**Final Presentation Brainstorming**

**Project Brief/Background Research**

Imagine being in a room full of conversations, laughter, and ideas—but unable to join because you can't speak. For the 170 million people worldwide with speech impairments, this is a daily reality. Among these impairments, **Cerebral Palsy** (also known as CP) is a significant condition which affects over **17 million** people globally. CP is a neurological disorder that affects the brain’s ability to control muscle movement and coordination. [31s]

To help people with cerebral palsy who have difficulty controlling their facial muscles therefore affecting speech, **Augmentative and Alternative Communication** devices (also known as AAC) were developed. These devices are tools or systems used to help individuals who have difficulty speaking or cannot speak at all to communicate. These devices can range from simple picture boards to advanced electronic devices—such as keyboards, joysticks, and tablets— all providing an alternative way for individuals to communicate.

AAC devices can be life-changing, but the limited hand movement makes operation challenging, and the heavy equipment becomes a daily burden, turning a tool for communication into a constant struggle.

We aimed to change that. What if assistive technology were as simple as wearing glasses? Today, we present a solution that replaces wheelchair-mounted AAC devices with an affordable, wearable alternative. Our goal is to make communication effortless and empowering, allowing users to focus on expressing themselves, not the device.

**Requirement Specification (hui sin)**

Before we dive into the device design, it’s important for us to first define the requirements our project must meet.

The core idea behind our design is to replace traditional AAC devices, which are often bulky and impractical as they need to be mounted by a carer on a wheelchair. Hence, we’re focusing on making our device **wearable** and **portable** so that the device can be stored away easily**.**

As cerebral palsy patients are our **target users,** the device must be easy to use, accessible and hands-free. In addition, the device must provide **accurate** text output to help individuals communicate clearly.

**Durability** is a critical aspect of our design. Since the device will be used daily for extended periods, it must withstand regular wear and tears and potential drops, to ensure long-term performance.

Finally, **safety** is paramount, given that the product will be used in direct contact with the patients. [38s]

**Preliminary Designs/Prototypes(Cissy)**

After completing our morphological analysis, we then developed the following ideas by combining a set of parameters.

The first combination led us to detect face and jaw muscle movements, each corresponding to one of 44 phonemes, to generate speech. We designed a mask with surface electromyography (sEMG )to detect muscle signals and a detachable collar with a speaker.

The second design uses electromyography (EMGs) and strain sensors to detect low-amplitude muscle activity, along with Inertial Measurement Units (IMUs) to track subtle jaw and facial movements. These sensors were integrated into a pair of glasses and headphones.

After talking to an AAC specialist, we learnt that our first design was intrusive and could stigmatise users, and it lacked durability due to issues like drooling and symptoms of cerebral palsy.

The electronic technicians informed us that the muscle signals were too weak to differentiate sounds in our second design, and attaching electrical components to the skin posed safety concerns.

After receiving feedback and evaluating these ideas using the concept evaluation table and finding that they scored low, this led us to reimagine our approach and ultimately to our current design.

**Detailed Design:**

Overview: Our smart glasses enable communication through eye movements. The system combines eye-tracking technology with Google Glass, projecting a virtual keyboard onto the lens. The eye tracker detects and analyses real-time eye movements, including gaze direction, blinking, and pupil dilation. By focusing on specific keys, the user can select characters and form words. The system then converts this input into speech, which is output through a speaker, providing a seamless, hands-free communication experience.

**And for this, we name this device the WAACKEYBOARD,** *“****W****earable* ***A****ugmented and* ***A****lternative* ***C****ommunicating* ***K****inematic and* ***EY****e-tracking* ***B****ased* ***O****mnidirectional* ***A****ctive* ***R****eal-time* ***D****evice”*.

Now, let’s dive into the design and take a closer look at each game-changing feature.

* **Eye-tracking Jimmy**

To achieve this, we’ve chosen to use a camera-based system over infrared-based eye-tracking, which will continuously capture frames for real-time analysis. The camera will be embedded in the frame of the glasses and positioned to capture data from the left eye. This configuration is sufficient, as tracking both eyes would only add unnecessary complexity and cost, without significantly improving accuracy.

The chosen camera model is the Raspberry Pi Camera Module, selected for its compact size, lightweight design, improved image quality, reduced smearing and fixed pattern noise (FPN).

To process the visual input from the camera, we connect it to the Raspberry Pi through Camera Serial Interface (CSI). This setup is ideal for our project because the Raspberry Pi is compact enough for a wearable design, yet it offers a great processing unit.

Then, we leveraged pre-existing code from open-source packages, such as the **OpenCV C++ librar**y, which will run directly on the Raspberry PI.

Firstly, we locate the Region of Interest (ROI), the pupil area. This is done using detection algorithms like Haar cascades or Hough Circle Transform. Once the pupil has been identified, the image is filtered to improve the quality of the image by reducing unwanted noise and emphasizing key features. This involves grey scaling, thresholding and blurring. After preprocessing, the system tracks the movement of the pupil over time. This is done by analysing contours and using optical flow techniques.

On the screen, you’ll see a quick demo where a webcam captures input, and the code processes frames in real time to track eye movements to control the cursor [Show code on one side and a video demo on the other].

To adapt this for our project, we’ll tailor the algorithm for close-up camera shots and convert the eye’s deviation from the centre in polar coordinates that corresponds to mouse control navigating our interface. We would also apply calibration to reposition the pupil centre whenever the device is removed and worn again.

Finally, to power this set-up, we plan on using rechargeable batteries for convenience, cost-effectiveness and enhanced sustainability for the user.

Xuan

* **Graphical User Interface**

We’ve redesigned our graphical user interface to be a keyboard which features a circular layout, divided into concentric rings and quadrants, each representing groups of letters or functions.

To select a letter, the user gazes at the corresponding region for a predefined duration, enabled by our hover control module. This approach ensures precise input while reducing accidental selections. The interface dynamically adapts, transitioning from a four-quadrant layout to a semi-circular menu for finer selection. [Video demo whilst the above paragraph is spoken]

Additionally, the outer ring provides essential functions like number/letter switching, back navigation, and confirmation. The design prioritises accessibility, with low-saturation colours and clear visual feedback to accommodate users with sensitivity to light.

* **Display**

To create a wearable solution without mounting a screen, we needed to **miniaturize the display** of the interface for seamless integration into the glasses.

At this stage, we have decided to go with **Google Glasses for our display.** These glasses use waveguide display technology to project images onto a small transparent screen in the user’s field of vision. A tiny projector sends light onto a transparent prism which then reflects and directs that light toward your eyes. This creates a semi-transparent display with a resolution of **640 × 360 pixels**.

Jackson

* **Speech Output**

After a sentence is constructed, it will be sent to a text-to-speech module that converts the text string into an MP3 file. Currently, we use the **gTTS** (Google Text-to-Speech) module in Python for this implementation.

The text is then output through an RS Pro 8-ohm 0.3W miniature speaker, which is connected to an amplifier to boost the audio signal so it can produce sound at a higher volume and quality.

* **Multimodal Interaction**

We’ve added alternative input methods to our device for sending out special signals more suitable for people with CP, making them more user-friendly and accessible.

**Visual feedback:** The device will use a visual cue to notify others when the user is about to speak. This ensures the slower pace of AAC devices doesn’t disrupt the user’s participation in conversations. An **LED**, connected to the Raspberry Pi with a 330ohm resistor, will automatically turn on when the user starts typing and turn off once they finish typing. [zoom into the LED section of the circuit]

**Head-tracking**: To improve accessibility and better meet user needs, we’ve added head-tracking. In case of an emergency, the user can perform **two left head tilts**, which will override any other commands and trigger an "Emergency" alert through the speaker to notify those around them.

To achieve this, we’ve integrated an IMU MC6470 sensor, as they include **gyroscopes, which are sensors** that track **head rotation**. Additionally, the IMU has built-in **filters** to reduce noise, eliminating the need for a separate low-pass filter. It also allows for high shock tolerance , low cost and lightweight

* **Volume Control**

The volume control of the device will be integrated into the software to make the device more accessible. We might need to add a high pass filter after testing the output for clearer sound quality.

* **Full diagram**

Once all these elements are adjusted, the final design should look like the following. [zoom in the final circuit].

* **Frame**

The frame features a foldable design thanks to the use of a **hinge** [zoom in on hinge]. On the side frame, we’ve added a **case** to hold all the electronic components. This case will be opened and closed using **snap fit** [zoom in snap fit]. Additionally, we’ve created a socket to place the LED, holes for the speaker, and a slit for the elastic band.

* **Manufacturing Plan**

3D printing is preferred over injection molding because it enables faster prototyping, cost-effective small production, and more design flexibility for customized eyewear frames. Although 3D printed frames may have lower durability compared to injection molded ones, this is not an issue for eyewear as we plan on using materials that provide sufficient strength for everyday use.

Specifically, we plan on using FDM (Fused Deposition Modeling), which is a 3D printing process where a material (usually plastic filament) is heated and extruded through a nozzle to build up an object layer by layer. We’re choosing FDM over other 3D printing methods (such as SLS and SLA) because, for eyewear frames, the **high precision** of SLS isn’t necessary. FDM provides the **durability** and **customizability** needed at a more **cost-effective** price, making it ideal for functional, everyday eyewear.

The material chosen is ABS plastic. This choice was made because this material is more suited for everyday use. ABS is more durable and resistant to wear and tear, compared to materials like PLA. It is also less brittle than resin and offers high impact resistance.

All the electronic components used in the design were **sourced** from **external suppliers** and the department’s **electronics lab**. Depending on the component, we may use **wires** and **insulating tapes** to connect them. To secure the glasses to the user’s measurements, we will use a **hypoallergenic** **elastic strap**.

* **Limitations and possible improvements (hui sin)**

Making the device wearable comes with limitations. Key concerns include potential eye strain from the small screen, which could be challenging for individuals with reduced vision, and latency, which is common in advanced AAC devices.

The current display has limited options. We’re considering an adaptive screen system that lets users switch screens with head gestures, enabling quicker selection of commonly spoken words instead of individual letters. This would increase speed and reduce eye strain by minimizing the need to focus on small text.

Minor issues include the device's weight, primarily due to the battery. We plan to explore lighter power supplies and boost converters to reduce this. Additionally, since we are using Google Glass with its built-in API, we need to ensure compatibility with Google, limiting platform transferability. We aim to develop software that could be compatible with other AR glasses.

We plan to add autocorrect software for better accuracy and implement a customizable ML model using the patient's speech data to make the output voice more personal and authentic.

* **Progress**

At this moment, we have completed the **CAD** of the frame and gotten all the electrical parts. In parallel, we’ve completed successfully the programming of the eye-tracking, IMU sensor and LED-light. Our next step is 3D printing. Then comes safety, durability and functionality testing.

* **Evaluation**

To legally classify and distribute our product as an assistive technology device in the UK, it must meet safety, performance, and effectiveness criteria specified in the UK MDR.

The device will undergo testing to comply with relevant safety and durability regulations, as outlined in our PSD, and adhere to **IEC/ISO standards** for specific areas. Clinical data may also be needed to confirm its safety and effectiveness for the intended use.

For higher-risk devices, an independent third-party organization (Notified Body) will review testing documentation, risk assessments, and other data to ensure compliance with both regulatory and **IEC/ISO standards**. This will allow us to obtain a Declaration of Conformity and the **UKCA** mark, which is required to legally sell the product in the UK.

**Functionality:**

**Software-Based Testing**: To evaluate the device's performance, we’ll use analytical tools, including a **confusion matrix** to assess speech accuracy, **Latency testing** testing software to measure response time, and speech-to-text software to analyze clarity. (Referencing PSD for details)

**User Experience Testing**: We will recruit a diverse focus group of individuals with CP, representing various mobility levels and genders, to test the device's accessibility, wearability, and affordability. Participants will provide feedback via a detailed questionnaire after testing the device.

User experience testing will be an ongoing, iterative process, refining the product based on feedback to ensure continuous improvement and the best user experience.

**Conclusion**

In conclusion, our wearable AAC device offers a portable, innovative solution for individuals with speech impairments. Its advanced connectivity and adaptive features ensure seamless daily use, providing reliable communication support. This device marks a significant step toward making communication more accessible, inclusive, and empowering for those with speech challenges.

However, while we’ve taken every measure to comply with all the current rules and regulations, we must ask ourselves: In a world where user data is a powerful tool, *is mere compliance enough*? Are we truly safeguarding what matters the most, or are we simply meeting the minimum requirements?

Acknoledgement:

We would like to express our deepest gratitude to all those who supported and contributed to the completion of this project. First and foremost, we are sincerely thankful to Dr. Ian Radcliffe for their invaluable guidance, encouragement, and expertise throughout the process. I would also like to extend my appreciation to Mr. Egan Paschal and Mr. Tariq for their continuous support and constructive feedback, which helped shape our work. Lastly, we are truly grateful to Jane Bache and Kate Nelson, for giving us great insightful information that has helps us consrtruct our device accordingly.

Currently, our device is limited to users with CP. In the future, we plan to expand its accessibility to individuals with ALS and other neurological conditions, broadening its impact and improving communication for a wider range of users.