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Communication Prototype for Post-Stroke Patients Using Electrooculography (EOG)

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ABSTRACT Background this prototype is intended for post-stroke patients experiencing disabilities in their daily activities, particularly in communication with others. The challenge they face is difficulty in communication, leading to a diminished quality of life for post-stroke patients. The purpose of innovating this communication aid prototype is to facilitate communication between post-stroke patients and caregivers. The method employed in the post-stroke communication aid prototype utilizes Electrooculography (EOG) signals generated from eye muscle movements during eye gazes, captured by the MaM Sense sensor. The variation in Analog-to-Digital Converter (ADC) values in the MaM Sense sensor is exploited to produce various forms of EOG signals. The resultant command signals from this method are processed by a microcontroller and displayed on a 20 x 4 Character LCD. Testing was conducted on 9 healthy individuals, comprising 5 males and 4 females. To ensure the prototype's functionality, testing was also performed on 1 post-stroke patient. The success rate of MaM Sense sensor readings was 80.5% for the 4 communication modes employed, involving 4 eye gaze movements: right gaze, left gaze, upward gaze, and downward gaze. Thus, the post-stroke communication aid prototype proves effective in assisting communication for post-stroke patients and aiding caregivers in understanding the patients' desires. In the future, a wireless system may be implemented for the acquisition of EOG signals attached to the face to minimize the use of cables.

INDEINABILITY TERMS Post Stroke, Communication, EOG, MaM Sense

I. INTRODUCTION

Cerebral infarction or ischemic stroke stands as a primary cause of long-term disability in adults worldwide [1][2][3]. Post-stroke disabled patients encounter challenges in performing daily activities, particularly in communicating with others [4][5]. Aphasia is a common disorder observed in stroke patients [6][7][8][9]. Aphasia denotes a language processing impairment that affects an individual's communication skills, predominantly arising due to a stroke's impact on the left hemisphere of the brain responsible for speech and language control. Individuals with aphasia experience language impairments, particularly in speaking, comprehending other languages, reading, and writing [10][11].

Communication difficulties exacerbate the quality of life for post-stroke patients [12][13]. Furthermore, caregivers or companions, who are typically family members, neighbors, or close friends responsible for attending to individuals affected by mental illness or physical function decline, such as that resulting from a stroke, also encounter challenges in communicating with post-stroke patients. They may occasionally experience depression and feelings of guilt due to the difficulty in interpreting the wishes of the patient [14][15].

Previously, research has been conducted on communication aids for post-stroke patients utilizing finger movements captured by flex sensors. However, this tool proves less effective as not all post-stroke patients can flex their fingers adequately [16]. Subsequently, an eye-writing system has been developed using electrooculography (EOG) as a communication tool based on eye movements [17]. EOG is a recording technique for eye movements that records the electrical activity generated by human eyes [18][19].

Given the issues previously outlined, there is a need for an innovative prototype that can assist post-stroke patients in communicating easily without requiring challenging movements in line with their basic needs [20]. This innovation aims to facilitate communication for post-stroke patients and aid caregivers in interpreting the desires of the patients through the utilization of EOG.

This prototype can contribute to assisting caregivers in understanding the desires of post-stroke patients and helping post-stroke patients communicate, thereby improving the quality of life for patients. Future contributions to this prototype could involve the incorporation of machine learning to provide more accurate results.

II. MATERIALS AND METHODS

The method employed in the prototype for aiding communication in post-stroke patients involves the interpretation of electrooculography (EOG) signals. This method utilizes human eyes for basic communication, deriving signals from the electric potential difference during each gaze. The cornea serves as the positive pole, while the retina functions as the negative pole. A stable potential is formed by this potential difference, which can be measured using electrodes placed near the eye. When the electrodes are symmetrically positioned, and the gaze is centered, EOG signals will not be generated [21][22]. Eye movements utilized include glancing to the right, left, up, and down, with each gaze producing a basic communication sentence. The block diagram in FIGURE 1 illustrates the operational system of the prototype.

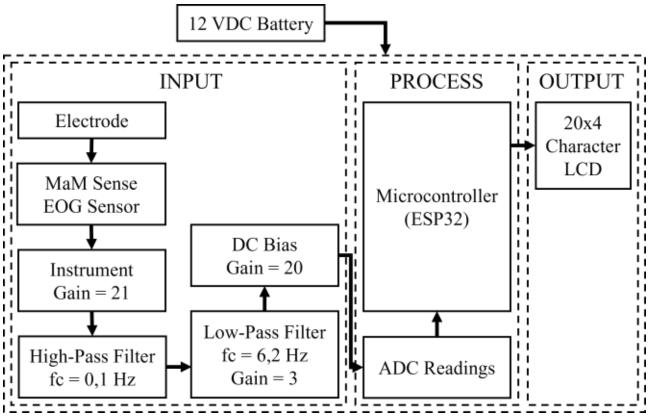


FIGURE 1. Operational System Prototype for Communication Assistance in Post-Stroke Patients

The 12 VDC power supply from the battery serves to provide DC voltage to the entire circuit. In the input section, electrodes act as intermediaries to facilitate the reception of muscle movements in the eye, producing signals that can be captured by the MaM Sense sensor. The MaM Sense sensor processes the signals in the form of an instrument with a 21-fold amplification, which will be filtered using a High-Pass Filter with a cut-off frequency (fc) of 0.1 Hz. Subsequently, it undergoes further filtration using a Low-Pass Filter with a 3-fold amplification and an fc of 6.2 Hz, resulting in a 20-fold amplified DC Bias. The signal amplification is then processed in the ADC reading by the ESP32. The ESP32 processing yields communication sentences that will be displayed on a 20 x 4 Character LCD.

A. ELECTRODES

To capture EOG signals effectively, precise electrode placement is crucial to ensure that the generated signals can be adequately captured by the MaM Sense sensor. The electrodes are positioned at the upper right eye, lower left eye, right side of the right eye, left side of the left eye, and below the right earlobe [23][24][25] as illustrated in FIGURE 2. Horizontal electrode placement is employed to capture eye movements to the right and left, vertical electrode placement is used to capture eye movements upwards and downwards, while one electrode located below the earlobe serves as the reference electrode.

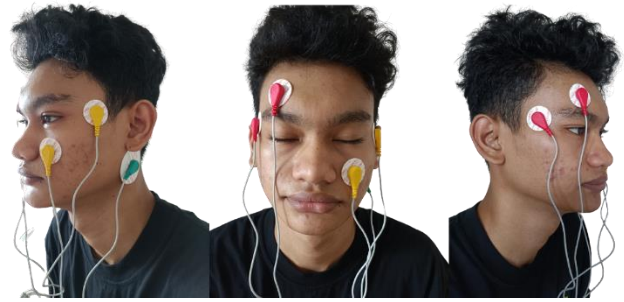


FIGURE 2. Electrode Placement: two electrodes are oriented horizontally, two vertically, and one serves as a reference point

B. EOG

EOG signals are generated by the movement of the eyes, causing the muscles around the eyes to contract and thereby producing electrical signals that will be processed into ADC values. The ADC values obtained vary for each gaze. Consequently, these ADC values can be decoded to produce basic communication sentences [26].

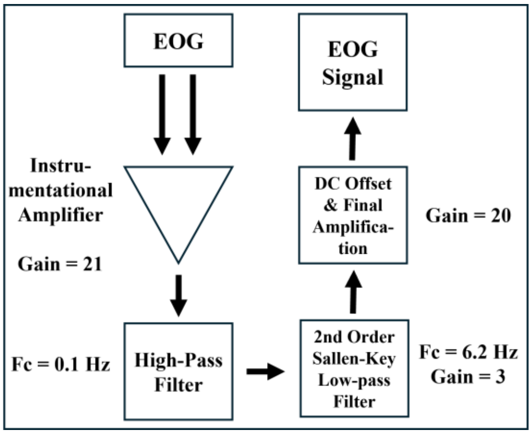


FIGURE 3. Filter In Circuit EOG of MaM Sense

C. SENSOR MAM SENSE

In this prototype, the eye movement detection sensor takes the form of gaze using the MaM Sense sensor. The MaM

Sense sensor is a device designed to process three different types of signals within a single module: EOG, ECG, and EMG [27]. In the communication aid prototype for post-stroke patients, EOG signals from the MaM Sense sensor are utilized by detecting signals received by electrodes through the differential potential of eye muscle movements. The filtered MaM Sense sensor can be connected to an analog-to-digital converter to obtain output and create a digital signal processor [28] in FIGURE 3.

D. ARDUINO IDE

The Arduino IDE application is an open-source platform employed for the creation or management of programs, processing inputs, and generating outputs. In this prototype, Arduino IDE is utilized to program the input of EOG signals, which results in an output in the form of communication sentences displayed on the Liquid Crystal Display (LCD) [29].

E. BOARD ESP32

The ESP32 is a powerful System on Chip (SoC) microcontroller with numerous peripherals, integrated Wi-Fi 802.11 b/g/n, and dual-mode Bluetooth version 4.2. It represents an advanced development from the 8266 chip, particularly in the implementation of two cores operating at different versions with speeds of up to 240 MHz. In comparison to its predecessor, it introduces several additional features, including an increase in the number of GPIO pins from 17 to 36, the number of PWM channels to 16, and equipped with 4MB of flash memory [30]. In this prototype, the ESP32 is utilized as the processor to process EOG signals with inputs and outputs as illustrated in FIGURE 4 the diagram below.

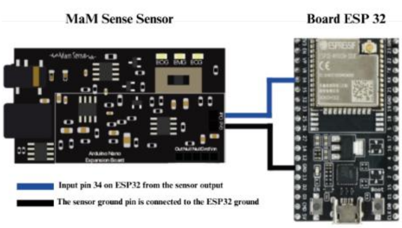


FIGURE 4. Input-Output of ESP32 and MaM Sense Sensor

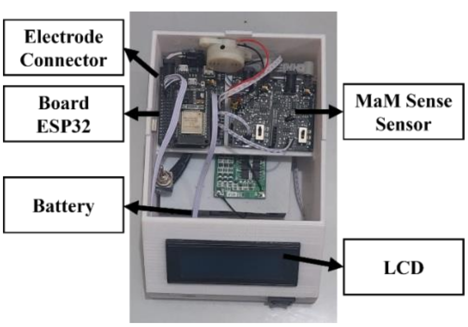


FIGURE 5. Configuration of the Communication Assistance Prototype for Post-Stroke Patients: MaM Sense Sensor, Electrodes, ESP32 Board, Battery, and LCD (Liquid Crystal Display)

III. RESULT

The achieved outcome is the creation of a prototype communication aid for post-stroke patients, facilitating basic communication for these individuals and aiding caregivers in understanding the desires of post-stroke patients. The prototype communication aid device consists of MaM Sense sensor components, an Arduino in the form of an ESP32 board, a battery, and an LCD display (Liquid Crystal Display) as the presenter of communication sentences. The components of the prototype communication aid for post-stroke patients are illustrated in FIGURE 5.

The EOG signals generated from the MaM Sense module will be processed by the ESP32 into ADC values. The ADC values produced are derived from the serial plotter within the Arduino IDE, subsequently forming a graph depicting the variation in ADC values between the non-gaze position and the position during eye gaze.

The EOG signal results have been displayed on Delphi software with different ADC values for each eye gaze, as depicted in FIGURE 6. In the right gaze, the signal waveform initially descends with an ADC value of 1850, then rises to a peak with an ADC value of 2350. For the left gaze, the signal waveform ascends with an upper limit of ADC value at 2350 and descends with a lower limit of ADC value at 1850. In the upward gaze the signal waveform reaches its peak first with an upper limit ADC value of 2350 and then descends to the lower limit ADC value of 1850. Lastly, in the downward gaze, the signal waveform initially descends to the lower limit, reaching an ADC value of 1850, then ascends tothe upper limit ADC value of 2350. The resulting waveform for each eye gaze, defining the basic communication sentences, is presented in TABLE 1.

TABLE 1
Definition of eye gaze directions and corresponding generated communication

Eye Gaze Direction	Communication
Gaze to the Right	I Want to Eat
Gaze to the Left	I Want to Drink
Gaze Upward	I Want to Bath
Gaze Downward	I Want to Go to the Toilet

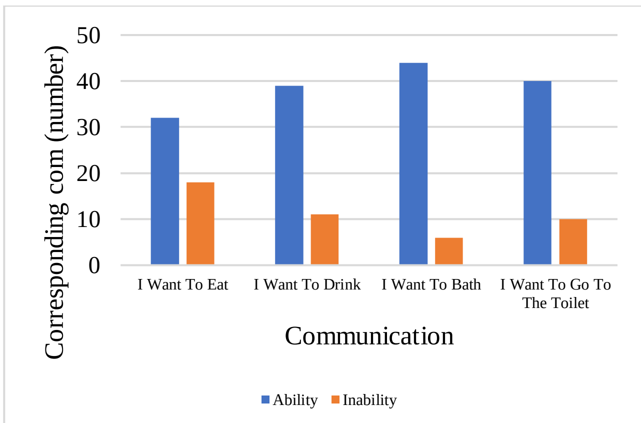
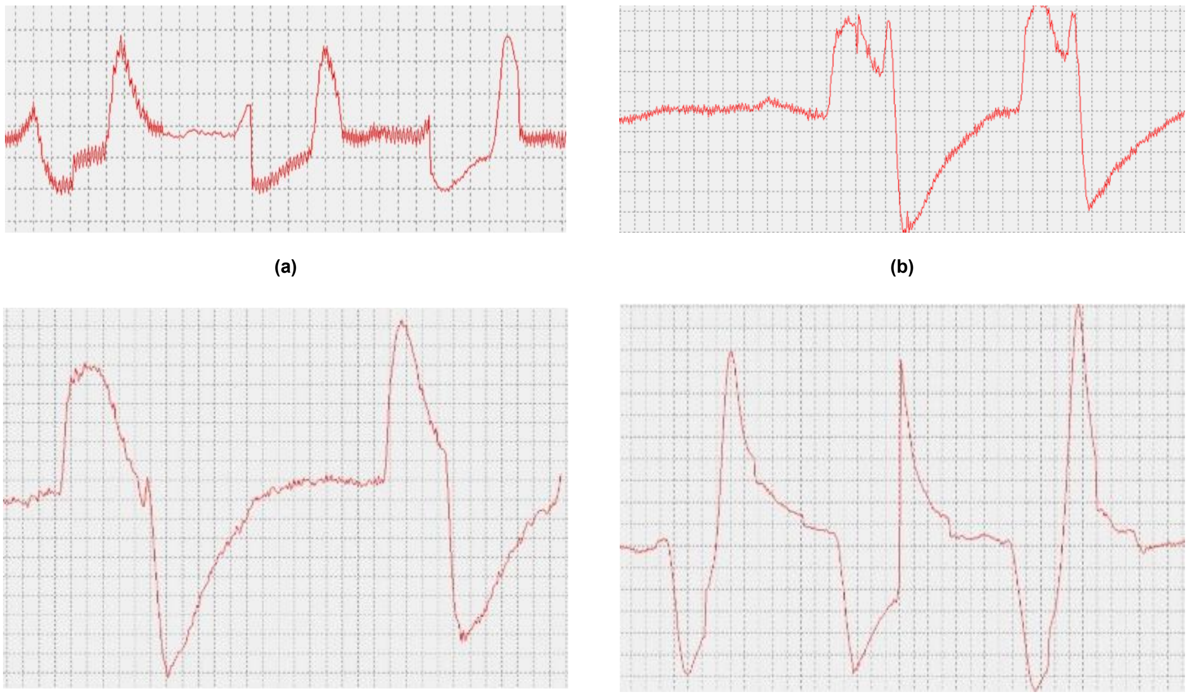


FIGURE 6. Graph of Result of Prototype Functionality Testing Data Acquisition



(a) (b) (c) (d)

FIGURE 7. Graphic of Eye Gaze (a) The Outcome of Eye Gaze Signal Toward the Right, (b) The Outcome of Eye Gaze Signal Toward the Left, (c) The Outcome of Eye Gaze Signal Upward, (d) The Outcome of Eye Gaze Signal Downward

The functional test was conducted on ten respondents, consisting of nine healthy individuals, comprising 5 males and 4 females, and one male post-stroke patient, as indicated in FIGURE 7 contains a graph depicting the functional test results for each eye gaze corresponding to each sentence, indicating whether it can function properly or not. The indicator of success for this prototype is determined by generating a sentence that aligns with the direction of the eye gaze used.

When the eyes perform a gaze, it generates a predefined waveform signal. After defining the signal shape by the sensor, the desired communication sentence will be displayed on the LCD according to the respondent's eye gaze, as shown in FIGURE 8.

FIGURE 8. The Displayed Communication Results on the LCD

IV. DISCUSSION

The prototype's functional test data for the right eye gaze resu lting in the communication sentence "I Want to Eat" is depicted in FIGURE 9(a). Out of 50 attempts, the prototype functioned correctly 38 times, as indicated by the communication displayed on the LCD, and failed 12 times. Thus, the percentage success of the prototype's functionality test for "I Want to Eat" communication is 76%. Prototype functionality test data for "I Want to Drink" communication, generated by eye gaze to the left, is presented in FIGURE 9(b). Out of 50 attempts, 39 were successful, and 11 failed, resulting in a prototype functionality test success rate of 78%.

Out of 50 prototype functionality tests for the communication "I Want to Bath" generated by eye gaze upward, 44 were successful, indicating a prototype functionality test success rate of 88%, as shown in FIGURE 9(c). FIGURE 9(d) displays the prototype functionality test results for the communication "I Want to Go to the Toilet" based on eye gaze downward. In this case, 40 out of 50 prototype attempts were successful, resulting in an 80% success rate. The percentage of prototype success for each communication is used to derive the overall prototype success percentage.

The prototype testing resulted in 161 successful trials out of 200 conducted, with 39 trials deemed unsuccessful. Therefore, the overall success rate of the prototype is 80.5%, as depicted in FIGURE 9(e). With this success percentage, the prototype can be considered as one of the options from previous research [16] With this success percentage, the prototype can be considered as one of the options from previous research

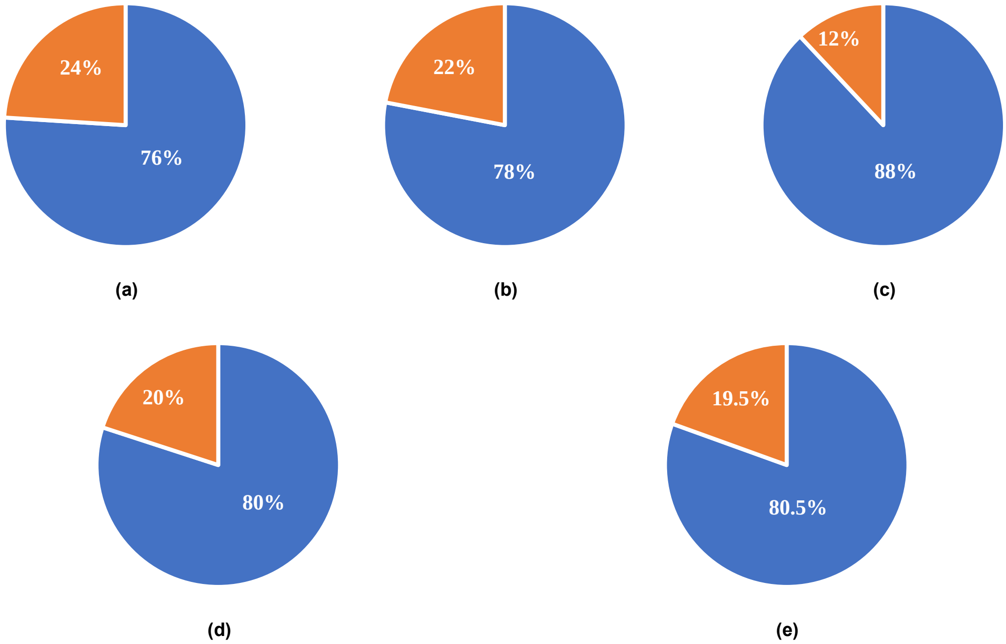


FIGURE 9. **(a) Percentage for the Communication "I Want to Eat", (b) Percentage for the Communication "I Want to Drink", (c) Percentage for the Communication "I Want to Bath", (d) Percentage for the Communication "I Want to Go to the Toilet", (e) Overall Success Percentage of the Prototype**

However, there are some drawbacks to this prototype due to several factors, including misinterpretation of eye gaze readings resulting in sentences that do not match the desired command, improper electrode placement or mismatch with the designated points, leading to poor signal readability by the sensor, and the movements performed by the respondents. The continuity of this prototype aims to minimize the use of electrode cables for EOG signal reading, utilizing communication messages to facilitate long-distance communication between caregivers and post-stroke patients, and conducting tests on a larger number of post-stroke patients.

V. CONCLUSION

The communication aid prototype for post-stroke patients using the EOG method has an 80.5% success rate. The prototype and its components operate in accordance with the working principles, where basic communication sentences generated from eye muscle movements are displayed on the LCD, serving as an indicator for the post-stroke communication aid prototype. With these results, the communication aid prototype for post-stroke patients can facilitate communication between post-stroke patients and caregivers, making it easier for caregivers to understand the desires of post-stroke patients. The continuity of this prototype aims to minimize the use of electrode cables for EOG signal reading, employing communication messages to facilitate long-distance communication between caregivers and post-stroke patients, and conducting tests on a larger number of post-stroke patients.

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