software. We call this LumaKeys. Through the observation of various studies and research on existing eye tracking technologies such as Dasher and Optikeys, we found that users of these existing technologies face numerous complications such as slow input speed, eye strain, and poor error prevention. This is due to the use of inadequate layouts which are poorly optimized for eye tracking. Our soft keyboard will seek to provide users suffering from these degenerative disabilities an improved method of data input.

1. Introduction

Users that suffer from degenerative motor function disorders such as ALS or stroke face severe limitations in their abilities to communicate, as major bodily functions such as speech or movement is severely hindered or sometimes, outright impossible. They generally rely on some system or simple gestures to establish communications. In modern times, this is aided by computer technology. A famous example is the scientist Stephen Hawking, who suffers from a rare form of ALS. There are many different types of accessibility and assistive typing keyboards currently available.

With the lowering cost of Eye Tracking technologies, such as the Tobii EyeX, the two most promising solutions currently are OptiKeys and Dasher. OptiKeys allows users to select characters by hovering over characters for 1.25 seconds to select that corresponding character. Dasher operates by placing a crosshair in the center of the screen that users drags the crosshair over colored areas that represent characters. In experimenting with both designs, we found that both systems have unique strengths and weaknesses.

1.1 Dasher

Dasher's unique typing mechanic is interesting and useful and allows users to type faster if the word they type is easily predictable and short. However, its biggest strength, its powerful predictive typing algorithm is also its biggest weakness, as it can be very difficult to type nonstandard/non-English words and can create many errors. Additionally, the constant motion and concentration needed can cause additional strain after pro-longed use.

1.2 OptiKeys

OptiKeys is the most vanilla option, as it utilizes the standard key layout. This helps alleviate any learning curve, which is compliant with the recognition heuristic. On the other hand, it scores low in the efficiency heuristic as the 1.25 second delay puts an artificial limit on the effective typing speed. The QWERTY layout, was also not designed for single input methods, such as eye tracking, which contributes to user's eye strain and low efficiency.

2. Problem Statement

We attempted to create our own soft keyboard input method that will help users improve typing speed, while lowering eye strain and reducing the amount of errors the user makes. This will address the issues we discovered while using other input methods. We will try to accomplish this by reviewing research to try to come up with an optimal soft key layout that improves on QWERTY, as well as creating an input mechanic that will specifically cater to users who are using eye tracking.

3. Literature Review

We initially read many studies on keyboard layouts, eye tracking software as well as medical journals on ALS to better understand some of the things we will be working with. The following studies were reviewed by our team when initially creating our project proposal

3.1 Caligari, M., Godi, M., Guglielmetti, S., Franchignoni, F., & Nardone, A. (2013). Eye tracking communication devices in amyotrophic lateral sclerosis

This study helped us to learn about the ways that eye tracking software has been used to create accessibility tools for users with physical disabilities. It helped us focus on eye tracking as the most optimal solution.

3.2 Nicolson, R. & Gardner, P. (1985). The QWERTY keyboard hampers schoolchildren

The focus of this study helped us identify the specific weaknesses of QWERTY, such as the splitting apart of letters commonly used together to prevent typewriter jams. It helped us think about how we can rearrange our keyboard to overcome these shortcomings.

3.3 Reeves AG, Swenson RS. Disorders of the System: a primer.

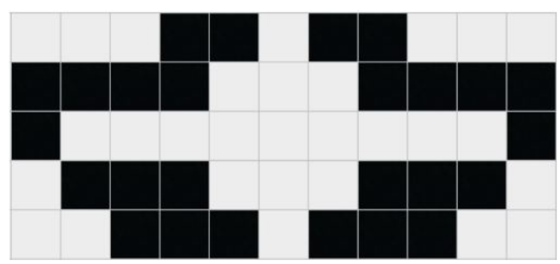
This study helped us to determine the limitations of patients with ALS, or other nervous system disorders. We learned about the need to reduce the vertical movement of the eye as it is one of the more straining movements of the ocular muscles as well as the need to recalibrate the keyboard size, as stages of ALS can slowly cause ocular muscle deterioration

3.4 Yin, P. & Su, E. (2011). Cyber Swarm optimization for general keyboard arrangement problem

This study of keyboard layouts introduced us to concepts such as N-grams, which are letters of n length that are most commonly used together (Eg. The most common 3-gram is “the”). This gave us the idea to place n-grams closer together to reduce travel distance for the eye, which will improve user speed and lower eye strain. It also introduced us to the mechanics of the Swype

4. Initial Prototype

We came up with an initial prototype as part of our project proposal. It is extremely simple, but put into practice the different aspects that we learned.



With this layout, we planned to combine it with a Swype input style, as we felt that the swiping motion of one finger most resembled the eye tracking motion. With optimal key placement based on our research of keyboard layouts, we believed this method will allow users to gain speed and reduce eye movement.

5. Requirements Gathering

While gathering user requirements, we realized that it was not possible for us to conduct interviews and experiments with ALS patients. These patients have difficulty communicating with others and finding an ALS patient to interview was impractical. Instead, to gather user requirements, we observed previously conducted academic studies from peer reviewed journals as our main source. Videos of ALS patients explaining their disease, giving feedback and describing their experiences with existing technologies also complimented our research. Most of the findings reinforced what we had learned in the previous studies that we had reviewed.

We also closely analyzed Dasher, and how users interacted with it. We found its use of digital space, as well as its fluid auto-completion system, inspiring. Thus, we decided to incorporate these features into our own project.

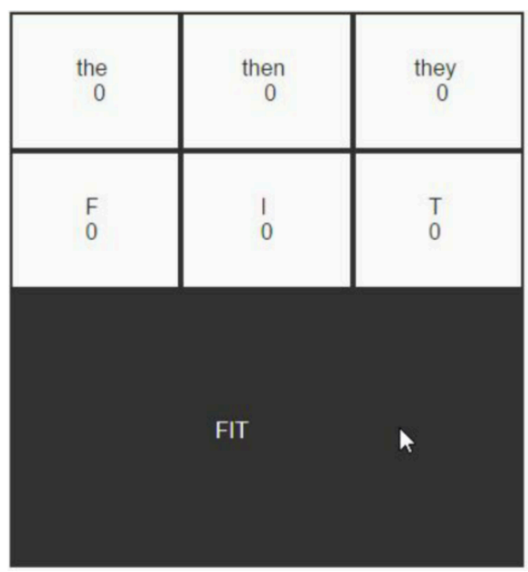
5.1 Eye Tracking Experiment

Continuing our research, we conducted an experiment with a group of ten people who did not suffer from any physical ailments. This allowed us to better understand the capabilities of eye tracking under perfect conditions. We had our participants conduct an accuracy test, where the goal was to initially focus on the center of one of two squares we projected on opposite edges of an image, and next to use the 'snap to gaze' feature of the eye tracking software to focus on the center of the opposite square in as little time as possible. We found the accuracy neared 100% when squares had a dimension of 6x6. Thus, we decided our keys should have the same dimensions.

5.2 Redesigned Prototype

After gathering user requirements, for our redesigned prototype, we eliminated the need to "Swype" across multiple keys. Instead we added sections of three letters. The keys were accessible by hovering over each section. Each letter in the hover sections is picked based on an "expansion rate" which is the result of the time a user keeps their gaze on a specific letter. This made our keyboard typing speed non-linear and allowed users to easily increase typing speed with practice. This also entirely removed the "attended keys", the keys that are picked up by the user when moving from one key to another. This improved error prevention for our prototype.

(Hover over the block containing the letter 'A'. Note the dialogue that has popped up over it.)



8. Usability Study

Surveys and interviews are too structured and prevent further discussion amongst participants of usability studies. When conducting our usability study, we wanted to encourage open and free discussions amongst participants because these discussions tend to generate constructive feedback, as well as innovative ideas. Focus groups provided us with an avenue to generate these discussions so we decided to evaluate our tasks by conducting an informal focus group in a combination of controlled and natural settings.

Controlled settings evaluations made sense here, because the nature of our technology is not exactly accessible to everyone. It would be unreasonable to assume that the average person would have an eye tracker/eye tracking software at home. Also, asking them to install the necessary tools could lead to further complications if they are not familiar with the technology involved; ultimately discouraging participants to evaluate our product.

However, it would be highly beneficial to see how participants fare in the wild. Thus, after undergoing controlled settings evaluations and developing an understanding of the product (thus mitigating the initial problems with this approach), we will ask the participants whether they would be willing to continue using it on their own. This allows us to make the best of both worlds.

8.1 Evaluation Process

To begin with, we asked five participants to sign an Informed Consent Form. The easiest way to do this is to simply model ours on an existing one, such as the one provided by the University of Toronto's Research Ethics Board.

The controlled setting evaluation can be done as follows. We will start out by giving the five participants a brief introduction/overview of what the product is all about. This will be followed by a quick tutorial on how to use the keyboard, and then the participant will be given some time to play with it on their own to allow them to develop some familiarity with it. After a set duration (3-5 minutes), we will conduct a quick interview with the participant to gage their initial reaction of our product.

Participants will then be asked to complete three separate tasks. (Note: For each task, participants will be required to focus their gaze on the cursor to replicate an eye tracker.)

1. Type the sentence "The quick brown fox" using our soft keyboard layout.
2. Type the same sentence using OptiKeys.
3. Type the same sentence using Dasher.

For each task, we will monitor how fast the participants can complete each task, and the rate of errors. Both statistics will provide us with quantitative data that we can utilize to analyze our usability study. We considered asking the participants to think aloud as they worked, however, we decided against it as we feel it is more detrimental to the participant's ability than it is valuable to us.

Once this is completed, we will ask the participants for feedback on how easy, or hard, the different interfaces were to work with. We will try to keep this feedback session concise (roughly 5 minutes), to ensure our usability study is completed in a timely manner.

We will specifically ask the participants to describe their experience with each input method (qualitative data), along with what they liked and disliked about each input method. This will provide us with qualitative data that we can utilize to discover how our same amount of time as our initial focus group because those layouts put a cap on the speed at which you could type.

Since our initial focus group participants never used any of the keyboard layouts before, we knew that the results would not accurately represented. To overcome this limitation, we conducted the exact same focus group with five different participants but during this focus group we allowed users to practice using all the keyboard layouts for 15 mins before completing the same tasks.

8.2 Results

Intial Results (Without Practice)			
Participants	LumaKeys (mins:secs)	OptiKeys (mins:secs)	Dasher (mins:secs)
A	1:20	0:50	1:07
B	1:40	1:00	1:02
C	1:30	0:45	1:12
D	1:40	0:53	0:56
E	1:00	0:55	1:08
Average	1:26	0:52	1:05

These table describes the results from our initial focus group. From these results, it is evident that the participants took the longest time to type the sentence on LumaKeys. This shows that since LumaKeys is a completely new, the participants had a hard time locating the specific letters. The reason OptiKeys took the shortest amount of time was because the OptiKeys layout is built with the standard QWERTY layout (something participants use daily). These results tell us that our LumaKeys layout was hard for users to pick up initially (ie. our layout has a learning curve) compared to the other layouts.

Results (With Practice)			
Participants	LumaKeys (mins:secs)	OptiKeys (mins:secs)	Dasher (mins:secs)
F	0:35	0:45	1:04
G	0:38	0:52	1:02
H	0:39	0:45	1:06
I	0:32	0:53	0:56
J	0:37	0:42	1:01
Average	0:36	0:47	1:01

Our second focus group results reflected our initial hypothesis, over time LumaKeys would be a better input method for users with degenerate motor function disorders. OptiKeys and Dasher took the same amount of time as our initial focus group because those layouts put a cap on the speed at which you could type.

9. Limitations

During our usability study, one major limitation we faced was that we did not have any ALS patients or patients with degenerate motor function disorders participant in our verification and validation phase of our product. The innovative keyboard layout was designed specifically for them, but because these patients have difficulty communicating with others, and finding an ALS patient to interview was impractical we did not include them in our study.

Another limitation was that we did not use a specific eye tracker during our usability study. We used a cursor/mouse to replicate an eye tracker. This might have skewed our results a little bit, but we did not see an advantage of using eye tracker because it we are still in the development phase of our product.

10. Future Work

For our future work, one task left to complete is to remove the timers used to determine which key is toggled and instead use expanding and shrinking blocks for each character. Since our soft keyboard is meant to be used with eye tracking, these expanding and shrinking blocks would make it easier for users to detect which character is currently the largest and would be toggled once they removed their gaze from the current hover section.

We also plan to use DIPs instead of pixels to improve the flexibility of our application. Having DIPs will assure the correct size regardless of the resolution on screen. It would allow users on different platforms to use our application without difficulty.

As another task, we plan to implement mouse functions and additional keyboard features into our prototype. During our focus groups, we received feedback that users would prefer mouse functions and additional keyboard features to be built in to our application. We concluded that having mouse functionality and keyboard features is essential for data input software.

Our high-fidelity prototype was a JavaScript web application. For our application, implementation into the Operating System is necessary. Potential target users would want this application to be possible to install the application within their preferred operating system.