BMEG 3111 Course Project

<u>Paralyse need to type word</u>

Stage 1 Report

Group 6

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1 Background Information

Amyotrophic lateral sclerosis (ALS) is a rare and terminal neurodegenerative disease that results in the progressive loss of motor neurons that control voluntary muscles [1]. ALS patients have difficulties speaking or moving their limbs [2], making them unable to communicate effectively. We are investigating to develop a new input method that allows patients to navigate a computer and communicate by typing.

2 Market Research

Some existing products allow ALS patients to speak or type in an alternative way instead of using their mouths or hands. Some current products in the market are listed below, supplemented with their respective advantages and disadvantages.

2.1 Eyegaze Edge

2.1.1 Basic Description

This product is an eye-tracking camera for capturing the user's eyeball movement and screen [3]. It can analyse eyeball rotation, which functions as a cursor on the screen, by calibrating in the first 15 seconds to set up the system. Users can select the function or button by staring at it for at least half a second.

2.1.2 Advantages

The required setup is minimal. Only a camera is required as an accessory.

2.1.3 Disadvantages

It is unsuitable for users to type words or communicate with others by selecting the words individually.

2.2 Laser Pointer on the Head

2.2.1 Basic description

Users can wear the laser pointer on their heads and mount an alphabet communication board on their wheelchairs [4]. Using the laser to select words on the communication board, ALS patient can convey their idea to others.

2.2.2 Advantages

A minimal setup is required. A laser pointer and a board with words are all that are necessary. Users can modify the board to optimise their communication however they see fit.

2.2.3 Disadvantages

It is slow to convey ideas, and it is not very dynamic since users cannot possibly anticipate all the words and phrases they might want to communicate with and put them on the board beforehand.

2.3 Neuro implant

2.3.1 Basic description

The system employs a network of tiny electrodes implanted in the brain's motor cortex, which can detect electrical activity generated by neural activity and interpret it [5].

2.3.2 Advantages

Since no actual physical movement is required from the user, patients can use the product regardless of physical or nervous deterioration.

2.3.3 Disadvantages

Since this technology has to analyse the user's neural activity, it would require the user to concentrate intensely for an extended period of time to be able to use it; otherwise, there would be a great deal of random neural noise. There is a very steep learning curve.

2.4 Speech-Generating Devices

2.4.1 Basic Description

ALS patients who cannot speak can record a voice bank using software such as Acapela and ModelTalk to have a personalised voice that mimics their natural voice [6].

2.4.2 Advantages

It allows a personalised communication mode that can enhance person-to-person interactions. Voicebank technology also enables users to record voice samples with different tones, such as joyful or angry, enabling them to convey emotions more effectively than pure text.

2.4.3 Disadvantages

The users must have recorded their voicebank samples before succumbing to the illness. Therefore, patients in the advanced stage who have not previously recorded voice samples cannot use this product.

3 Literature Review

Several technological solutions have emerged to enhance communication and independence for individuals with severe motor impairments, including brain-computer interfaces (BCIs), eye-tracking technology, and mouth- or head-controlled interfaces.

BCIs enable direct communication between the brain and external devices. Studies by Vansteensel et al. [7] and Pandarinath et al. [8] indicated successful intracortical BCI implementation, which allows individuals with paralysis to type words using their thoughts.

Eye-tracking systems track eye movement and translate it into computer input. Valliappan et al. [9] examined eye-tracking technology for text input on phones, showcasing its feasibility and effectiveness in enabling quadriplegia patients to select and type words.

Mouth-controlled interfaces are categorised into sip-and-puff, bite, and mouth-shape types [10]. The sip-and-puff type utilises air pressure sensors to detect breath patterns, translating them into commands for typing words. The bite type combines bite with blowing and sucking actions, while the mouth-shape type uses image recognition to determine mouth gestures.

Head-controlled interfaces, investigated by Feng et al. [11], enable users to control a cursor or virtual keyboard by assisting gaze typing with head gestures.

4 Proposed Design

4.1 Product Overview

Figure 1
Sketches of the glasses-mounted laser pointer.
Note that the laser pointer is angled inwards to centralise the laser point and allow intuitive control.

Figure 2
Sketch of the camera box.

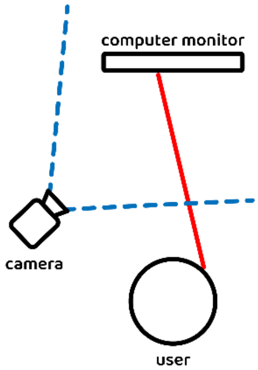

Figure 3
Birdseye illustration of the input setup.

Our product comprises a glasses-mounted laser pointer (*Figure 1*) and a camera (*Figure 2*). As demonstrated in *Figure 3*, the user would place the camera nearby and wear the glasses while sitting in front of a computer monitor to use our product. Since people with quadriplegia are our target demographic, we designed the product to be operated solely with facial muscles and minor head movements.

4.2 Working Principles

4.2.1 Pointer

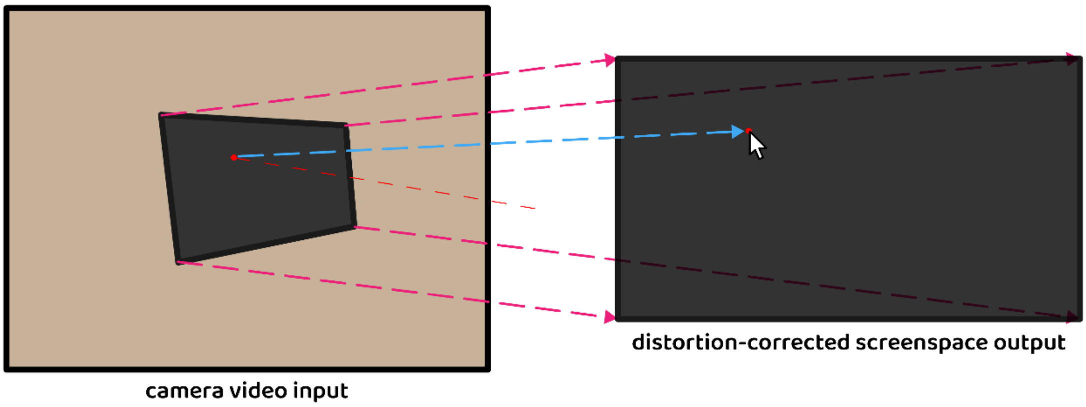

Figure 4
Diagram depicting the distortion and perspective correction of the camera video input.

As per *Figure 3*, the camera is positioned to view the computer monitor. During the calibration phase, the program first instructs the user to aim the laser at the borders of the monitor. The Arduino can then locate the laser point within the video input and store the input-space monitor vertices using image processing. During the use phase, a distortion-correction algorithm interprets the input-space laser point location as screen space cursor movement (*Figure 4*). Thus, Mouse movement can be emulated. The user can use the mouse while only having to aim the laser at the monitor.

In typing mode, a pop-up keyboard appears on the screen, and the user can type using the same mechanism as when using a regular mouse with an on-screen keyboard.

4.2.2 Buttons

Electromyograph (EMG) electrodes are placed onto the user's facial muscles (frontalis and bilateral zygomaticus). Muscle potentials are measured by the electrodes and interpreted as button inputs by the Arduino using an algorithm [12].

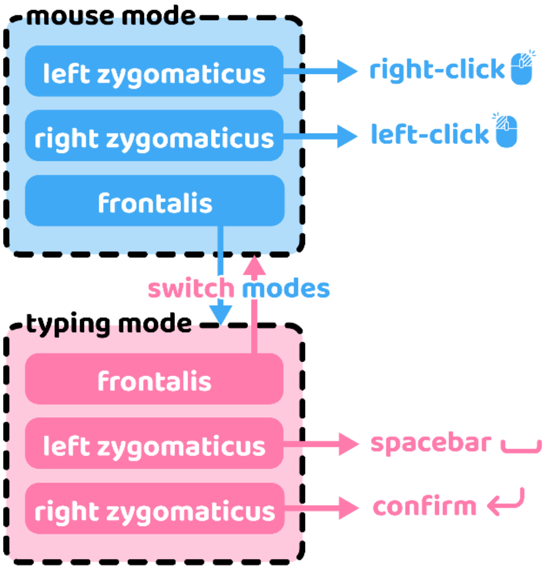

Figure 5
Diagram depicting the electrode potential interpretation in different modes.

As illustrated in *Figure* , the user can switch between mouse and typing modes with their frontalis (forehead muscle). In mouse mode, the left and right zygomaticus (cheek muscles) potentials are interpreted as right-click and left-click, respectively. In typing mode, the right zygomaticus potential corresponds to the confirm key, while the left corresponds to the spacebar. A simultaneous potential on both sides is interpreted as backspace.

4.2.3 Input Assist

In software, users also have the option to activate input assist mode. In assist mode, our software attempts to enforce rudimentary autocorrect and autocomplete features, similar to those on modern mobile phone keyboards, to enhance input speeds and reduce error rates. The contact zones for each key are also adjusted in the background so that the inaccuracy tolerances automatically increase and decrease as necessary.

4.3 Product Budget

Item	*Standalone price (HKD)*	*Shipping fee (HKD)*
Arduino Leonardo	0	0
VC0703 TTL camera	95.98	35.88
Electromyograph set	198.93	
Laser pointer	19	0
Total	*349.79*	

4.4 Safety Concerns

4.4.1 Laser Safety

Inherent hazards are associated with our product since a laser pointer is used as our input method. For instance, the user may inadvertently direct the laser into the eyes of others. Studies indicate that a laser with a capacity greater than 5 milliwatts (mW) can potentially damage the display unit of a computer monitor.

To address the concerns, we opted to use a low-power (<5mW) laser to minimise the damage to the monitors and others' eyes. Studies have shown that low-power lasers are relatively safe and cannot easily cause retinal injury (permanent blind spot) unless viewed directly for a long time [13]. Alternatively, the user can use a projector instead of a computer monitor to mitigate the problem completely. When utilising our product, we would also recommend that the monitor be positioned so that the user is facing a wall.

4.5 Future Prospects

Our product currently exists as two distinct components. In the future, we hope to shrink the components and integrate the laser pointer and camera into a single pair of glasses so that the user does not have to manage two devices.

4.6 Marketing Value

Our product can fill the market gap by providing a user-friendly, economical and efficient way. As mentioned in Market Research (2), existing products provide either an accurate way or an easy way for users to convey their views, but with significant drawbacks and limitations. Notably, they all trade off speed, versatility, and intuitiveness. On the contrary, our product embodies all three criteria. It gives users an intuitive approach and a gentle learning curve since they only need to rotate their heads like a mouse to aim and contract their facial muscles to click or type on the screen. They are not required to record their voice, learn how to control their rotation of eyeballs, and even learn to control their EEG signal. Besides, our product is non-invasive, requiring the user to wear a glasses-mounted laser only.

In light of the advantages of our product in both the usability and technological aspects, we believe that our product can attract a vast majority of ALS patients to purchase and address their communication difficulty effectively due to its unique market identity.

4.7 Subjective Appraisal

4.7.1 Feasibility

4.7.1.1 Minimal Setup Requirement

Unlike most quadriplegic typing packages currently available, our product does not require the user to transport around a large box or other cumbersome accessories to function. Instead, our product only requires a glasses-mounted laser pointer and an external camera situated at any angle to function. The camera can be placed anywhere without prior configuration as long as it can capture a clear view of the computer screen, while any laser pointer and glasses can be used as long as the user can aim the laser comfortably. Only a quick calibration step is required to be performed each time the user changes the monitor or camera location.

As can be observed, our product is entirely portable and minimally obtrusive. Changing from a standard keyboard and mouse to our product necessitates no significant configuration changes.

4.7.2 Creativity

Our product uses a novel approach to type words. It is cheap, weightless, convenient and easy to use. The idea is built around the constraint of only having head movement without compromising typing speed. This product demonstrates a way for ALS patients to communicate as fast as the conventional way.

4.7.3 Applicability

4.7.3.1 Speed

Our product excels at input speed compared to other products on the market. Since the laser's aim is entirely controlled by minute head movements, it is incredibly rapid and straightforward to operate. In addition, the computer cursor is controlled directly by position rather than a joystick; therefore, users do not need to wait for the cursor to traverse the distance slowly. With practice, users can achieve velocities comparable to those using a standard mouse.

4.7.3.2 Intuitiveness

Since our product only requires our users to aim the laser in the same manner as a standard mouse, it is intuitive and has a minimal learning curve. Anyone who has prior experience with a regular mouse should be able to pick up our input method quickly and intuitively.

4.7.3.3 Accuracy

In proportion to the user's proficiency with the product, their typing accuracy is expected to improve over time. We employ a laser pointer with a 2mm-radius point, while the keys on the keyboard are much larger. This feature enables the user to accurately select which buttons to press on the screen, even with imperfect motor control.

4.8 Comparison

Compared to existing products, our proposed project provides a faster approach for users to convey their opinions by inputting words on electronic devices. With an expected typing speed of ~100 characters per minute (~25 words per minute), similar to what one can achieve typing with an on-screen keyboard using a regular mouse, our product is faster than the vast majority of existing products in the current market while maintaining a high degree of versatility.

Users are expected to be able to familiarise themselves with our product with ease. They can use the laser pointer as a tracker on the screen and confirm the typing by contraction of a facial muscle, instead of some product, like Neuro Implant, requiring users to consolidate their neural pathways via repeated training. Our product provides a highly reliable and accurate way to convey the user's ideas. It can be used in almost all circumstances as long as the laser and screen function as usual. Our product can also tolerate a high degree of disturbance; environmental changes do not affect the users' inputs since it does not involve the acquisition of neural signals or a multifunction camera, both noise-prone. Additionally, our product is modular so that it can be upgraded easily, and users can easily swap out components (for instance, swapping the EMG for regular buttons) as a contingency if they find it necessary.

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