THE *future* OF *fashion*

& Human Gesture Control: An Exploration of a wearable communication device for sign language speakers

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The Future of Fashion & Human Gesture Control: Exploration of a wearable communication device for sign language speakers

By Dextina Alana Booker

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abstract

This thesis is a design research project which began as an exploration of how to leverage clothing to further enhance capabilities and human computer interaction. While on this journey, this objective evolved with the help of continuous refinement of three key frames of reference; the experience of people with hearing impairments in India, the intersection of fashion and technology, and the concept of universal design. The purpose of this research was to uncover the needs of a communication system to translate sign language through the case study of people who need to translate spoken languages discreetly. The latent need for the people with hearing loss provided the framework for further study communication between spoken languages which could result in benefiting a broader audience. Wearables allow users to communicate without interruption and have become a pervasive fashion statement with over 526 million connected wearable devices. Gesture control technology sensors including EMG sensors, accelerometers, cameras, flex sensors, etc. can detect a range of gestures through their sensing elements. Each sensor has the potential to meet the needs uncovered in this thesis, but they also have limited capabilities. This thesis provides the requirements of a wearable gesture controlled translation solution for the context of people with hearing loss in India using humanistic co-design (human centered design+) methodology. It also addresses the ethical implications of a solution and the potential for erasure of deaf culture as well as the potential to create purpose, job opportunities and to increase the quality of life for people with hearing loss.

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By Dextina Booker

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For the sake of sounding like an unreasonably long grammy acceptance speech I just want to thank everyone who cheered me on including the best friends I could have asked for around the world.

And Finally I would like to thank Beyoncé. Not for anything in particular, but just because it feels like the right thing to do.

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introduction

This thesis is a design research project which began as an exploration of how to leverage clothing to further enhance capabilities and human computer interaction. While on this journey, this objective evolved with the help of continuous framing of the problem. As this thesis grew it became more difficult not to pursue a dozen theses in one, so framing became integral to solving the problem at hand. The reference points from which to frame this thesis were through the experiences of people with hearing impairments in India, fashion and technology, and the concept of universal design.

1.1 The hearing impaired population in India

A number of organizations in India have been working towards democratizing assistive technologies to help with the growing number of impairments present in India with hopes of improving the quality of life. According to the World Health Organization, over 466 Million people, roughly 5% of the world population experience hearing loss. This 5% represents people who cannot hear above 25 dB. Over 98% of people with hearing loss do not receive education in sign language and over 70% of people with hearing loss are unemployed. These numbers are dismal for the global population but are much worse in nations with larger wage gaps[1].

60% of childhood hearing loss is preventable. Early detection of hearing loss gives caregivers time to help develop speech, the window for which is between birth and seven years old. In the case of preventable childhood hearing loss, children require speech therapy and a quality hearing aid to prevent further degeneration of hearing.

1.2 Fashion, the Technology & the Wearables

Considering a wearable solution could allow for heads up communication, is socially acceptable, and powerful. The exploration of fashion technology and wearables provides an interesting opportunity for growth and unencumbered human augmentation. Wearables limit invasiveness of tech in terms of physical comfort and detracting from heads up communication. They have become more pervasive, with over 526 million people around the world holding some form of a wearable[2]. These wearables are both expressive and functional as both have been embedded into daily ware, leading people

1 Deafness and Hearing loss World health Organization. https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss

2 "Wearable Device Unit Shipments Worldwide 2017-2019, 2022 | Statistic."

to becoming more active, social and in some scenarios more capable.

1.3 Benefits of Inclusive Design

The last frame of reference is universal design. Inclusive design, also described as design for the margins, is a design theory that creates products, services and solutions for an ‘extreme use case’. A solution may be more applicable to a use case with more constrained need; it may also be adapted to a wider market of users. This design theory relies on creating solutions that are adaptable to larger markets and enables designers to deconstruct barriers to access we create intentionally or unintentionally.

It doesn’t excite me to have to quantify the economic benefits of impact, it would be a missed opportunity to do otherwise, so I’ll push through. According to the World Bank, people with impairments represent an $8.9 trillion market. It is estimated that over one billion people in the world have a form of an impairment. This data does not capture the full picture in developing nations and proves to be a conservative estimate. While it is both exciting and encouraged to create innovation for the benefit of young markets, it is a crowded space. If the goal is to be a dominant player in an underserved market, then capitalizing on this market’s spending capacity would be beneficial. Finally, situational and temporary disability further expand the market through the concept of inclusive design which is explored later in this chapter.

Disability is often misconstrued with impairments. Disability is a circumstance that is the result of a design (or lack of design) that creates inaccessibility. Impairments are the state of a hindered faculty which can be designed around. Inaccessible designs, whether intentional or not create physical barriers like entrances without ramps, informational barriers like creating tech only signs, along with attitudinal barriers of exclusion due to stigma. Luckily this means there is opportunity for growth. We could have more inclusive infrastructure, create text and pictorial documentation and enact social change to further include marginalized peoples.

Considering an 'extreme' use case of gestural or physiological recognition to output, and limiting scope to the use case of people with hearing impairments, encourages precise interpretation of an existing gestural language. This challenge also confines solutions to seamless tech incorporation.

1.4 Research Questions

This thesis is founded on the following three major questions:

Preliminary Question: *What would your clothing do for you if every day people were superheroes? - What would we be capable of?*

Hypothetical Question: *Considering the trend of responsive fashion how might human computer interaction evolve while leveraging integration into functional clothing and wearable devices? Who could we be?*

Use case Question: *Which users would most immediately benefit from the seamless integration of sensor tech for HCI? Who should we focus on?*

1.5 Synopsis:

India presents a use case for communicating between sign language users and non- sign language users because of its potential for impact and value creation. This communication can be deconstructed into two major tasks: Audio to visual communication, and a visual or physical input to an audible output. This thesis focuses on the potential gestural inputs to interpret and translate language. It also explores a case study of a use case to create a framework for considering other domains.

The problem

How might we provide a more accessible and seamless communication for the inclusion of people with hearing impairments in the workplace, education, and society.

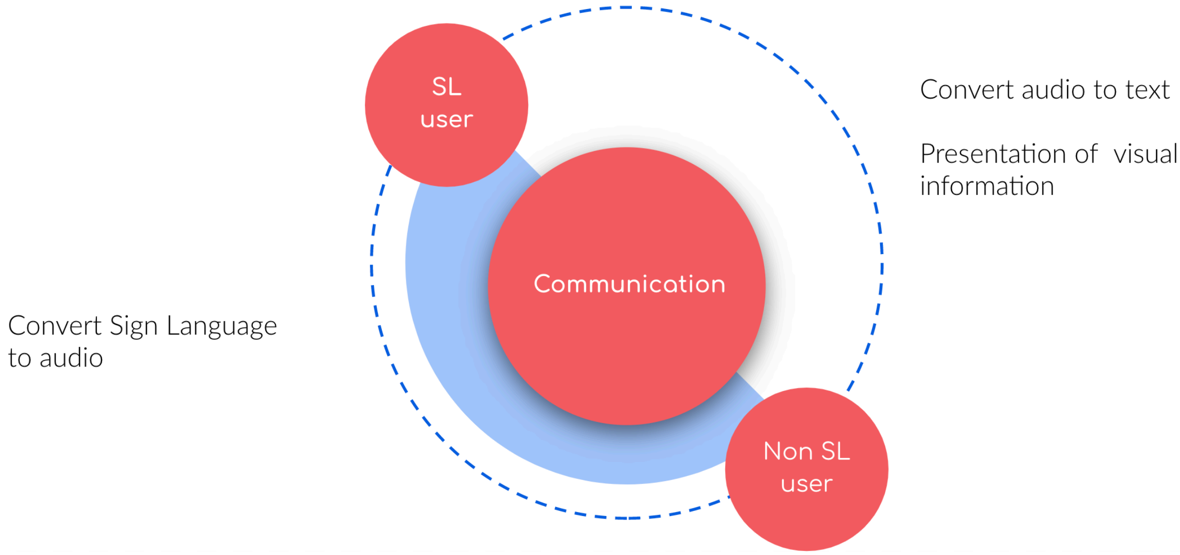


Figure 1.5 A

Communication ecosystem

2. literature review

To begin this research, I had to get the lay of the land. This chapter summarizes current research and consumer goods and services that attempt to create communication devices for the deaf, as well as hypothetical opportunity areas to better meet those needs.

2.1 Assistive Tech for the Deaf:

Figure 2.1 A

Existing solutions to communicating between sign language and non-sign language users covered in further detail in this literature review. ered in further detail in this lieratur review.

Above are existing solutions to communicating between sign language and non-sign language users covered in further detail in this literature review.

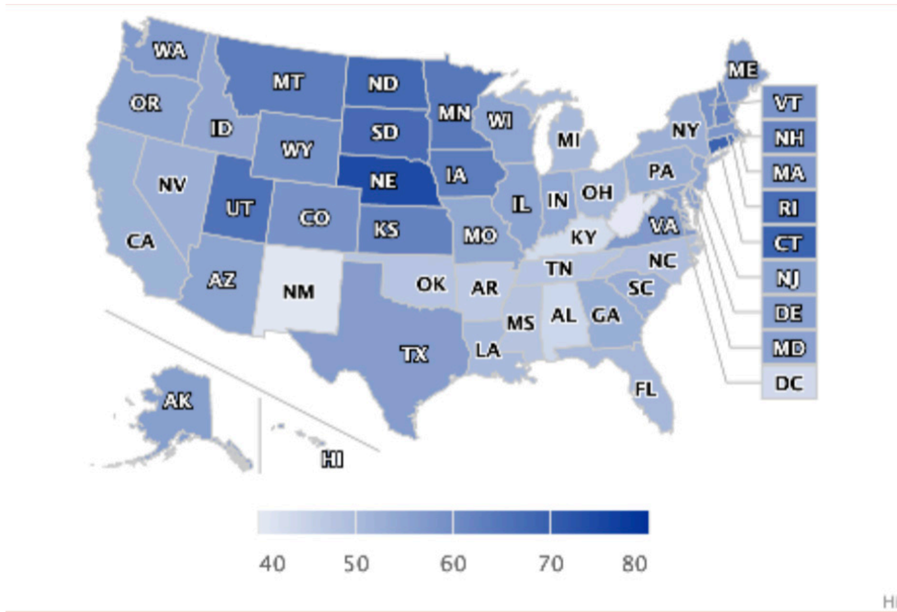
2.1.1. Language literacy Lens

While in India for a course on humanistic co-design, MIT students, myself included visited the Indian Institute of Technology Delhi (IIT Delhi) Assistive Technology lab run by Professor Rao. This lab developed technologies for people with impairments in India. They featured refreshable braille displays, ultrasound walking canes and even a new process for manufacturing tactile displays for people with visual impairments. The IIT Delhi Assistive Technology lab also advises a number of budding technologies. One such company is Transcribe lens[3], which created a 3D printed attachable device that identifies sound and displays text onto a glasses display to hearing impaired wearers. The goal is so not to detract from conversation, as breaking eye contact in sign language is the equivalent of walking away from a discussion in spoken language. The glass display projects text into infinity for the ease of sight. The lens in its current iteration is large and bulky and draws attention to the wearer. The concept however is particularly impressive and represents half of the communication between people with hearing impairments and spoken language users. The device aims to be low cost for the Indian hearing impaired community which has been traditionally marginalized and stigmatised out of job opportunity and limited their earning potential. Constrained to the access of material, the Transcribe lens is facing an uphill battle attempting to miniaturize and reproduce at scale.

3 "Delhi Teen Invents Glasses That Could Revolutionise How the Deaf Communicate!" The Better India, June 21, 2018. https://www.thebetterindia.com/146728/hearing-glasses-google-transcribe-deaf-delhi-madhav-lavakare/.

Figure 2.1.1 A

Cornell University Study, *Employment Rate: The percentage of non-institutionalized, male or female, with a hearing disability, ages 21-64, all races, regardless of ethnicity, with all education levels in the United States who were employed in 2017.*



2.1.2 Mobile Applications:

While phones feature accessibility settings a number of apps created for the hearing impaired or adopted by the hearing impaired community have come up in the marketplace and can be used to further leverage phones as assistive technology devices. One of these app types is speech to text including Google, iSpeech and Sorenson Buzzcards, which allows deaf users to save cards for communication with the hearing. The pitfall with this is that it relies on English literacy to understand the text. Almost 300 million people in India cannot read and 10% of the population speak English. Other apps are video calling applications that allow sign language uers to phone someone who can translate on their behalf. This further removes people from the conversation.

2.1.3. Sign Language Gloves

A number of researchers have developed sign language gloves to leverage a relatively unobstructive communication. The Sign Aloud[4] is one of many wireless sign language gloves that translate ASL into spoken English in real time using motion capturing sensors. Flex sensors detect the extent of the bend of individual sensors and accelerometers detect the position of the hands in 3D space, as well as motion. The gloves feature similar sensors to those found in joysticks, accelerometer etc, but also flex sensor to recreate hand motion. The device did not capture the nuances of sign language, including secondary signals such as eyebrow movements, shifts in the signer's body, and motions of the mouth, to fully convey meaning and intent. It also features a direct and strict word-for-word translations of ASL, which results in an inaccurate translation, as each language requires sentence structure and context in order to make sense. It also experiences more inaccuracies between distinct users.

2.2 Trends in Wearable Tech

Wearables in assistive technology provide an opportunity for elegant integration between form and function. The lightweight tech allow for the newly termed 'heads up communication' which is any communication form that allows users to make eye contact without disrupting the natural flow of conversation.

4 https://www.theatlantic.com/technology/archive/2017/11/why-sign-language-gloves-dont-help-deaf-people/545441/

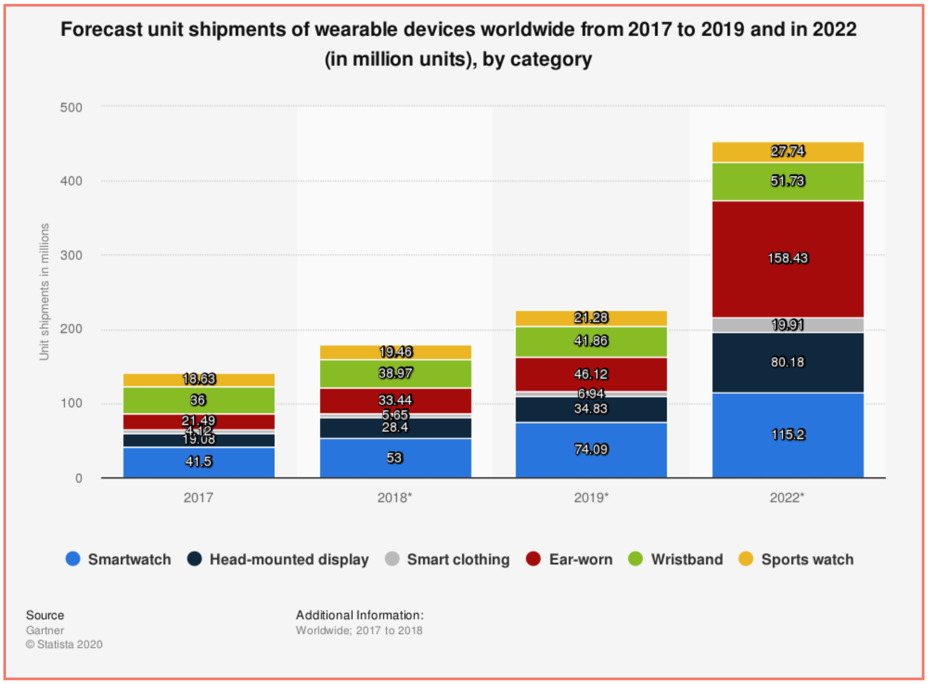
2.2.1 Focuses of new fashion:

The focus of new fashion tech can be described by some combination of three major functions or purposes. These include Wellness, making the intangible tangible, and fabrication techniques[5].

Figure 2.2.1 A

Forecast of Wearable Device Shipment expected to double 2019-2022 with Hearables being the largest sector at roughly 35% according to Statistica Gartner Survey

https://www.statista.com/statistics/385658/electronic-wearable-fitness-devices-worldwide-shipments/



5 Wearable Electronics and Smart Textiles: A Critical Review. (2014). Sensors, 14(7), 11957–11992. https://doi.org/10.3390/s140711957

Ryan, S. E. (2009). Re-Visioning the Interface: Technological Fashion as Critical Media. Leonardo, 42(4), 307–313. Retrieved from https://muse.jhu.edu/article/270362

2.2.1.1 Wellness

Wearables that promote wellness towards the augmented body take multiple forms. One common purpose is to protect. Consider an Astronauts space suit. The suit is fitted with temperature and environment control to protect astronauts from the harsh conditions of space including temperatures as low as -250 C and as high as 250 C as well as record vitals. Second, these wellness devices enhance abilities. We may see this and consider exoskeletons.

2.2.1.2 Sharing and making tangible the intangible

Designing for multiple forms of expression is the duty of fashion designers, and it is no wonder wearables have become expressive as well. The future of fashion is consistently depicted in cold stark and sterile whites, intimidating motion, and overly robotic and inorganic. Functionality of some textiles and wearables allow for increased interconnectivity. With the multitudes of designs and possibilities Clothing is how people choose to align themselves to groups, highlights individuality and belonging and is how we communicate to others before we speak. New modes of fashion are allowing for new and interesting functionality and features in smart textiles. There is so much that people want to say, do or express and the next phase of that expression will have to meet and exceed the current forms of expression rather than limit this expression.

2.2.1.3 Sustainability and Deliberate Design

Designers and researchers building with materials that either mimic or are made of natural materials with the hopes of creating less environmentally impactful processes and designing more sustainable fashion. While manufacturing properties and materials represent a large part of sustainability, designers must or at the very least begin thinking about social implications and responsibilities when creating anything that requires engagement of communities.

In designing some functional clothing based solutions, some companies have made faux pas in not designing for systemic change. Without considering where new technologies plug in, and how they fit into the bigger picture they occupy, some solutions fall short. Designers of clothing geared at people who are homeless have focused on functionality. Often these items are designed to withstand the harsh environments of the outdoors, maybe are lightweight, and or focus on the need to carry. Unfortunately that solution doesn't begin to address the reason people may be homeless. Sometimes it makes homeless people targets for other people in the same conditions. This shouldn't barr designers from creating design solutions for this group. But designers in this area have a responsibility to identifying the root of the issue and larger insufficiencies in what currently exists rather than creating small scale band aid solutions.

The body is an underutilized canvas for technology that provides space for expression as well as impact. With the success of current wearables, simple adjustments can be made to appropriate these technologies for assist tech devices.

2.3 Alternative augmented communication

Alternative augmented communication (AAC)[6] is an alternate mode of communication that allows users to pick preselected words, typically in app form on a tablet or mobile device. They are made to aid a variety of impairments which may include limited mobility, difficulty forming sentences, and limited vocabulary. AAC devices come in multiple forms including iPad, tablets, dedicated talk devices, and wearable watch devices. While easy to use, thee have a limited has a limited conversational range based on the number of words and icons programmed into the system, it can help understand the most useful part of language. The icons are typically arranged in a grid and are iconographic for the ease of reading. In some cases AC is also used to enhance the vocabulary of its users. It builds repetition and helps grow the memory. Each device is programmed to its users needs. The topics on each device varies based on the users age, life

6 "The Changing Face of Augmentative and Alternative Communication: Past, Present, and Future Challenges." Augmentative and Alternative Communication 28, no. 4 (December 1, 2012): 197–204.

experiences, and mobility. The input for most of these devices is a touchscreen, but a variety of input can be based on the needs of the user.

3. user needs finding

3.1 The Hearing Impaired in India

This project began to take form during a trip to India for a course on Humanistic co-design. Thirteen MIT students travelled to three cities in India to work with nonprofits, Universities, and other private and public organizations to explore topics in assistive technology for people with impairments in India. Our team ran workshops that facilitated technological and social solutions to the lack of access in India and worldwide, for people with impairments.

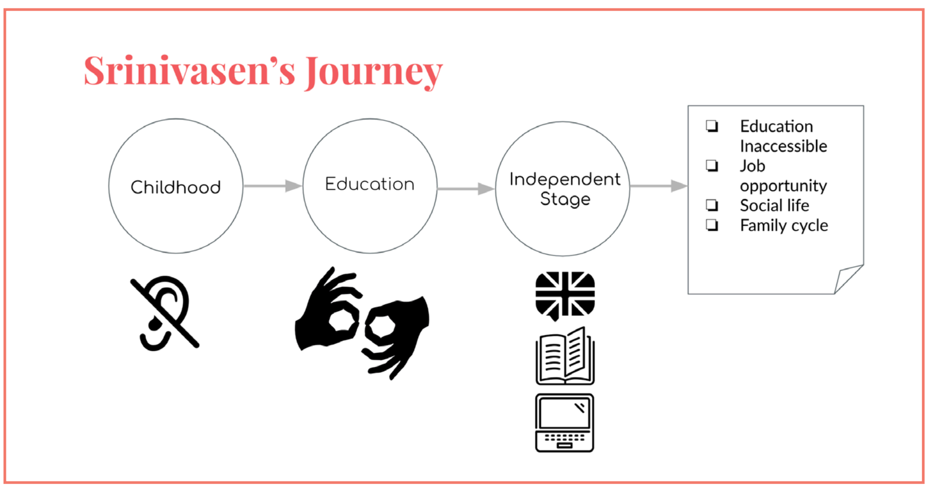


Figure 3.1 A

Through interviewing and learning from our co-designers, a similar patterned experience emerged. Often our co-designers family detected their hearing impairment after it was preventable. They experienced isolation in schools and even after learning signn language and going to SL universities, stigma in the workplace made finding work difficult.

During one of the workshops I was fortunate enough to work with eight people with hearing impairments, collect information on their experience, and find specific pain points participants could address with design research and concept generation.

3.1.1 Communication vs. Erasure

First it's important to acknowledge that there is a deaf community risk of erasure through creating technologies that asked them to assimilate to spoken language. While in India, there is a different form of stigma that limits earning potential and quality of life of people with impairments. When interviewing participants and Co designers in Chennai, a co-designer was was asked what his dream job would be if he could have any job. Without hesitation he responded, any job. While technology can't remove the stigma that question his cognitive abilities, his story highlighted that human beings want jobs, opportunity, and purpose. Technology does give him the opportunity to communicate his own original thought, and make incremental steps towards purpose.

3.1.2 Emotional Human Experience using an assistive tech

One overwhelming piece of commentary while interviewing people with impairments was that it is an emotional experience to use assistive technologies. It was almost a universal experience that users are often concerned about drawing unnecessary attention to themselves, whether it be drawing attention to a pricey object that people may want to steal, or strong attention to their impairment itself. Assist tech encourages a vulnerability that most people never experience. When designing any solution or system you must consider the context within which the wearable will be worn, and how it may enhance or interfere with the wearer's self-expression and self perception. Designers may try to create affirming and 'cool' solutions to uphold dignity.

The co-designers greatly informed the direction of the research and are central to its conception. Their experiences were in some ways more isolating than one may imagine. They attended schools that could not cater to their needs, were left out of socializing and human interaction because they were seen as inferior and could not participate in a spoken exchange. Their experiences are captured and translated into direct needs in this chapter.

Lastly one final pain pulled from the interviews in Chennai was that often the sign language users would change their activity and behavior to accommodate for being able to sign. One common example of this was in the case of signing with their friends in the evening. Streets of Chennai don't have very many lights and so it's difficult to notify each other or to chat without physical contact. It is also difficult to know when there is oncoming traffic. Current solutions include signing into each other's hands or waving at torchlight to get each other's attention.

3.2 Current solutions

Co-designers shared that rely heavily on a notepad and pen to communicate while out and about. Unfortunately the average person they encounter does not read English or otherwise, given English is not their native language as well as the striking literacy rate in India. The first thing to note when trying to use a notepad, was that there was only one translator in the room during oour design sessions. The translator was expected to speak on behalf of five people, abput their lived experiences. While interviewing, workshop participants and co-designers frantically wroote their questions down and hope to have them answered. The process was inefficient and hectic. We had a hard time deciphering each other's hand writing, and generally took longer writing rather than speaking or signing questions and answers. Our communication with each other was consistently interrupted by designers eager too answer thier questions in the time alotted and looking down at notepads. We were inefficiently scribbling just to learn about their communication difficulties while experiencing the very difficulties.

Other common solutions include video calling friends who speak both sign language and spoken language to translate for them. Sign language users also text or use a notepad and write down some of the things that they may need to say in the market or another scenarios in their daily life. One trouble that they run into with these massive methods is that not everyone is literate nor are they always able to speak English. And the final solution used by the users interviewed was reading lips. While they could mouth words to explain themselves to others others were not as capable or well practiced in lipreading.

3.3 Characterizing the basics of Sign Language

There are over 300 distinct sign languages in the world. Fortunately, for the sake of interpreting these languages, the majority of these languages are constructed of similar motions. The signing area is from the top of the user's head to their waist and shoulder to shoulder. Facial expression, eye contact, body language, and lip reading are all part of sign language.

Time is represented spatially. The present is in front of the speaker, the past behind. Punctuation is defined by facial expressions and breaking eye contact is the equivalent of ending a conversation by walking away. When both hands are required for one sign, both hands are doing the same motioon but mirror each other. Much like spoken language there's also nonverbal communication. Hand placement can change the definition of a word. So if the sign is done on the forehead it could mean father versus on the chin it means mother. Typically the right hand is leading in the left hand is doing the same motion or the mirrored image. Signs can either be initialized or still. Initialize signs are signs that are defined not only by the hand but also by emotion.

Facial expressions create context. Much like in spoken language if someone says the word happy or smile, their facial expression will determine the extent to which they are happy. If said without a smile it is assumed that that person is expressing sarcasm. Facial expression is just another detail of nonverbal communication. We

Figure 3.3 A

Sign Languages around the world are made up of roughly fifteen hand shapes

Source: Signing Illustrated by Mickey Fodin

use nonverbal communication in our everyday lives not just in the case of hearing impairments.[7]

Sign language comes in a multitude of slang and dialects. Slang varies greatly by region. Martha's Vineyard sign language existed almost entirely on one island between a single deaf community and developed independently of other sign languages and is evidently

7 Signing Illustrated Mickey Flodin the Complete Learning Guide

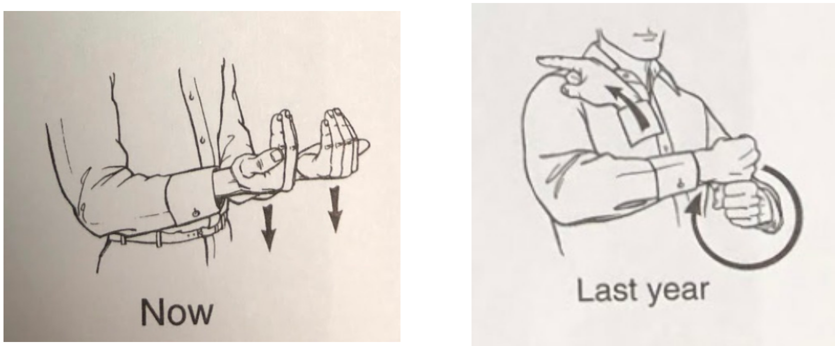


Figure 3.3 B & C

Images show how time is represented spatially Source: Signing Illustrated by Mickey Fodin.

very different from English sign language[8]. Indian sign language is also based on English spoken language but varies greatly from ASL.

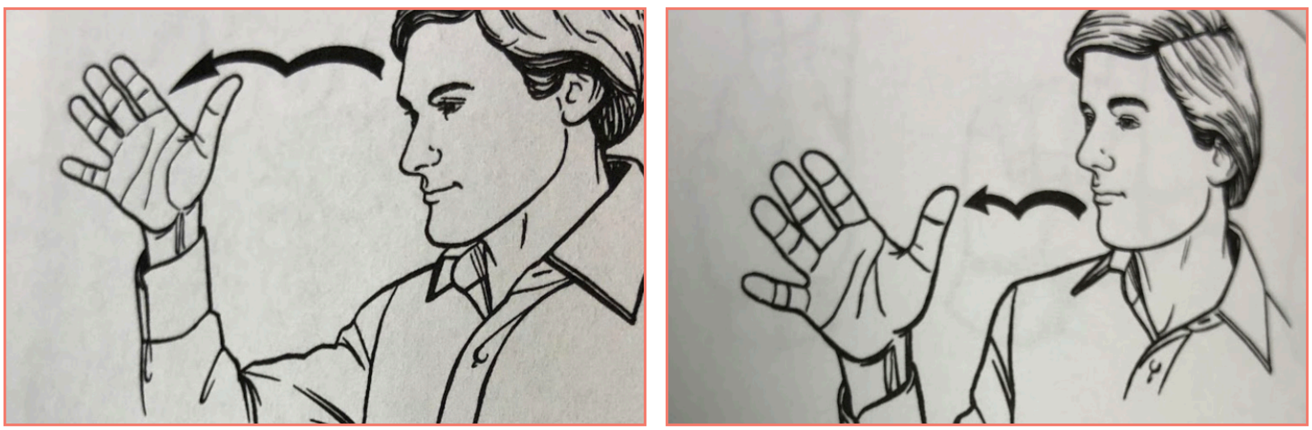


Figure 3.3 D

Placement of the same sign changes the signs meaning as seen in the figures above. Grandfater is signed from the forehead versus grandmother, the chin

Source: Signing Illustrated by Mickey Fodin

Signed English is a simplified version of sign language that matches spoken English in every word. Some signs cannot be directly translated or spoken words do not exist in sign language and must be determined based on context. Sign language contains its own grammar rules distinct motions and shapes and sentence structure.

8 https://www.atlasobscura.com/articles/the-hidden-history-of-marthas-vineyard-sign-language

3.4 Perkins School Visit

During this research it was important to find a community of people with hearing impairments in the Boston area. One such communities was the Perkins school for the blind. The school originally founded in 1851 was created for blind students around the country and has since grown to accommodate students with multiple impairments. Expansion began in the early 1970s when the education mainstreamed system begin to adopt some of the teachings of institutions like Perkins to better meet the needs of students with visual impairments. Once the shift began in the United States Perkins adapted to further serve the larger community of people with impairments.

Perkins has classes, sports, and every other amenity imagined at an average US public school. However it also operates as a research center for the blind which develops assistive technology devices including a refreshable braille display to better serve those in need.

Since its inception Perkins has been a part of developing products devices systems and other innovations to better support people with impairments. Some of those include braille which simplified written language for the blind, simplified the manufacturing and shortened the time taken to read original books for the blind which featured embossed letters to decipher. This embossing was once expensive to make and slow to read. Perkins also creates teaching material and curriculum available online for free for educators who need help learning how to better support their students. Brooke is his goal is to democratize access to education and technology.

The campus was specifically designed to fit the needs of blind students. The main building features a cobblestone hall so that students know where in the building they are. Just to the left and right of the hall are low ceilings, and arches that also helps students orient themselves because the difference in sound. Through the main hallway there is a crossroad under a hollow tower that echoes substantially. These design features of the hallway are recieved as checkpoints for orientation inside the building. Just outside the main tower, a bell rings every hour so those in the neighborhood can to orient themselves in case they have been lost.

With this visit a few things were reiterated from the experience of people with impairments in India. A common experience of students who join the Perkins school is the experience of isolation, bullying, and teasing at mainstream schools. The deliberate design helps alleviate additional difficulties face.

Martha Major of the deaf blind program provided insight on the signing experience. There is a personality with sign language as their is with spoken language. While there are dialects that vary regionally and culturally driven colloquialism, even within a region or cultural group personality manifests physically in the intention and expresiveness of a sign as someone may be more expressive in a spoken language. Even a single sign language user may express the same sign in different ways based on background, mood or other factors.

4. sensing mechanisms

Gesture Control Technology can interpret a person's gestures and take directions without the user having to touch a mouse, keyboard or screen. A human is therefore able to control a piece of equipment or a machine without directly touching it. This can be done through a variety of ways, including wire gloves that provide input to a computer system, special cameras that detect and transfer motion, and controller-based systems that transmit actual gestures to the machine that will replicate them.

Sensing technologies and gesture control have come a long way in an unsuspecting form. Video game manufacturers have been challenging the expectations of video game controls since their conception. Nintendo, a leading gaming company, focuses primarily on new interactions. From the high conductive foam power remote control to the power glove (which later evolved into current day Wii Mote), Nintendo has been creating new computer interactions and input devices through gamification. Microsoft, a competitor in the gaming space is also no stranger to new controllers and input methods for users to interact with their games. Through devices like the Microsoft Kinect, gamers motions are mapped in three dimensional space as well as AR and VR headsets. These controllers in their essence encourage an immersion into the gaming environment and an integration with technology has furthered sensors and human computer interaction.

In order to compare the sensors discussed in this chapters we had to compare preliminary metrics to help quantify appropriateness of a solution. The metrics helped further prioritize needs. Some of the metrics are made up words but all words are made up. So the explanations are provided. During the early phase of ethnographic research with co-designers in India, the following key performance indicators came to the surface:

Affordability:

In the context of an Indian market it is important to note the lower cost of living compared to that of much of the western world. Co-designers specified the range of affordability as 10000-15000 rupees ($144-$216). Further exploration would be necessary to determine the appropriateness of this range, however for a quick sanity check, the range of an average smartphone in the region will do.

Feasibility:

Feasibility is the ease with which one might implement a sensing solution. While this is subjective, we can likely all agree a thermometer is a simpler sensing mechanism to implement than a LiDar sensor.

Applicability:

Applicability is the overall appropriateness of the sensing mechanism for a gesture interpretation.

Discreteness:

Discreteness is a measure of the size, form factor, placement of a sensor as well as the obviousness of a motion required to meet the threshold of a sensor. The more ostentatious, bulky or generally cumbersome a device is, the lower its score in discreteness.

Robustness:

Robustness defines the range and number of motions a sensor can detect.

Wearability:

The general form factor of a device is determined by how comfortable it is to wear and whether or not it fits social norms and expectations of clothing.

Resolution:

The lower the threshold of detection the greater the resolution.

These factors are not exhaustive, but prove the highest priorities of a sensor requirements. They were selected to determine the likelihood of adapting a sensing mechanism to identify gesture. The following sensors were discovered and compared with the factors described above in mind.

4.1 AR/ VR Functionality

Augmented and virtual reality lenses offer tracking of the user in three dimensional space. Current forms of these lenses require sensors in a room to locate the user’s head and hand controls. The location is then recreated in an application that imitates the user, this is referred to as ‘registration’. Often there is some representation of the user’s hands, or any other avatar whose actions correspond to those of the user. If the application or game requires user input there are controllers which is most cases. These input devices take the form of joystick and button combination, however this trend is not the only form of input. Some systems replace joysticks and handheld devices with gloves. Each button corresponds to an action a user can take with a game and vary from application to application. The remotes are designed to be gripped and the buttons are placed along the body of the remote to be easily accessed by the average hand. “Eye and head tracking can be ensured using laser pointers, led lights or mobile sensors. In mobile, we use the accelerometer to detect three-dimensional movement, gyroscope for angular movement and magnetometer to identify the position relative to the Earth. If we need to achieve a very high accuracy then cameras and sensors can be installed”

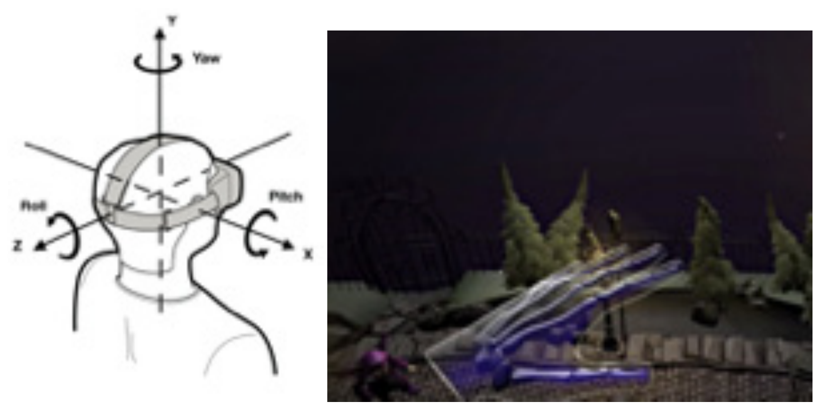


Figure 4.1 A & B

Shows the orientation and form of the system as well as the hand representation in a VR environment

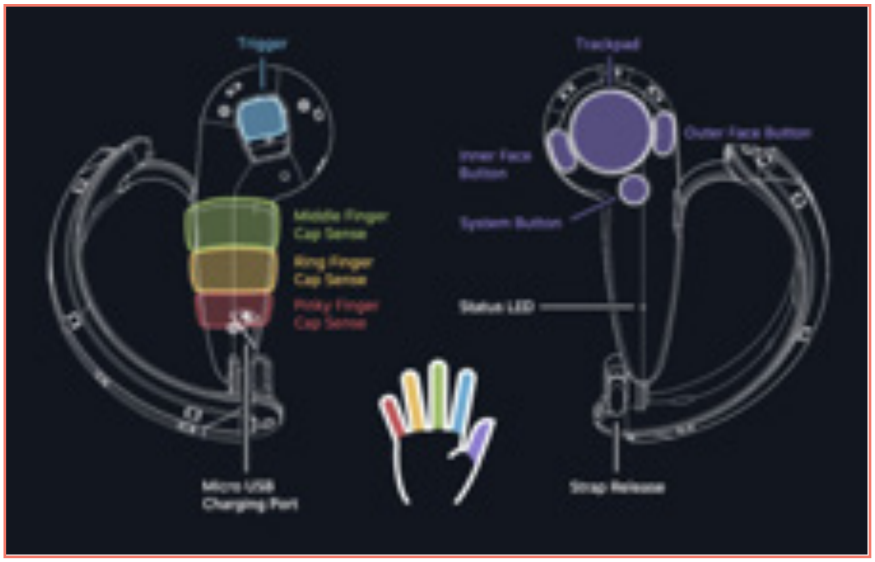


Figure 4.1 C

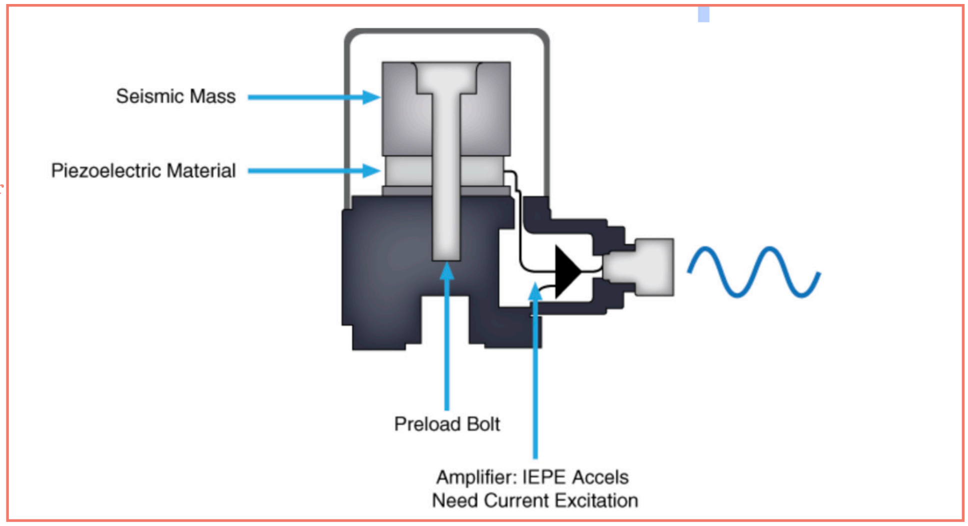
VR controllers, typically used in gaming provide multiple modes of interacting in space.

Finally the system also requires a sensor to track headset position. The information from each of these sensors is combined through the sensor fusion process to determine the motion of the user's head in the real world and synchronize the user's view in real-time. The sensors also define play space which updates the headset location in the game.

4.2 Accelerometer & IMU Sensors: Location Rotation based Sensing

Accelerometers rely on the piezoelectric effect which is when a mechanical stress is converted to electrical charge in a crystals[9]. An acceleration is transmitted to an inner mass which generates the proportional force on a piezoelectric crystal. This external stress on the crystal then generates a high-impedance, electrical charge proportional to the applied force and, thus, proportional to the acce-

9 "Measuring Vibration with Accelerometers - National Instruments."



Figur4.2 B

Accelerometer outputs voltage signal proportional to vibration of crystal induced by motion detected.

Source:National Instruments Measuring Vibrtions with Accelerometers

leration. Note that most low cost accelerometers are not well prepared to measure rotation around the vertical axis because the crystal's location changes because of gravity.

Sensitivity is a huge determinant for the usefulness of an accelerometer. Sensitivity can be amplified and/or altered but keep in mind different users and variance in hand motion and signalling.

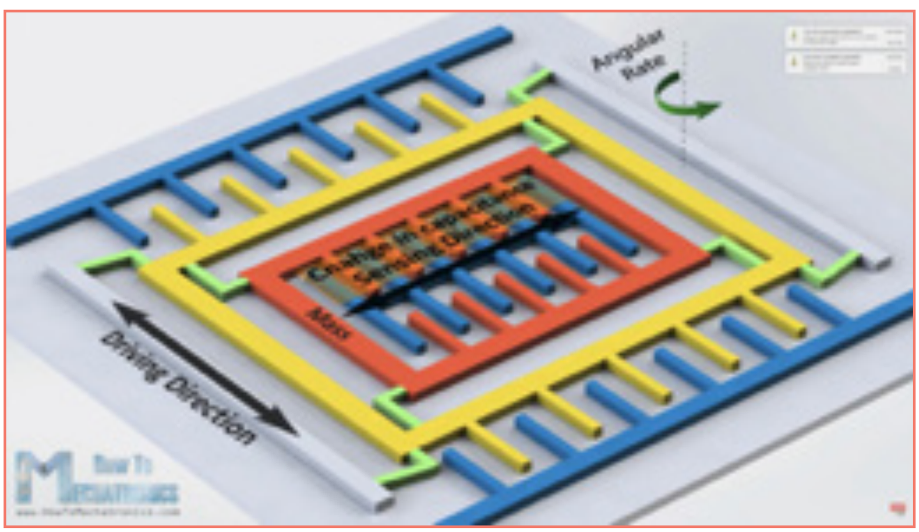


Figure 4.2 A

Accelerometer crystal in an IMU sensor

The accelerometer is capable of detecting the physical orientation of a hand to interpret motion but would need to be coupled with other sensors to be useful.

4.3 Electromyography (EMG): Electrical Signal Processing

EMG sensors use a gel or electrode in silver chloride solution to detect a signal created by the contraction or expansion of a muscle. It measures the differences between the electrodes to determine the frequency without interference from surrounding frequencies. The more electrodes use the more accurately you can understand the muscle motion and detect the signal. The electrodes also have to be in close contact with the muscles which makes it more reliable to

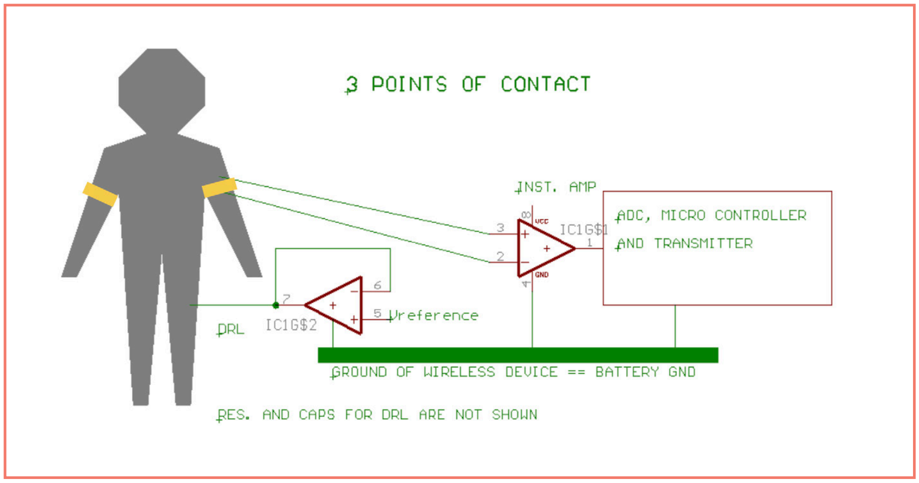


Figure 4.3 A

EMG right leg drive system

have more in case any of them are not touching the skin. Right leg drive EMG measures the surrounding frequencies and counteracts those frequencies in order to detect signals.

The system has to correct for surrounding frequencies. If using in doors correct for frequency of wall EMG requires signal processing and an algorithm that is patentable and the secret sauce of the product. Researchers at the National Technical University of Athens built a robotic arm that imitates the motion of the user[10]. The business model is centered on their patented algorithm which senses signals while correcting for ambient frequencies and uses the signal to control a system of actuators.

EMG electrodes must be in close contact with the skin in order to more accurately detect signal. Some forms of the electrodes require a conductive fluid between the skin and electrode for accuracy. Silver chloride and other solutions introduce an added level of complexity as they are consumables that must be reapplied.

The Myo armband is an off-the-shelf EMG armband that sends a voltage differential to a full-fledged computer, raspberry pi or computer module. It requires calibration by going through set positions to attempts per person. While the device was meant to be for average consumers the company found that their products were mostly being used by researchers other academics which did not sustain the company financially as they're no longer selling the product. Myo armband was intended to be a simple solution that almost anyone could pick up[11]. Another downside is that the myo armband is parti-

10 Artemiadis and Kyriakopoulos, "EMG-Based Control of a Robot Arm Using Low-Dimensional Embeddings."

11 https://www.zdnet.com/article/thalmic-labs-shuts-down-myo-gesture-

cularly chunky and requires very close contact with the wearers to be able to send the muscles movement. Overtime that proves uncomfortable and the device like this may be worn for hours before causing fatigue.

Myo sends voltage differentials to a computer or microprocessor. An algorithm must be calibrated to individual users. In the case of the researchers who created the robotic arm, their algorithms are accurate enough to to re-create motions in a robotic arm remotely from a

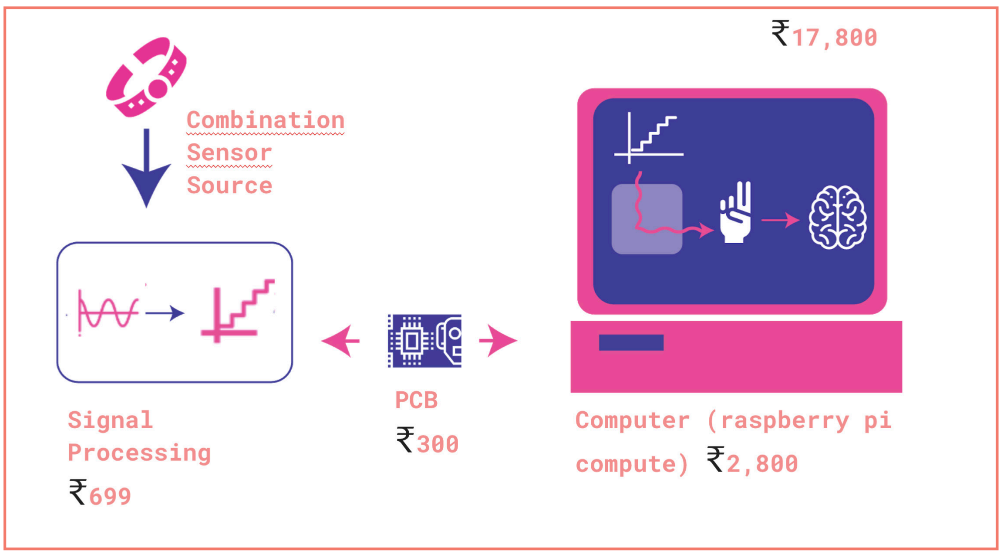


Figure 4.3 B

Potential system proposed to co-designers for feedback. Affordability was important to co-designers in Chennai. This potential component layout fits within the price range self reported by co-designers.

variety of users. EMG sensors require complex algorithms for signal processing beyond the scope of gesture interpretation.

To further explore EMG as a potential gesture detection device one may consider starting with the ability to collect data and signal and to convert that into a gesture logged in their system. To create that

-control-armband-project/

system hardcode single gestures or sign language signals and continue to include up to 1000 gestures. EMG sensors can be coupled with an accelerometer and magnetometer to be able to send the location of the hands in three-dimensional space. The complexity and inaccuracies of a system are increased as sensors are added though they do help to parse out signals it does further complicate the system.

4.4 Camera and Leap motion detection

Camera apps are able to interpret signs that are hard coded in and talk to a machine. It exhibits the same difficulties as other methods of interpreting sign languages including requiring a lot of training to know the difference between users and between six symbols and signs. This also further removes the sign language user from the conversation and requires them to be in front of a camera in order to communicate with someone else. This does not present a seamless communication experience or exchange.

Another sensing and camera related solution is the Leap motion controller. Leap motion uses IR and re-creates your hands in a three--dimensional space. The device itself has a small visibility range if you will. Which requires any users to put their hands just within sight which is no more than 1 foot for current market off-the-shelf Leap motion cameras. The equivalent of a device like this in spoken language, is one which requires users to whisper in order to speak. The camera's recetive area is much smaller than the space necessary for signing as described in Chapter 3 of this thesis.

4.5 Speech Prosthesis Electrolarynx Devices:

Another subsect of sensing devices explored was the electrolarynx device which detects a vibration in the larynx. Unfortunately the developmental stage in speech is age zero to seven and of late detection usually means no development.[12]

Currently, there are three main methods of voice restoration: the electrolarynx, esophageal speech, and tracheoesophageal speech through a tracheoesophageal hole which relies on the continued use of natural nuances of speech including the use of the mouth and the ability to articulate.

Newer innovations in projecting "silent speech" focus on tracking the articulatory tract (i.e., mouth, tongue, palate, etc.) movements as people attempt to speak, with computer analysis then interpreting these movements and generating corresponding speech.

Similarly the MIT Media Lab has developed a system leveraging internal speech as a new HCI device. This kind of speech bypasses the vocal box and only require users to use their tongue and muscles

12 Kaye, Tang, and Sinclair, "The Electrolarynx."

in the face. It is adhered to the face and proves distracting and

Figure 4.5 A

Device by the Media Lab group Fluid Interfaces. The device detects minute muscle motions in "internal speech". Pictured is the creator asking the AlterEgo the time using internal speech and the device responding with the time in his ear. Questions and prompts are curently hardcoded in

Source: https://www.media.mit.edu/videos/fi-alterego-2018-04-04/?autoplay=true

obtrusive but its sensitivity could be promising for signal detection.

4.6 Kai

Kai is a new gesture controller developed by a team creating a low cost way to interact with a computer or other devices. It is worn around the user's palm excluding the thumb. Setup involves updating the firmware on both the device and its receiver that is connected to the USB port of your computer. It utilizes customizable controls in a device that includes an IMU sensor to detect the wearers hand in 3-D space.

While the device seems promising, the company behind it, Vicara, is in its early stages and the device is reflective of that. The Kai is neither intuitive to set up nor to use. The signals are often confused with each other. The user can fold their hands at the wrist left or

Figure 4.6 A

The Kai

Source: https://www.indiegogo.com/projects/kai-gesture--controller-buy-now-at-vicara-co#/

right to swipe left or right. They can utilize any combination of bent finger versus straighten finger and codify that to a command for their applications. The most significant shortcoming of the device is that it is neither sensitive nor accurate. Left and right swipes are mistaken for each other consistently throughout usage. The interface requires an intimate understanding of the device and system in a way that should not be expected of an average user.

Kai also requires a dongle receiver which makes it more difficult to control smart televisions drones and other devices in the future. In order to adopt their device users would have an intimate awareness of Kai and software development. While the device can detect a bend at the wrist, a bend where the palm of the hand is perpendicular to the rest of your arm, it cannot detect the difference between that bend and bending the fingers to be parallel to the arm. If the user moves their whole hand up and down, or covers the sensor by bending their fingers, the device is able to detect that information using the IMU sensor. It is also capable of sensing and detecting rotations around 3 axis.

Setup requires installing an application both on your phone and computer. The user has to update the firmware on both the device and the dongle before use. Upon syncing the dongle and the device the users are instructed to calibrate to their needs. First they are asked to bend each finger individually while the computer application reflects those bends, if the sensor is working correctly. Currently there are 17 distinct motions that could be used for different controls on your applications however up opposite motions are often could mistaken for one another. The resolution of the same signals are not yet known.

Sensing Mechanisms can be run together to properly detect all the needs of sign language users. While the sensing mechanisms and requirements are advanced, detecting motion can be equally so. In an initial prototyping phase it may prove prudent to use a combination of sensors to account for inaccuracies.

5. case study

In order to further prove or explore the translation of sign language to spoken language, a parallel had to be drawn between a case that could be accessed more easily and the case of sign language users in India. 27 users were interviewed who had recently travelled to countries where they did not speak the language within the past three years. Three years was chosen in order to mitigate the possibility of users forgetting the nuances of their experiences.

The underlying assumption of this parallel was that translating between spoken languages shares similar complexities as translating between sign and spoken language. There are not always one to one translations of words and phrases, the syntactic make up of languages do not always lend themselves towards clear translations, and the history, culture, context and development of a language creates a context that cannot always be replicated in another language. Viewing a problem through the lens of situational impairment also allows the designer to find the user in themselves and others. Difference frames of reference result in new insights as found with this case study's reframing.

Focusing on people with hearing impairments in India makes this process more difficult because of my limited access to the user group. This parallel case study is an alternative approach to the more ideal case, more observation of the intended end user. The overarching discussion of this thesis is to identify how wearable technology can have that communication between people who speak different languages. The focus on sign language required particular context that may be different from most spoken languages. However the complexity of differences between spoken languages parallels that of the difference between sign and spoken language seeing that spoken languages do not always have direct or accurate translations between them, and they have differing syntax, grammar and sentence structure.

After interviewing 37 participants who self identified as having recently travelled to a country where they could not speak the local language, some trends began to emerge, leading to the following expectations of a translaton device:

Durability:

Durability can be decomposed into the durability of the electronics and durability of hardware. The more someone may have to charge the device the less likely they are able to wear it. This is the equivalent of removing your voice at the end of the day or halfway through the day because your voice died. In hardware, users want their device to hold up to daily wear over the lifetime of the product.

Speed:

Users complained about the difficulty of communicating with people when time was a concern. If a traveler is looking for help from a stranger they are often at the mercy of the person's time. In order to limit frustration between people, focusing on getting to the translation requiring as few moves or user engagements as possible. AAC devices successfully average 1.73 seconds per click and represent a reasonable target for a single communication attempt. AAC also provides the case for pictures and other images in place of any text. The brain can process an image in as little as thirteen milliseconds[13], which suggests that images could be more useful for people who can read and people who cannot. A picture based solution is also suitable for children as well as adults alike.

Accuracy & Assurance:

A recurring frustration in translation was the inaccuracy of the statement. Aforementioned difficulties with translating between languages are the root cause of the inaccuracy. These difficulties are further exacerbated by the use of technology. Google is the most

13 "In the Blink of an Eye."

referenced translation tool by the interviewees and it is imperfect. It often falters when it comes to double meanings, idioms and other ambiguities. This is a problem that is insurmountable with today's technology as it relates to language processing. This does not mean there is no fix. A simple work around is relaying to the user what they have said with a translation back to their original language to give a general idea of how accurate the statement was compared to what they intended to say[14].

Aesthetic & Discretion:

While traveling and getting around users do not want to draw more undue attention to themselves or to make themselves a target. While discussing wearables, a recurring concern was making sure the wearable was unobtrusive, not flashy, and did not clash with the personal style of the wearer.

Reliability:

In some cases users travelled to countries with limited data access. One particular user spent two weeks without access to the internet in the streets of Cuba but WiFi at home. They worked around this by preempting conversations and downloading conversation guides.

14 McGuire, "How Accurate Is Google Translate in 2018?"

The translations proved difficult to search without access to the internet but the frustration of losing their voices while out socializing suggest that an offline or limited reliance on the web would provide a solution that is accessible.

Accessibility

Financial, physical and mental accessibility are a must have for a communication system like this one. Creating a low cost, intuitive, and multisensory solution further democratizes access to communication. Physical accessibility also includes ensuring that the devices cause little to no fatigue, and no harm to the user over time. No system that compromises the well being of the user is worth the trouble.

Robustness:

Though in the early stages of a system that could communicate between languages there will be limitations, it was found that communicating in a different language is a vulnerable experience. Limiting the ability to communicate by creating an incomplete language of hindering speech in any way creates frustrations where there need not be.

Synopsis:

The case study surfaced the following findings for the needs of a communications device like this below.

Finally, through this case study we can conclude that the organization and contextual awareness of words are key in the success of a device, discretion is highly important and most importantly, communication is a *human* need.

Travellers are operating in a new location and set of experiences - *Device adapts* Unfamiliar and want to stand out less - *Discreet* Works in low connectivity settings - *offline* Confirms what user has said - *reliable* Supports changing environments - *Contextual awareness*	SL Users would be using device in daily life - *socially acceptable* Worn all day - *comfortable, long lasting, unobtrusive* Expansive number of contexts - *Contextual awareness expansive vocab detectable*

Figure 5 A

Needs as determined by interviewing two end users; travellers in non-native countries and Sign Language users in daily life

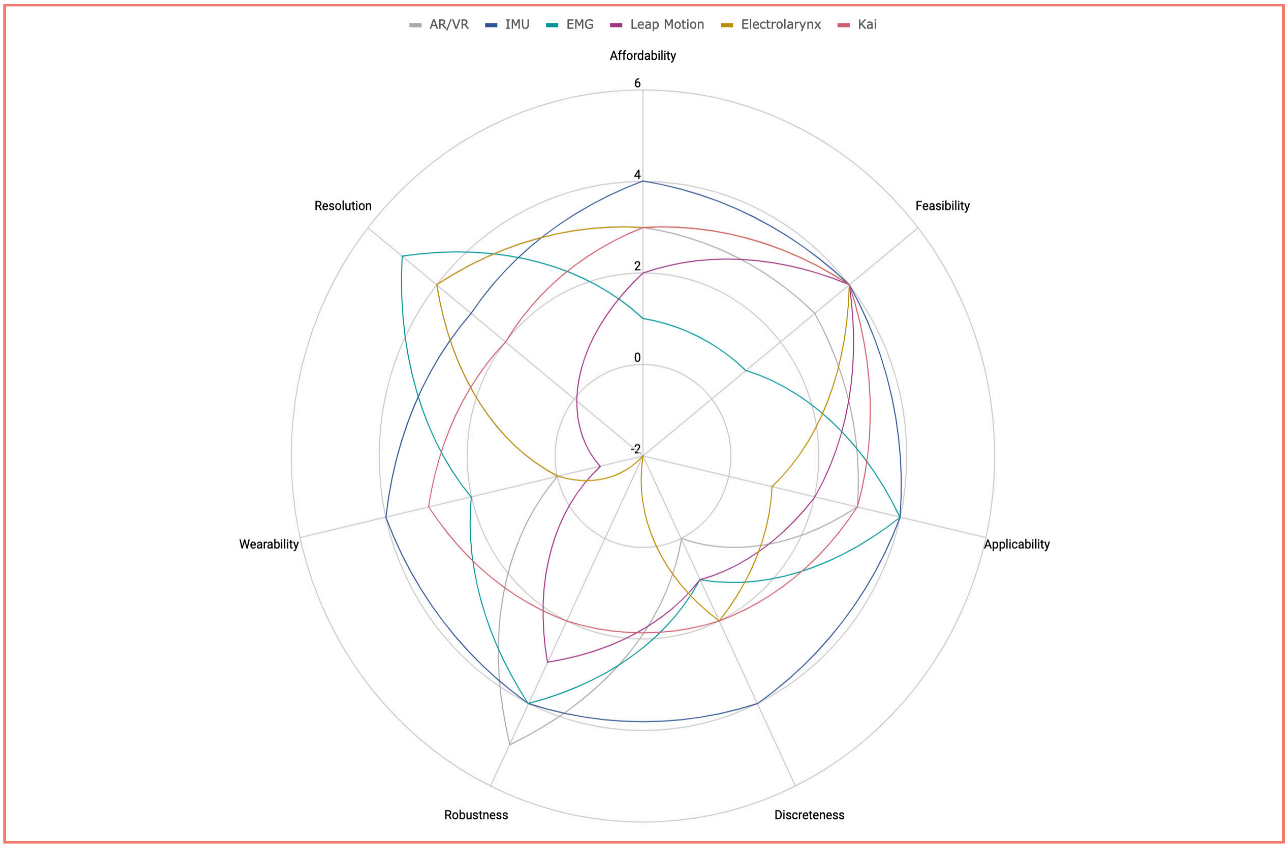


Figure 5 B

Sensing Mechanisms comparison chart was created based on preliminary needs identified by co-designers.

6. build phase

While this thesis focuses primarily on the exploration and research behind the development of a communication device, It is important that I also propose a solution to better report the needs and how they may be met.

6.1 Language interpretation

Because of the complexity and wide variety of sign language dialect expression it may be beneficial to begin with simple signals and motions match to words. These motions can be created leveraging timing of (and between) motion, simple distinct motions (that are reasonable within a social context), and compounding motion.

In the first phase of the system, the gestures could begin with four elements or motions that can be combined in different orders to represent different words. Simply programming new gestures and matching them with motions simplifies the process of calibration and interpretation of a variety of dialects. While this does require the sign language user to adapt and change their natural language, it is the beginning stage to create a menu of options that can easily be flipped through by gesture. An image heavy system requires intuitive organization of the menu so as not to compromise the speed of an interaction.

6.2 Physical Form and Sensing Needs

As we move into a more screenless society, it is becoming an expectation for users to interact with technology while interacting with other human beings. This heads up display and wearable solution moves towards a positivist fusion of technology and fashion. Wearable technology, especially with gesture control, allows the user to be more in tune and present in the moment.

Beginning with a cell phone helps use the built-in sensors that already detect some of these things. A wearable such as an Apple Watch is a small cell phone with the very same sensors. Leveraging existing phones and wearables make allows users to not have to purchase a dedicated device. People's attachment with their devices further reduces the barrier of entry to adoption of a communication system.

6.3 Language organization

If we follow the same organization for capillary method as AAC devices the more used icons would be in the top left corner of the page and decreasing diagonally towards the bottom right corner of the stage in importance. In this case a few more metrics should be considered[15], some of these metrics should include the saliency of the need for a single piece of communication. For instance needing help in an emergency situation may be used much less often than purchasing knick knacks on the street. However in a time of need help is much more important to focus on accessing the emergency phrases in the menu than accessing everyday conversation.

15 Brownlee, J., & Brownlee, J. (2015, June 1). Meet Project Jacquard, Google's Plan To Turn Your Clothes Into A Touch Screen. Retrieved December 9, 2018, from https://www.fastcompany.com/3046864/meet-project-jacquard-googles-plan-to-turn-all-your-clothes-into-a-touchscreen

7. conclusions and recommendations

7.1 Summary

Over the course of this process I explored the needs of a communication wearable system that allows communication between different languages. This process began with an exploration of wearable technologies as it relates to those who may benefit from it most, people with impairments. Wearables allow users to communicate without interruption. Technology has already become more pervasive fashion statement with over 526 million connected wearable devices people already have some of the sensing technologies required to sense motion and translate that to audio. Inspiration for gesture control technology was inspired by co-designers in India with hearing impairments who wanted job opportunities and to increase the quality of life. This latent need provided the framework for further study of communication between languages while designing for a unique scenario that could benefit a broader audience in the end.

Through the exploration of a communication device from different lenses, user needs emerged. The commonalities were that people want to gain confidence in communicating and interacting with others. They want access to their communities and new ones they may find themselves in. The lens of hearing impairments as well as situational impairments help guide designers towards solutions that are inclusive and encompassing of the needs of those in the margins as well as helpful to a wider audience.

Challenges

The Tech

- Computers contextualizing language requires large dictionary and clean data
- Interpreting EEG signals requires complex proprietary algorithm
- Longer term solution based on tech cost and limitations
- Frequency Adjustment

Language Interpretation

- SL includes facial expression, spatial awareness, movement of the torso and moving lips not captured with EMG alone
- No word for word translation from SL to English
- Dictionary size weight on data processing

Societal

- Onus is on the SL user to find a way to communicate with non SL user
- Doesn't change stigma keeping people who use SL from being employed

7.2 New Tech

The next phase this project can be split into three steps. The first is to further explore, quantify, and characterize sign language. As sensing technology becomes more accurate we will better understand the thresholds necessary to detect signs both between users and sign language dialects.

The second is to continue to observe and gather more information. This could help determine material selection considering current wearables and the context of wearing things in India. Focusing on the Indian context yields more battery power, tech durability and other benefits of designing for the margins. This could also uncover more discreet and unobtrusive ways to integrate these technologies changing lives without detracting from human connection

The third is further exploring translating incompatibilities between seemingly incompatible languages. This would not be a thesis at MIT in 2019 if there was no mention of machine learning. Designing with a hearing-impaired in mind further highlighted the difficulty of translating between languages that barely have word for word translation. To predict the users sentences and provide complex sentences and natural conversational responses there needs to be a growing understanding of language. The nuances of language will be considered in the future iterations of translating application software. So as it stands translating software often misinterprets language as it may be able to translate a direct word but to translate the definition of an idiom with connotation hidden meaning history and contacts that is not explained in a language currently is still out of reach.

7.3 Ethical Implications

There is still much to be discovered about the effects of smart textiles and wearables on their wearers, as it is a growing field and the technologies are not yet widely available. Assuming wearable smart textiles become as integrated and accessible as current social technologies, we may find that human-to-human interaction will shift. The lack of human contact creates a dissonance that may be paralleled in fashion as technology is further integrated. The lens and filter of technology allows users a growing wall between ourselves and others that Turkle describes as the fear of intimacy soothed by the comfort of technology[16].

A sign language translation system requires sign language users to adapt to a spoken language in the early stages of a system. It also limits the extent of their communication. As the technology further understands the complexities of sign language and is able to identify and correctly match them to a similar sentiment and spoken language the limit does exist in how well we may be able to understand each other. Non-sign language learners on average need roughly 2 to 4 weeks to learn the basics of Sign language and yet it is not something that is actively explored. Perhaps the communication device would be better serving to those who are learning Sign Language rather than another burden to sign language users. The line for me as a designer is to ensure that the things I create, or at least hypothesize, result only in secondary gains not losses, even

16 Turkle, Alone Together.

if the device is inteded to make itself obsolete. If the true goal of a research project is to get rid of communication barriers obsoletion is warant If the user in the margins eperiences loss because of my design (i.e a wearable that comunicates but draws unwanted attention), the design is not finished. The deaf community is alive and well and may face erasure the more that we ask sign language users to adapt to spoken language.

The dueling concerns there or that there are some people who do not have a deaf community. In Chennai, much like the rest of the world, there still is a stigma about impairments and disabilities. 98% of people with hearing loss don't receive education in any sign language. During the user needs uncovering phase, tales of stigma and prejudice keeping students out of schools, parks, and other socialization spaces because they may have an impairment emerged. One of the interviewees and codesigner spent 10 years of his education in complete isolation. He sat in the back of the class and didn't learn anything from the teacher. When he went to a deaf college when he was older he had to learn sign language and it made it difficult for him there too. He missed out on prime socialization in both the mainstream and deaf schools. He also did not create networks that could further provide career opportunities in the future. He stated that if he could have any job he would be happy. There is no room for dreaming for him. Though he would be able to communicate if a system could exist to give a spoken voice to the hearing impaired, it would not eradicate the stigma that someone may have because of their own biases.

Designing for analog and digital is growing in importance with the development of new smart textile and wearable technology. Technology in the clothing we wear encourages interconnectivity and access. Clothing is being created with embedded identification systems, responsive and interactive surfaces, and other new functionalities that could inadvertently cause isolation of those without access, further marginalizing some groups. The more integrated technology is in our clothing, and the more on this we depend, the wider we make the gap between those who have and those who have not. So one thing to consider is what happens during the prolonged phase of the technology not being pervasive enough? Will we be leaving out entire chunks of the population or could we potentially design less exclusive solutions that provide functionality in the analog as well as in the digital space.

People seek jobs and purpose. They want to be useful and fulfilled. If there is an opportunity to provide more purpose where there is mostly isolation, perhaps we can all try to create technology diligently and deliberately build respect for the people who may use it. Products like this exists but don't capture the full range of inputs for sign language communication. Limiting the ability to deliver original thought allowed to those who may not understand is a potential outcome of systems like these in the short term.

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9. appendix

9.1 Interview Protocol

Over the course of this thesis, 27 individuals were interviewed who self Identified as having recently travelled to a country where they did not speak the native language. The pool was made up of 19 MIT Graduate students, two of whom spoke the language in the country they visited. The students were between the ages of 23-31. I also interviewed a two Post doctoral candidates, one professor and five 24-30 year old early to mid career procfessionals and found the major take aways.

Travellers are operating in a new location and set of experiences - *Device adapts* Unfamiliar and want to stand out less - *Discreet* Works in low connectivity settings - *offline* Confirms what user has said - *reliable* Supports changing environments - *Contextual awareness*	SL Users would be using device in daily life - *socially acceptable* Worn all day - *comfortable, long lasting, unobtrusive* Expansive number of contexts - *Contextual awareness expansive vocab detectable*

Findings:

Needs as determined by interviewing two end users; travellers in non-native countries and Sign Language users in daily life

Protocol Questions:

Can you tell me about your recent experience travelling in a country with a language that you are not fluent in?

Think about the last time you travelled to a place where you did not speak the local language. How did you complete your everyday tasks? How did your interactions change?

What were some experiences you had , difficult, easy, positive or otherwise?

What were some things you discussed or would have liked to?

How did you communicate with locals, if you did at all, and in what context?(I.e Taxi driver, airbnb host, new friends)

9.2 Notes from co-designer

Our time spent with co-designers who hd hearing impairments revealed a lot about their experiences. They shared the solutions they current ly live with as ell as some of their difficulties in communication. This section summarizes the high level takeaways of our discussion.

Existing Solutions

No Tech

- Interpreter
- Notepad and written messages

Low Tech

Device

- Video calling
- Texting

High Tech

App

- Camera-based sign language reader
- Audio-to-Text translator

Hardware

- Sign Language Glove
- Hacked Gesture Recognition solution using Myo or Leap Motion

Wow you're still here? Honestly I'm shocked.