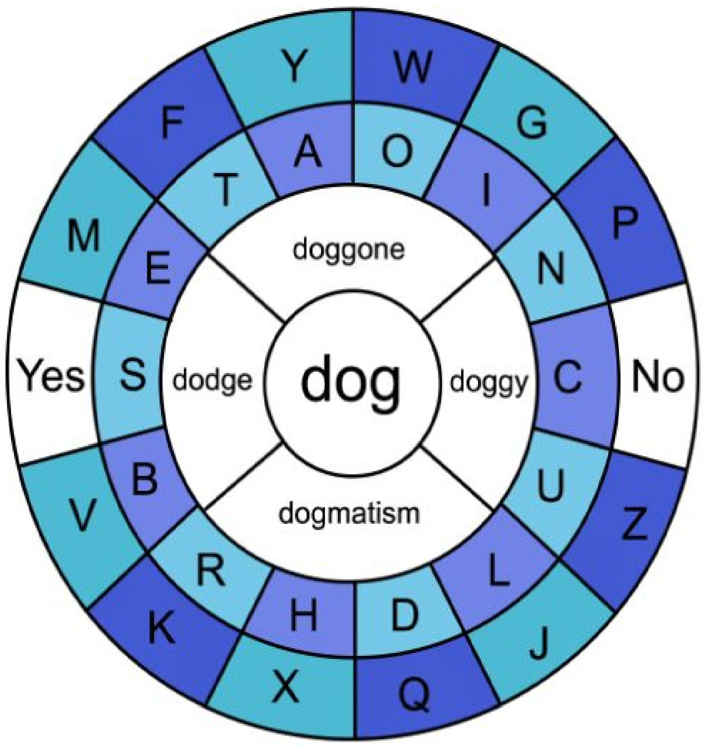
EF 203

PiBoard

The newly designed keyboard for eye tracking



Designed by Morgan Louis and Swasti Mishra

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Introduction

For the past few months, we have been working on redesigning the keyboard that is used with eye tracking software. Our keyboard is designed around the idea of making navigation on the screen easier for the eye, specifically for the disabled community. Eye tracking software is a new technology with plenty of areas for improvement. Our design will improve upon eye tracking devices that are used for communication by providing a keyboard that allows for more ergonomic navigation and faster use.

Purpose

Our goal of this design is to create a keyboard for the disabled community that is used along with eye tracking devices to allow the user to communicate faster and more comfortably than ever before.

The Problem

Eye tracking in its current form is a relatively new technology. Since 1879, it has been used to track where people look on pages (both digital and physical), but it wasn't until 2001 that control of a webpage, through the eyes, was invented. Since then, eye tracking has become the standard of communication for many people with disabilities.

Within the disabled community, eye tracking software has been able to help people communicate on their own again. There are many disabilities that cause a person to lose their ability to speak or move, and eye tracking software has been key to developing devices that read the movement of one's eyes on a keyboard. This allows them to interact with others on their own. However, this is also the basis of our design problem. The keyboard that is being used on these devices in the status quo is your standard QWERTY keyboard, which was designed for ease of use with hands and fingers. When using a keyboard that was designed for the hands with your eyes (which most eye tracking companies are currently doing) it makes use more difficult and uncomfortable. While the standard keyboard's design is familiar, a new design is needed for eye tracking software to perform at its best. A keyboard designed around the eye would allow the user to communicate more quickly and comfortably, allowing disabled users to feel more at home when conversing with others.

Importance to Us

Often, groups working on these types of projects are encouraged to brainstorm multiple ideas and pick the best one farther down the line. However, creating this optimized eye tracking keyboard was a very early idea for us. We both saw that there was possibility for improvement in this technology, and soon after exploring it, identified a specific area we were passionate about solving.

Morgan Louis

Personally, I do not have a connection to the technical side of this design. My passion for this project comes from wanting to help the disabled community. When we decided to work with eye tracking software, my first thought was how this software has helped people living with disabilities be able to communicate. The reason for this was because in high school, I worked with the disabled students at my school. My junior and senior year, I took a class called LABB that put me as a student aid in the classes for the disabled students.

From this class, I learned a lot about the disabled community, but more importantly, I met several people that impacted my life. I was very nervous when I started the class because I had no experience working with disabilities. However, I very quickly became comfortable and began to learn about their lives. All the students in the class were very welcoming of me and I became friends with all of them. I gained knowledge about what it is like for them to live in a world surrounded by people that do not have disabilities and do not understand what living with disabilities is like.

Due to this experience, I have become more aware of the possible mistreatment and challenges that the disabled community faces. I began to be more aware of how disabled people were treated and the possibility of this keyboard being able to help them excited me. It did because I knew that so many great people face challenges that we can not understand. If this design would be able to make some kind of difference in their lives then the project would be worth it in the end for me.

Swasti Mishra

My passion for our keyboard comes from a lifelong interest in learning how people communicate. This interest originally manifested in drawing and painting, public speaking, and working with organizations that helped me practice empathy. Through these activities, I met people with experiences vastly different to mine, learned about the things they care about, and how to convey ideas that resonated with them visually and through speech.

This is the background that I took into our project. In the same way that we invented computers to speak to those far away from us and the computer mouse to make that communication easier, I believe that eye tracking is the next frontier in bringing people into the conversation. I am excited by our project because I'd like to meet people who have struggled to communicate because of technological limitations in the past. I want to know what they have experienced and what they look forward to, and I believe our project can help us all achieve that.

Value

We both feel that the end result of this project could lead to significant changes in the disabled community and within technology as a whole, which we expand on below.

The Disabled Community

The goal of this design is to make communication faster for the disabled community. The initial development of eye tracking software caused a huge improvement in the quality of life for people with disabilities that needed help communicating. Within five years, Tobii, the leader in eye tracking technology, had brought its product to more than 7,000 users. Their product improved these user's lives because they were now able to communicate on their own with the help of a device that tracked their eye movement. However, there are problems with the design of the device.

The three main problems are as follows:

1. Eye tracking still relies on a keyboard optimized for typing.
2. Eye tracking is still quite slow, as compared to the average conversation.
3. Eye tracking doesn't optimize color to its benefit.

From the outset, these seem like simple problems. However, if addressed properly, they can greatly increase the quality of life for disabled users even further. Our product will support the disabled community through allowing them to express themselves more efficiently and with greater comfort.

Technology Improvements

This design would also help to advance technology that relates to eye tracking. At the moment, eye tracking is mainly being used for research and studying the movement of the eye. The implementation of this keyboard will encourage use of eye tracking in more devices along with the creation of other new technology that will work with eye tracking. In the far future, we hope to integrate our technology into smartphones and other devices to bring eye tracking to a larger population.

Requirements

While designing this product, we wanted to make sure that we researched all of the possible requirements for our design and how to design a keyboard that would suit our customers the best. In the following sections, we will explain our process in designing our keyboard and how we looked at the needs and wants of our customers.

Initial Requirements Matrix

The matrix below shows our brainstorming and beginning thoughts on our project. We later built our other matrices based on this matrix. Similar to the other matrices, we looked at what our design requirements were going to be and who the stakeholders in this project were. From that, we assessed the importance of the design requirements to the stakeholders on a scale of 1 to 5. Below is the result of our brainstorming and the initial thoughts on our design, along with the requirements we found through our research.

		Stakeholder Requirement Matrix												
		Functional Requriements									Non Functional Requirements			
		Physical		Usability			Performance				Experience		Aesthetics	Economics
		Size of Screen*	Comfort on Eyes*	Placement of Letters	Ability to download different keyboards (languages and symbols)	Ability to download on different devices	How fast it functions	Auto Fill	Web scrolling features	Common Phrases	Ease of movement from each letter	Color Coding of Keyboard	color of the screen*	Cost*
Stakeholders: Intial Beneficiaries	Cerebral Palsy	4	4	4	2	2	5	4	4	4	3	2	3	1
	ALS	3	4	5	2	2	5	4	4	4	5	2	5	1
	Autism	3	4	4	2	2	5	4	4	4	3	4	4	1
	Rett	4	5	5	2	2	5	4	4	4	5	5	3	1
	Brain injuries	3	5	4	2	2	5	4	4	4	5	5	5	1
Secondary Beneficiaries	Caretakers	1	1	1	4	4	5	2	3	4	1	1	1	5
	Public	1	1	1	3	1	3	3	3	3	1	1	1	1
Companies producing Assistive Communication	Tulip	1	1	1	1	1	5	1	1	1	5	1	1	3
	Orcam	4	1	5	5	1	5	1	1	1	1	1	4	5
	Tobii Technology	5	5	3	5	4	3	3	3	2	3	1	1	5
Other	Caretakers/Nurses	3	4	1	4	5	5	4	1	4	4	4	4	4
	Doctors	3	2	1	2	5	5	4	1	4	1	1	1	4
	Hospitals	1	1	1	1	3	1	1	1	1	1	1	1	5
	Insurance Companies	1	1	1	1	3	1	1	1	1	1	1	1	5
	Average	2.6	2.8	2.6	2.6	2.6	4.1	2.9	2.5	2.9	2.8	2.1	2.5	3.0
	Total	37	39	37	36	37	58	40	35	41	39	30	35	42

Scaling	
Not a considerat	1
Not important	2
Indifferent	3
Important	4
Very Important	5

*Size of Screen- found to not be neccessary to our keyboard since we are building off of a known technoloy and device that has been developed by companies like Tobii.

*Comfort on Eyes- found to be a too high of a risk to change due to a needed amount of infrared light for the eye tracking software to work properly.

*Color of Screen- not a needed considerate based on the change of color in each letter on the keyboard. Necessary to focus on the individual color more than the overall color

*Cost- found to not be a factor due to the lower cost of a keyboard to download verus a completely new device and software

Prioritization Requirements Matrix

Below is our Prioritization Requirements Matrix, which highlights the key functions and design elements that we wanted to focus on. These elements were selected based on what would allow our customers to have the best functioning design for their wants and needs. This information was gathered from research into our technological area, but because this is such a new field with few developers, we spent much time brainstorming new and unique features we would additionally like to focus on.

The matrix also includes our stakeholders for this design. These stakeholders are the people that are going to be most affected by our project. We wanted to focus on five different disabilities and the people that directly support a person with disabilities to gain insight into what the best design for all of them would look like.

We researched each stakeholder and design requirement to get the best understanding of the elements in this matrix and design. We then, on a scale of 1 to 10, rated how much each design element would be important to each stakeholder. From looking at our research, we were able to create our design criteria which are at the bottom of this matrix. This matrix is our final matrix that outlines what our goals of this project are.

			Stakeholders Requirement Matrix									
			Functional Requirements								Non Functional Requirements	
			Usability			Performance					Experience	
			Size of letters on the device's screen	Ability to download different keyboards (languages and symbols)	Ability to download on different devices that are being used to help the disabled commuinty commicate	How fast the software can follow the movement of the eye	Ability to track uneven or unstable eye movements	Autocompletion of a word that is being spelled out by the user	Ability to control functions of the keyboard with eye movement	Common Phrases placed around the screen	Position or arrangement of letters and other function that is comfortable for the eye	Color Coding of Keyboard and Individual Letters
Stakeholders	Initial Beneficiaries	Cerebral Palsy	8	5	3	9	10	10	10	9	9	7
		ALS	3	3	2	8	1	8	10	8	2	3
		Autism	7	9	2	10	2	5	4	6	7	10
		Rett	5	4	2	10	7	7	9	6	9	10
		Brain injuries	6	10	2	4	5	5	4	3	8	9
	Secondary Beneficiaries	Caretakers	1	10	9	8	2	4	2	7	1	1
		Public	1	4	1	1	1	3	1	3	1	1
	Existing Assistive Communication Software	Tulip	1	1	1	9	8	1	1	1	9	1
		Tobii Technology	2	10	8	6	8	3	3	2	2	1
	Stats	Average	3.8	6.2	3.3	7.2	3.1	5.1	4.9	5.0	5.3	4.8
		Total	34	56	30	65	37	46	44	45	48	43
Design Criteria			Letters be 2-5 mm wide	Include English, Spanish, Japanese, Italian, German, Chinese, French, and Korean	Ability to download on Tulip and Tobii.	run at the speed of 900 saccades	account for fixation on spot and when the eye closes	Have a working auto fill	No use of hands or mouse needed to control device	Common phrases border the keyboard	Letters be placed circularly in order of most used letters on the screen	Colors will be dull and different tones
		Scaling										
		1 (Not Important)- 10 (Very Important)										

Specifications Requirements Matrix

The matrix below shows a compiled version of our research. We took our Prioritization Requirements Matrix and researched each section of how our design elements related to our stakeholders. To best design our keyboard, we knew we needed all the information we could find relating to this project.

We researched our five disabilities, being cerebral palsy, ALS, autism, Rett's Disease, and concussions. Along with the disabilities, we researched products that were being made by three companies, Orcam, Tulip, and Tobii Technologies because each of these companies are producing products that help the disabled community with communicating. Our last stakeholders are caretakers, hospitals, and the public. For these stakeholders, we researched what the impact our product could have on them and what they currently do for the disabled people around them.

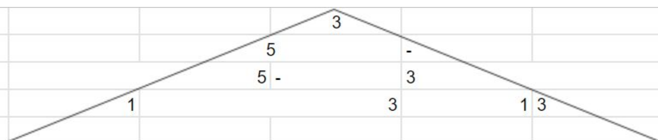
We also researched our design requirements. Our main goal with this research was to find out the way the eye worked and how fast it functions. We also wanted to learn more about keyboards and the effect colors have on the brain, along with all the factors that go into our design. In the matrix below, the result of our research is shown.

			Stakeholders Requirement Matrix									
			Functional Requirements								**Non Functional Requirements**	
			Usability			**Performance**					**Experience**	
			Placement of Letters	Ability to download different keyboards (languages and symbols)	Ability to download on different devices	How fast the software can follow the movement of the eye	Ability to track "bad" eye movements	Auto Fill	Web scrolling features	Common Phrases	Ease of movement from each letter	Color Coding of Keyboard
Stakeholders	**Initial Beneficiaries**	Cerebral Palsy	Considering the slow eye movement of **under 400 degree saccades per second*** and limited angles of the sight being between **5-40 degrees,** the closeness of letter would be helpful.	Useful for development this of product worldwide- individuals are **29% more likely to have CP if black compared to white, 20% less likely to have CP in Asians compared to white, no difference in hispanic and white**	**Not applicable-** this would typically be done by caretakers	Based on saccade movement of the eyes typically developed in people with cerebral palsy, the software needs to handle **less than 400 degree saccades per second.**	Symptoms tend to include difficulty with sight relating to **blurring, loss of vision, and slow eye movement**. Need a high quality, high-resolution camera. Eye function is limited to **5-40 degrees of the pupil in saccades.**	The slowness of eye movement of **under 400 saccades per second*** leads to the completion of a word being useful for faster communication.	Saccadic eye movements and other ocular abnormalities will **make this process using the eyes relevant**. Especially seeing as cerebral palsy affects hand movement as well.	Communication is a basic issue and cerebral palsy affects the muscles of people living with it which can make it harder to speak. **1 in 4 people with cerebral palsy can not talk**. Therefore, **access to frequent phrases that are used could be extremely helpful.**	A study showed that children with cerebral palsy struggled to accurately view a target if it was **larger than 15 degrees** from eyesight, causing the movement from letters to be significant.	Color perception based on chromaticity discrimination is generally reduced in SCP children. **This means that "colors" may not be helpful, but tonal differences may be.**
		ALS	ALS does not affect eye muscles, therefore their eyes function at the normal speed of **900 degrees per second.** Placement would not affect their ability to find a letter faster or slower.	High numbers of ALS cases in US (growth of 34% projected for 2040), Europe (growth of 20% projected for 2040), and China (growth of 46% projected for 2040). **This means that English, specific European languages, and Chinese should be prioritized.**	**Not applicable-** Typically this would be done by the caretaker.	ALS does not affect eye muscles therefore their eyes function at normal speed of **900 degree per second (in saccades)**.	ALS patients have effective eyesight late into their disability- see **900 degrees per second statistic.**	ALS does not affect eye muscles therefore their eyes function at the normal rate of **900 degrees per second**.	Takes about 9-12 months for muscle weakness to start occuring. **Complete muscle deterioration is common, making the ability for the computer to function only with eyesight is important.**	Most ALS patients develop the condition called dysarthria which happens when the muscles used for vocalization weaken and articulation decreases. Therefore communication is hard and typically requires help. **This means that common phrases would be a requirement.**	ALS does not affect eye muscles therefore their eyes function at the normal rate of **900 degrees per second**.	Research shows that people with ALS can still properly perceive colors. **This means that integrating them with the keyboard would be useful.**
		Autism	People with autism have higher saccade duration meaning they focus on one visual for longer roughly **4 seconds longer** than a normal child.	**Hong Kong, South Korea, United States, Japan, and Ireland** are the countries with highest cases of autism. Affects multiple other countries in Europe and Asia. The languages of these respective countries should therefore be prioritized.	**Not applicable-** Typically this would be done by the caretaker.	Autistic children have reported lower saccades per second than any children. Typically, with an average of **0.575 less saccades** than a normal child.	Autism affects **bad eye contact** in social situations, but should not affect their ability to look at a computer or sensor.	Children with autism have slower acceleration, roughly **0.8 seconds slower.** Which would cause them to take longer to complete words.	**Not applicable-** people with autism have slower saccade eye movement but do not suffer from any other lack of control in their eyes.	Autism makes it harder for people to understand social situations and cues. Communication is hard for them because of lack of understanding not lack of ability. **There is no evidence that Autistic individuals would require a common phrases feature.**	People with autism require more saccades to locate their intended target (have higher number of corrective saccades) with differences ranging from **ASD=0.28 and Control=0.25, ASD=0.48 and C=0.001**	It has been found the people with autism have a larger number of synapses, connections between brain cells. This causes them to process things differently. **Dull and cool colors** have a calming effect.
		Rett's Disease	After calibration, three different pictures were presented for 8 seconds each, Before each picture, a black plate with a white circle in the center was presented for 5 seconds. Fixation time required was between **0.8 and 2.5 secs.**	Rett syndrome has been identified in 4 of the 7 continents; is seen across all social, religious, and ethnic groups; and has eluded all efforts to unravel its suggested genetic cause. This means about **15,000 girls and women** in the US and **350,000 worldwide** have the disorder. **It is therefore difficult to prioritize a specific language.**	**Not applicable-** Typically this would be done by the caretaker.	Fixation time ranged between **0.8 and 2.5 s**.	Children with Rett syndrome tend to have unusual eye movements, such as **intense staring, blinking, crossed eyes or closing one eye at a time.** Any software developed would have to account for this.	Fixation time ranged between **0.8 and 2.5 s**.	The unusual eye movements that sufferers of Rett experience may make it more difficult to implement speedy web-scrolling features. However, if one were to implement it, then using the typical 0.8 to 2.0 seconds would make the most sense.	Rett syndrome is a neurodevelopmental disorder that affects girls almost exclusively, and the way their brains develop, causing a progressive loss of motor skills and speech. **Therefore, access to common phrases would be an extremely useful feature.**	Stimuli subtended a visual angle of **16° horizontally and 23° vertically** (with some minor variation for patterns); paired stimuli **were separated by 23°**.	For the most part, Rett's sufferer's do not significantly benefit from color coding. However, older subjects can often recognize the color **blue**.

		Concussion (Most common type of brain injury)	Effects of eye teaming could make it harder to differentiate between letters. **This would mean that the letters would have to be separated to some extent.**	Concussions are very common for everyone and happen typically in a hard hit to the head. **No language prioritized.**	**Likely not applicable-** based on how debilitating the injury is could be done by the person or caretaker.	Common eye problems after a concussion are problems with eye teaming and focusing causing it to **take longer to process words/letters.**	Concussions can cause problems with eye movements. Resulting in eyesight to "jump" around. **On average, concussion victims have a saccadic velocity to accuracy ratio of 3.**	Eye teaming, blurry vision and focusing issues all **make it harder for the person to read at a fast speed.**	**Not applicable-** blurred vision is the most common effect on eyes after a concussion and has a worse effect for patients to try focusing on a lot of web scrolling.	Eye teaming, blurry vision and focusing issues makes it harder for the person to read and focus at a fast speed. **Common phrases would ease this burden.**	**Slower vision post injury and lower saccades.**	Concussed people can experience sensitivity to bright colors. **Therefore, duller colors should be prioritized.**
	Companies producing Assistive Communication Software	Tulip Vision	The Tulip Vision is more of an eye sensor than an existing keyboard, so **it doesn't have letter placements.**	**Can detect all types of letters or symbols**	**Tulip can be integrated with almost any other existing technology.**	**Tulip is extremely versatile because of its common use on the factory floor.**	**Tulip is extremely versatile because of its common use on the factory floor.**	**Tulip can achieve this, but would require original code.**	**Tulip can achieve this, but would require original code.**	**Tulip can achieve this, but would require original code.**	**Tulip is extremely versatile because of its common use on the factory floor.**	**No existing keyboard is integrated with Tulip Vision.**
		Orcam	OrCam Read is a handheld device that instantly reads any printed or digital text from books, newspapers, smartphone and computer screens, and more. **Therefore it does not have letter placements, as much read letter placements.**	OrCam MyEye is available in **English, Spanish, German, Italian, Dutch, French, Hebrew, Danish, Polish, Norwegian, Portuguese, Romanian, Finnish, Swedish, Czech, Turkish, Hungarian, Russian, Bulgarian, Mandarin, Japanese, and Korean.**	**Orcam is an existing device and cannot be integrated with existing technology.**	Orcam reads existing surrounds, and not eye movement. **It can, however, be attached to a pair of glasses and "track" head movement that way.**	**This would be contingent on head movement.**	**Not applicable.**	**Not applicable.**	**Not applicable.**	**Not applicable.**	**Not applicable.**
		Tobii Technology	**Tobii's Virtual Keyboard is laid out identically to a classical QWERTY keyboard.**	**Brazilian Portuguese, Czech, Danish, Dutch, English, Finnish, French, German, Greek, Italian, Japanese, Korean, Norwegian, Polish, Russian, S. Chinese, Spanish, Swedish, Turkish, T. Chinese**	**Tobii is accessible on a number of devices, from their own hardware to downloadable software.**	**<35 ms**	**Can track accuracy up to 4.4 mm in ideal conditions**	**Tobii does not have an autofill or autocomplete technology integrated with their technology.**	**Tobii has a chrome plugin that can achieve this.**	**Tobii has common phrases on the I Series, but not on the keyboard for abled people and web scrolling.**	This is contingent on monitor speed, **but at absolute closest, the letters can be positioned 4.4 mm apart.**	**Not applicable**- the whole virtual keyboard is grey, though the buttons on the I Series are different colors.
	Secondary Beneficiaries	Caretakers/Nurses/Doctors	**There is a specific setting on the I Series devices for caretaker settings.** This pulls up an on screen keyboard that caretakers can type into.	**Caretakers can download keyboards in any of the languages listed above.**	**Tobii is accessible on a number of devices, from their own hardware to downloadable software.**	**Not applicable.**	Ideal operating distance for the eye tracker is between **40 and 90 cm**. However caretakers would be better off accessing the on screen keyboard.	**Tobii does not have an autofill or autocomplete technology integrated with their technology.**	**Tobii has a chrome plugin that can achieve this.**	**Access to the common phrases menu is not available on the caretakers on screen keyboard.**	**The same ease as typing on a QWERTY Keyboard.**	**Not applicable**- the whole virtual keyboard is grey, though the buttons on the I Series are different colors.
		Hospitals/ Insurance Companies	**Not Applicable.**	**Not Applicable.**	**Tobii setup is easy to setup and can be done in most cases by caretakers or nurses.**	**Not applicable.**	**Not applicable.**	**Not applicable.**	**Not applicable.**	**Not applicable.**	**Not applicable.**	**Not Applicable.**
		Public	**The commonly accepted ideal letter placement for the general public is the standard QWERTY arrangement.**	**Necessary if the keyboard is to be used worldwide so the public could understand the person using the device.**	**Concern based on if this keyboard could be used to help further research and studies.**	**Concern based on use in research**	**Concern based on use in research**	**Not applicable.**	**Not applicable.**	**Faster communication with people using the device.**	**Not applicable.**	**Not applicable.**
Risks			Potential for distance to cause issues with accurate chosen letters.	Ignore potential customers and their language needs	Ignores Orcam and leaves room for future companies to produce different software that could require adaptability	Accounts for the average speed of eye which would cover all stakeholders	Risk related to constant bad eye movement and abilities of current software	Require modification from current devices. Leaves potential for rejection from companies.	Potential for bad eye movements to obstruct the control.	Lack of certain common phrases.	Requires change from accepted QWERTY arrangement	Potental for not full use of stimulated brain activity.
	*average saccades per second is 508 degrees per second											
	A "saccade" describes the rapid movement of the eye between fixation points											

Quality Function Deployment (QFDs)

To start selecting our requirements, we first considered what our customers were looking for. To do this, we created a Quality Function Deployment which allowed us to look at our product from our customer's perspective. These matrices allowed us to analyze what is going to be on the customer's mind and how to best create a product that fits those needs. From the first QFD, we looked at the initial wants of our customers and how to satisfy them. The second QFD looked at how we were going to satisfy the customer's wants and how we are going to physically design our product to make sure those wants were satisfied. The third QFD goes to further detail how we were going to ensure that their wants were met. From our QFDs we were able to learn what some of our design requirements were going to be and what to look at next for our design. Below are our three Quality Function Deployment matrices.



							Competitors		
#1		Place letters in an easier position for the eyes	Color the individual letters for brain stimulation	Track eye movements	Ability to add different languages	Adapt to current devices used to help with communication for the disabled	Tulip	Tobii	Orcam
Easy to Use	4	5	5	3	3	-	F	F	F
Reliable	5	-	-	5	1	5	G	G	G
Afforable	2	-	-	5	-	-	G	P	F
Play the words aloud	5	1	1	-	3	3	F	F	F
Good Battery Life	3	-	-	-	-	3	G	G	F
Like the appearance of the screen	1	-	5	-	1	-	P	F	P
Big Screen	2	3	-	1	-	1	P	G	P
High Quality Camera	4	1	-	5	-	5	G	G	G
Our Importance Rating		30	5	59	33	56			

#2		Distance between letters	Choice of colors	Order of letters	Software to allow to download on devices	Camera to follow eye saccades	Tulip	Tobii	Orcam
				5					
				-	-				
			3	1	3				
		-		-	1		Competitors		
Place letters in an easier position for the eyes	3	5	-	5	-	-	P	P	P
Color the individual letters for brain stimulation	1	-	5	1	-	-	P	P	P
Track eye movements	4	-	-	-	1	5	G	G	P
Abillity to add different languages	4	3	-	1	1	-			
Adapt to current devices to help with communication for the disabled	2	-	-	-	5	1	G	F	P
Our Importance Rating		27	5	20	18	22			

#3		Size of the device's screen	Programing to support current devices	The Quality of the Camera	How the eye functions in the user of the device	Tulip	Tobii	Orcam
				3				
			1	-				
		-	-		5	Competitors		
Distance between letters	3	5	-	3	5	P	G	P
Choice of colors	1	-	-	-	-	P	P	P
Order of letters	4	1	-	1	3	P	F	P
Software to allow to download on devices	4	-	5	1	-	G	P	P
Camera to follow eye saccades	5	1	1	5	5	F	G	P
Our Importance Rating		24	25	42	52			

5	High Relationship
3	Medium Relationship
1	Low Relationship

G=good
F= fair
P=poor

Analytic Hierarchy Process (AHP)

Our next step was to create an Analytic Hierarchy Process. The reason for creating this graph and doing these calculations was to ensure that we were focusing on the right areas of our project. We created two different AHPs, one that related to our stakeholders and the other relating to our design requirements. The AHPs are done by looking at how each individual factor may be more or less important than the other factor. By using this method, we were able to focus on certain stakeholders and design requirements. The process for deciding which element was more important to us was based on how high the numbers were that were produced from this graph.

We were able to determine that cerebral palsy, ALS, Rett, and Tobii Technologies were going to be our most important stakeholders. Along with that, we determined that how fast our software runs, its ability to track “bad” eye movements, placement of letters on the keyboard and the ease of movement from each letter on the keyboard are our most important design requirements. This graph was able to help us focus our efforts on elements of our project that could have the largest impact on our design. Below are our Analytic Hierarchy Process graphs where our numbers are shown.

Stakeholders	CP	ALS	Autism	Rett	Concussion	Tulip	Orcam	Tobii	Caretaker/N/D	Hospital/Insurance	Public
CP	1	3	8	4	9	8	6	3	5	9	9
ALS	1/3	1	7	1/2	9	7	5	3	4	9	9
Autism	1/8	1/7	1	1/6	7	6	4	1	3	9	9
Rett	1/4	2	6	1	9	7	5	2	2	9	9
Concussion	1/9	1/9	1/7	1/9	1	2	2	1/3	1/4	5	7
Tulip	1/8	1/7	1/6	1/7	1/2	1	4	1/5	1/2	6	6
Orcam	1/6	1/5	1/4	1/5	1/2	1/4	1	1/7	1/3	5	4
Tobii	1/3	1/3	1	1/2	3	5	7	1	1	8	8
Caretaker/N/D	1/5	1/4	1/3	1/2	4	2	3	1	1	7	5
Hospital/Insurance	1/9	1/9	1/9	1/9	1/5	1/6	1/5	1/8	1/7	1	2
Public	1/9	1/9	1/9	1/9	1/7	1/6	1/4	1/8	1/5	1/2	1
Totals	2.9	7.4	24.1	7.34	43.3	38.6	37.5	12.7	17.4	68.5	69

Normalized	CP	ALS	Autism	Rett	Concussion	Tulip	Orcam	Tobii	Caretaker/N/D	Hosptial/Insurance	Public	Average
CP	0.3488	0.4053	0.3320	0.5450	0.2079	0.2073	0.1600	0.2362	0.2874	0.1314	0.1304	0.2720
ALS	0.1163	0.1351	0.2905	5/6	0.2079	0.1813	0.1333	0.2362	0.2299	0.1314	0.1304	0.2386
Autism	0.0436	0.0193	0.0415	5/7	0.1617	0.1554	0.1067	0.0787	0.1724	0.1314	0.1304	0.1596
Rett	0.0872	0.2702	0.2490	0.1362	0.2079	0.1813	0.1333	0.1575	0.1149	0.1314	0.1304	0.1636
Concussion	0.0388	0.0150	0.0059	5/7	0.0231	0.0518	0.0533	6/12	11/23	0.0730	0.1014	0.1868
Tulip	0.0436	3/19	0.0069	5/7	10/8	0.0259	0.1067	6/12	11/23	0.0876	0.0870	0.3144
Orcam	0.0581	3/19	0.0104	5/7	10/8	2/8	0.0267	6/12	11/23	0.0730	0.0580	0.3251
Tobii	0.1163	3/19	0.0415	5/6	0.0693	0.1295	0.1867	0.0787	0.0575	0.1168	0.1159	0.1730
Caretaker/N/D	0.0698	2/7	0.0138	5/6	0.0924	0.0518	0.0800	0.0787	0.0575	0.1022	0.0725	0.1580
Hospital/Insurance	0.0388	6/4	0.0046	5/7	10/8	2/8	3/13	6/12	11/23	0.0146	0.0290	0.4555
Public	0.0388	1/6	0.0046	5/7	10/8	2/8	3/13	6/12	11/23	9/30	0.0145	0.3589
	*Numbers rounded to 4th decimal											

Criteria	Placement of Letters	Ability to download different languages	Ability to download on different devices	How fast software tracks eye movement	Ability to track "bad" eye movement	Auto Fill	Web Scrolling Features	Common Phrases	Ease of movement from each letter	Color Coding
Placement of Letters	1	5	7	0.25	0.5	8	7	6	1	9
Ability to download different languages	0.2	1	3	0.125	0.1429	0.5	2	0.25	0.1667	6
Ability to download on different devices	0.1429	0.3333	1	0.125	0.125	4	5	4	0.3333	7
How fast software tracks eye movement	4	8	8	1	1	7	8	7	2	9
Ability to track "bad" eye movement	2	7	8	1	1	9	9	9	7	9
Auto Fill	0.125	2	0.25	0.1429	0.1111	1	0.3333	1	0.25	7
Web Scrolling Features	0.1429	0.5	0.2	0.125	0.1111	3	1	3	0.2	6
Common Phrases	0.1667	4	0.25	0.1429	0.1111	1	0.3333	1	0.2	7
Ease of movement from each letter	1	6	3	0.5	0.1429	4	5	5	1	9
Color Coding	0.1111	0.1667	0.1429	0.1111	0.1111	0.1429	0.1429	0.1429	0.1111	1
Totals	8.8886	34	30.8429	3.5219	3.3552	37.6429	37.8095	36.3929	12.2611	70

Normalized	Placement of Letters	Ability to download different languages	Ability to download on different devices	How fast software tracks eye movement	Ability to track "bad" eye movement	Auto Fill	Web Scrolling Features	Common Phrases	Ease of movement from each letter	Color Coding	Average
Placement of Letters	0.1125	0.1471	0.2270	0.0710	0.1490	0.2125	0.1851	0.1649	0.0816	0.1286	0.1479
Ability to download different languages	0.0225	0.0294	0.0973	0.0355	0.0426	0.0133	0.0529	0.0069	0.0136	0.0857	0.0400
Ability to download on different devices	0.0161	0.0098	0.0324	0.0355	0.0373	0.1063	0.1322	0.1099	0.0272	0.1000	0.0607
How fast software tracks eye movement	0.4500	0.2353	0.2594	0.2839	0.2980	0.1860	0.2116	0.1923	0.1631	0.1286	0.2408
Ability to track "bad" eye movement	0.2250	0.2059	0.2594	0.2839	0.2980	0.2391	0.2380	0.2473	0.5709	0.1286	0.2696
Auto Fill	0.0141	0.0588	0.0081	0.0406	0.0331	0.0266	0.0088	0.0275	0.0204	0.1000	0.0338
Web Scrolling Features	0.0161	0.0147	0.0065	0.0355	0.0331	0.0797	0.0264	0.0824	0.0163	0.0857	0.0396
Common Phrases	0.0188	0.1176	0.0081	0.0406	0.0331	0.0266	0.0088	0.0275	0.0163	0.1000	0.0397
Ease of movement from each letter	0.1125	0.1765	0.0973	0.1420	0.0426	0.1063	0.1322	0.1374	0.0816	0.1286	0.1157
Color Coding	0.0125	0.0049	0.0046	0.0315	0.0331	0.0038	0.0038	0.0039	0.0091	0.0143	0.0122

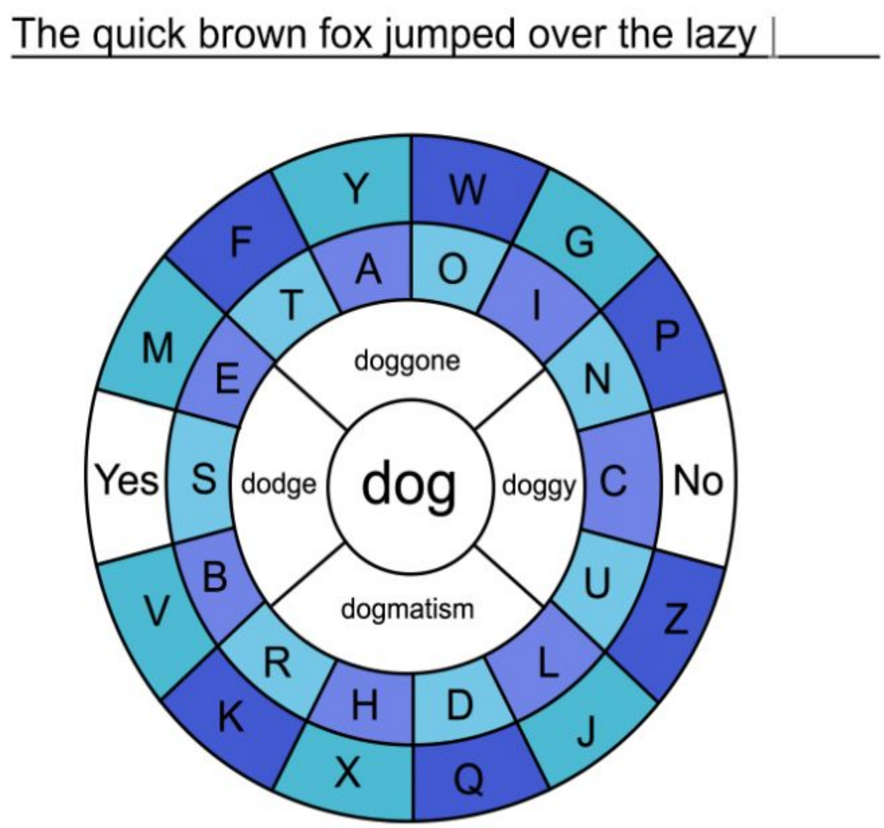
Failure Mode Effects Analysis (FMEA)

The last step before creating our design was to build a Failure Mode Effects Analysis. This table allows us to look at all the possible ways for our design to fail. This analysis was critical in taking a step back from our design to evaluate what we were attempting to create. We analyzed each input of our design and the ways it could go wrong for our stakeholders.

From this analysis, we were also able to look at the functions we would need to include and consider in our design to prevent these key inputs from malfunctioning. Finding where our design would fail, we discovered how to design around these failures. We were also able to evaluate which possible failures would be riskier to not design around. That conclusion was drawn from the Risk Priority Number that was calculated from the Severity Score, Frequency Score, and Deterrence Score. Those three scores were found from how bad the effect on the customer was, how often the failure occurred, and how well we are able to prevent the failure. Below is our FMEA showing all the possible failures, our solutions and priorities for them.

Process Step	Key Process Input	Potential Failure Mode	Potential Failure Effects	Severity score (S)	Potential Causes	Frequency Score (F)	Current Controls	Deterrence Score (D)	Risk Priority Number
What is the process step?	What is the key process input?	In what ways can the key process input go wrong?	What is the impact on customer or internal requirements?	How severe is the effect on the customer? (1-10)	What causes the key input to go wrong?	How often does the potential cause occur? (1-10)	What are the existing controls that prevent the potential cause?	How well can you detect the cause of the failure mode? (1-good detection - 10- bad detection)	equal F*S*D
		Letters are too close	Misinterpretation of eye movement causing wrong letters to be selected	5	Position of the letter on the screen	6	The identified space between the letters of 2-5 mm.	3	90
	Position of Letters	Caretaker cannot demonstrate proper usage on device	User cannot understand how to use device	8	Letters are too close for the camera to detect the focus of healthy eyes	4	The identified space between the letters of 2-5 mm.	3	96
		Non understood language on keyboard	Customer cannot use keyboard	8	Lack of languages on device	10	Programing of popular languages	2	160
	Languages	Caretakes cannot understand the language that is spoken	The user and caretaker cannot communicate	10	Lack of languages on device	10	Programing of popular languages	2	200
			Customer cannot use keyboard	8	Lack of software for certain devices	10	Programing software for known devices	2	160
Usability	Download ability	Progam is not compatiable with devices	Companies cannot use keyboard for their devices	8	Lack of compatiable software	10	Programing software for known devices	2	160
			The customer cannot communicate at the speed that they are physically able to	5	Insufficient software	7	Software able to keep up with 900 saccades (average rate).	4	140
		Too slow to keep up with the eye movement	Frustration with how slow the keyboard functions	2	Insufficient software	7	Software able to keep up with 900 saccades (average rate).	4	56
	Speed of Tracking	Limits the speed of communicate between user and others	Keyboard becomes less easy to use and unreliable	6	Insufficient software	7	Software able to keep up with 900 saccades (average rate).	4	168
					Squinting of the eye	5	Requiring fixation on a letter	5	125
		Track movement that was not intended	Letter selected based on unintended action	5	Eye to "jump"	5	Requiring fixation on a letter	4	100
	Tracking bad eye movements	Actions are not tracked	Keyboard becomes unreliable and difficult to use	8	Insufficient software	6	High quality camera is used	2	96
							Multiple options	1	10
		Wrong words are suggested	Commuincate becomes harder and slower	5	Lack of dictionary/words programed	2	Options change when a letter is added	1	10
	Auto Fill	Communication is slowed by lack of completed words	Device is not as easy to use	4	Device is not programed to autofill	1	Autofill is programed into keyboard	1	4
					Squinting	4	Requiring fixation on a letter	5	100
		Misinterpret an eye movement	The device could switch to an unwanted function or letter	5	Eye "jumping"	4	Requiring fixation on a letter	4	80
	Complete control of the keyboard through eye movement	Controls are hard to understand/use	Keyboard becomes less desirable	6	Bad intructions or clear use of the	5	Simple controls	3	90
							Programing basic phrases	3	24
			User must spell out each phrase frequently	4	Lack of programed phrases	2	Ability to personalize phrases	2	16
Performance	Common Phrases	Missing a common phrase	Takes longer to communicate with others	6	Lack of programed phrases	2	Programing basic phrases	3	36
			User cannot see letters with their eyes	4	Position of the letters on the screen	5	The identified size of the letters of 2-5 mm	3	60
		Letters are too far apart	Takes longer to communicate with others	6	Position of the letters on the screen	5	The identified size of the letters of 2-5 mm	3	90
	Ease of movement between letter	Letters not is best position for the eye	Device is not easier to use	5	Lack of research on best arrangement	1	Research on most used letters	3	15
					Screen is too bright	2	Brightness setting	2	12
			Device could cause headache	3	Colors are too bright	2	Brightness setting	2	12
		Colors do not help with use of device	Device could cause annoyance	2	Colors bother user	1	Ability to personalize colors	1	2
Experience	Color of Letters	Companies do not want to add different colored letters	The color of the screen holds no benefit to the user	4	Unwant to try new colors	5	Pitching the idea well to companies	7	140

Design



Our product was built on a few design choices. Through optimizing for speed, we wanted the user to be able to focus on the word they were typing, autocomplete the word, and have a few common phrases always accessible.

Users naturally like to focus on the center of a screen, so the word our user types will always be present in the center of the keyboard. Once they've completed typing the word, they look back to the center, and the word will be filled in on the textbox or line above. Around the center are suggested autocomplete words. If a user focuses on them, they will be filled into the textbox above instead.

The rings around the outside of the circle contain the letters used to type. We chose the placement of the letters with efficiency in mind, as the letters are organized by how frequently they come up in the English language. Starting at the left with E, and going along the top of the ring to N are the most frequently used letters. The next set of letters are from S to C, from M to P, and from V to Z. Along with frequency, we chose to align the letters from left to right and prioritize going over the circle rather than under the circle because of how the English language is set up- left to right and up to down. Of course, this means that when we branch out to developing the keyboard for other languages (specifically Eastern languages), we will have to format the keyboard in the opposite layout- right to left and bottom to top.

The color was based on our research. We found that the five types of disabled individuals we sought to help respond most positively to cool colors, especially blues. With this in mind, each letter is next to a letter of a different color, meaning eyes can adjust to the boundaries of each key more quickly. Going further, the keys on the outside ring are less saturated to encourage the eyes to focus on the innermost rings. This gently allows the user to focus on keys they are more likely to use in this order: the word, the autocompletes, and the most frequently used letters.

When not accessing the keyboard, a small moveable button will float on top of any windows. This button can be moved to the top left, right, or any other side of the screen, similar to Apple’s Assistive Touch. When the keyboard is in use, the textbox will be moved to the top of the page, and the keyboard will float underneath.

Business Model

For our business model, we formed three different stages of our plan that adjusts to the development of our product.

1. Early Development: Accept Donations

This is not so much a business model, as something we see commonly when tools like our are developed. Initially, we thought of making our product open-source, and accepting donations to market our product, develop it further, and confirm community builds with it. This would make it easier for others to update the keyboard with their languages and discover new utilities for it. However, we later realized that we could benefit more through acquiring community resources on a Kickstarter or GoFundMe type basis. In this way, we would gain enough funds to grow the project, but we still keep our quality control measures in place and are free to pursue the projects we find most important with our technology.

2. Mid-Development: One-Time Expense

We would then transition to selling our product like Clip Studio Paint, Lockdown Browser, or any other software that's sold through an independent website. Disabled people would be able to get it free through their insurance through partnerships we establish. Our initial donors would receive it for free along with access to betas of new features. At this stage of development, we would receive far more funds, and could begin to develop a) webcam eye tracking, b) partnering with existing eye-tracking companies, or c) developing our own hardware.

3. Established Development: Use of the upcoming Microsoft Eye Control Market

This is an idea based on a market that doesn't exist yet, but Microsoft has already started creating software with Tobii that will probably be sold on the Microsoft App Store. Additionally, Microsoft has been encouraging developers to use its platform. If we sold through this market, we could initially price the product compared to its competitors, and then scale it up to meet demand. Additionally, we could open our product up to a much larger market. At this point of development, we would be accessing people who aren't disabled, and aren't necessarily keyed into new technology. The Microsoft App Store is democratic in this sense, and we would be able to welcome new users into our base.

Each stage described is available to investors of different types. And based on our focuses for each stage, we are confident that investors will be able to both make money and contribute to disabled people and a larger community in an effective way.

In the first stage, we are interested in individual, small-scale, investors. These people can not only help us pay for development, they can show us who is interested in our product. By being able to see our investors, we are reminded which stakes are most important in our project.

In the second stage, we open up to larger investors. At this point, we will already have a product that works, is backed up by public support, and is not a risk. Their investment would be safe and fruitful, based on the projects we take on in the second phase of development.

We developed this business plan based on the following scaling concerns.

1. We would need to have a website for people to download the product from.

    a) We would need to buy a domain.

    b) We would need to buy a website builder (whether that's a person we employ, or a person we employ and a Wix/Mailchimp/WordPress subscription).

    c) We would need to cover team salaries.

2. We would like to explore scrolling, zooming, etc.

    a) We would have to pay coders, for what we approximate at least one business quarter to start, and then more following as the project becomes bigger and more ambitious.

3. We would like to develop our own hardware.

4. We would like to bring this software to the mobile market as an eye keyboard for mobile.

Reliability

We will run multiple betas in order to ensure we are delivering the maximum viable product. Once we finish the first phase of development, we will offer our product to the disabled stakeholders that we focussed on in our matrices (Patients with cerebral palsy, amyotrophic lateral sclerosis, autism, Rett syndrome, and concussions.) This also means that nurses, doctors, and caretakers will also be a part of our first beta, as they may be setting up the software on their own. In this beta, we will gather feedback on how the program works, what other features are wanted, and what features are being used the most. However, we will also gain insightful data on how easy it is for busy healthcare workers to set up our product. This may seem obvious, but many companies struggle to get useful feedback from their first betas because they show their product to their friends and family, who the product may not be aimed at. Alongside the more hands-on feedback forms beta testers will have to fill out, we will also set up online feedback forms and a helpline. These two features will only become more important as we open up to a broader audience in the next two phases.

The next stage of beta testing will bring in the aforementioned community backers. These investors are in a separate stage so as not to pollute the true goal of our product, supporting disabled people. At this stage of development, we will have grown large enough to support features that may not be necessary for disabled people, but do not draw away from our product's mission. Additionally, this stage would be an opportunity to grow our interest base. It's said that the best marketing is word of mouth, and when people who have used our product talk about their experience, we can grow to a bigger market.

Our "last" stage will be more feature-based. While we have a vision for what our product can become, it's difficult to pin down what that product will require testing for. Instead, we can allow users to opt into product "labs." Essentially, when we test out new features in our virtual lab, we can roll them out to users who are interested in these features. In this way, enthusiasts can get an early look at what we are developing next, more serious users can depend on a stable product, and we can gain valuable insight into what is and isn't working.

Conclusion

Our project has one primary goal, to increase the quality of life for disabled people. We worked towards this through designing an optimized eye tracking keyboard, which through ergonomic design and increased speed, would allow patients with cerebral palsy, amyotrophic lateral sclerosis, autism, Rett syndrome, and concussions to communicate similarly to people without a disability. We used design principles and applied research to develop a keyboard that is aimed for use with the eye, rather than with the fingers. While we intend to use existing hardware, we improved on software being used in the status quo. Through this project, we believe that we can help disabled people communicate more quickly and comfortably, thereby increasing their quality of life.

Additionally, we learned quite a bit over the course of this project. We learned that, in order to build a product that truly works for its users, we had to clearly identify those users. We couldn't just identify "everyone" as our end goal, even if that may be true. We had to focus on people with disabilities, and then people with specific disabilities, because different conditions can manifest in very different ways.

We also learned about developing in the long term. That included answering questions like, "Where do we want to go in a week? Three months? A year?" and "How do we plan for that growth within our business and our community of users?" Developing that vision alongside very specific goals and risks in the present was simultaneously difficult and exciting. It's also a practice we intend to carry into our further lives. Learning to live in the present while being prepared for the future is a lesson that will extend beyond the confines of this project.

The last thing we learned seems oddly specific, but is worth mentioning because it bodes well for the future of PiBoard. Despite the speed of the tech world, eye tracking in its current form is a relatively sparse field with few competitors. This means that there is much still to learn and develop. We are looking forward to discovering all that eye tracking has to offer.

Appendix

Appendix A

Overview of Disabilities that Require Assistive Communication Software

There are several disabilities that affect the person's ability to speak and their motor functions. For the purpose of designing this new keyboard and software to help with communication, we looked at the top users with disabilities that could benefit from this product. These disabilities are cerebral palsy, ALS, Autism, Rett Syndrome, and the most common brain injury, the concussion.

Relating to cerebral palsy, this disability largely affects the person's muscle tone, posture or movement. This can result in cases that need support in movement and speaking. This is where our device relates to this disability, as it can help improve communication for people with this disease. From our research, a symptom of this disability can be problems with vision, field loss, oculomotor concerns, and cortical visual impairment. These effects could impact the effectiveness of our design and needed considerations.

ALS stands for Amyotrophic Lateral Sclerosis. This disability varies quite a bit between individuals. However, ALS is almost always accompanied by the overall weakening of muscles that can start in multiple parts of the body. One group of muscles it is known to affect are the ones that control speech. This means that ALS sufferers would absolutely require assistance with communication. However, their senses are mostly not affected, leaving their sight untouched. This allows for our design to be very effective for people with ALS.

The next disability that could benefit from this product is autism. Autism also varies quite a bit in people affected by it. However, our design could be very effective for extreme cases. Their sight too is mostly unaffected, and they instead experience difficulties with social communication. This design would help the ease of communication of people living with autism and the factors of their disability will be acknowledged in the design.

Rett syndrome is a neurological and development disorder that primarily affects girls. The symptoms affect the way their brain develops which changes their motor skills and speech.

This makes it hard for these people to communicate and function without assistance. An important factor when considering this disability for our project is all symptoms including the eye movement. People with this disability tend to have uncontrollable eye movements along with many other symptoms that need to be considered in the comfort of this product.

The last disability that is being directly looked at are brain injuries, specifically concussions. While this disability tends to happen later in life, it also varies greatly in the effects and severity and can require help in communicating. Brain injuries can be known to affect vision and muscle movement. The factors along with these problems can affect the effectiveness of this design and use of the product.

Appendix B

Overview of Companies Producing Assistive Communication Software

Overall, our research showed that there are very few companies that are pursuing a project similar to ours. The main companies we found relating to eye tracking technology were, Tulip Vision, Orcam, and Tobii Eye Technology.

First, Tulip Vision is less eye tracking software and more a vision sensor. It is primarily used on factory floors to do things like quality analysis, read barcodes, and define regions of interest. We added it to our matrix for two reasons; first, in case we eventually need to develop our own hardware, it would be a good starting point for tracking eye movement, and second, as further proof that even the most applicable existing technology does not quite fulfill the need that we are hoping to address.

The next technology is Orcam, which is a device that helps people read items like menus, signs, and their surroundings while in public. This is also why so many of its boxes on our matrix are not applicable. Similar to Tulip Vision, Orcam is an “eye tracking” technology that doesn’t fill our specific needs.

The last technology is the best metric for our project, and that is the Tobii Series. In fact, when we do implement our software, it will likely be on the Tobii hardware. Tobii has developed some of the best eye tracking systems so far, but is lacking in the development of the keyboard, which is what we seek to address. They have a number of devices, software, and free-to-use data that we could access to optimize our project. The most important aspects of their technology are covered in our matrices, and include how fast the technology tracks eye movements, how accurately, and their existing keyboard.

Appendix C

Secondary Beneficiaries

When considering all factors, the people that surround and support the person that would be needing this device are an important part of the designing process. Caretakers are the ones that are providing constant support and could benefit from the success of this design. The modified keyboard would help to allow easier communication and a better understanding of the need of the disabled person. Hospitals and nurses require similar wants of success with this design. Much like with the caretaker, the success of this design would help with better communication and the ability to understand what is holding the patient back. The public would benefit from this design, but in a different way than all other beneficiaries and perhaps the least. However, they are still considered because the public could benefit in the future within research but also with communication in social situations with the disabled communities.

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