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A REVIEW OF COMMUNICATING DEVICES FOR PARALYTIC PATIENTS

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Abstract: For physically disabled people, assistive technologies, such as an alternative form of text entry, can be of tremendous benefit. Biosignal interfaces are utilized in the medical industry for patient health status monitoring, rehabilitation services, or medical automation because they provide crucial data that shows the physical situation of the user. Biosignals are vital for extracting user emotions or measuring user experience and can be combined with virtual reality to create fresh content. Coming to the medical side, an Individual who is paralyzed, is a condition where the patient is unable to move a limb or part of the body due to the inactivity of the muscles in that area. These people find it extremely challenging to communicate with others and express their feelings and desires. To address this need various systems have been developed to accept eye-gaze, muscle signal, brain signal, tilt mechanism of accelerometer, and so on as input and convey the patient need to the caretaker. The review paper's purpose is to describe the cause of paralysis and progress from the treatment and end with various communication aids.

***Index Terms* - Disabled people, Biosignal, Tilt mechanism, Communication aid, ECG**

I. INTRODUCTION

Muscles, one of the human body's most important features, are impacted by illnesses of the muscular system. We can move and function in the world because of the force that is produced by our muscles. The muscles in our bodies carry out a variety of tasks, including maintaining posture by constant contraction, moving the skeleton, and producing heat through cell metabolism. Without it, we would spend the rest of our lives confined to one location. Painful muscles, weakened muscles, and paralysis are all symptoms of muscular system disease. It may be brought on by several circumstances, including hormone imbalances, autoimmune issues, genetics, infections, malignancy, or misuse of the muscle [1].

Most frequently, damage to the neurological system, particularly the spinal cord, results in paralysis [2]. Many people in the actual world are paralyzed and find it difficult to communicate. Words and sentences can be conveyed to the audience through motions. New human-computer interfaces have been designed to offer multiform interactions as the demand for computing environments changes [3]. The introduction of wearable biological-signal devices has made use in conventional medical systems accessible to the public. Interfaces with biosignals are utilized in fitness, sports, and rehabilitative training, such as when learning how to manage respiration or balance one's body. As the usage of the internet and portable electronic gadgets have grown more commonplace, the use of biosignal systems has moved on the far side of healthcare services to several fields like human-computer interface, information security, and education. [4]

II. MATERIALS AND METHODS

The databases of PubMed, Academia, Scopus, ResearchGate, Springer Nature, Google Scholar, and Web of Science were systematically searched for a recent systematic review with randomized methods that evaluated the treatment for paralysis, its types, and communication aids, published to the present. A larger collection of articles were found after the search was conducted using the phrases "paralysis" along with "communication devices for severe motor impaired" or "biosignal-based communication devices." The etiology, therapy, and procedure descriptions from experimental research papers, reviews, and abstracts were merged. These publications are evaluated critically, and the superiority is debated using the data found.

III. PARALYSIS

A temporary or permanent lack of voluntary muscular action is referred to as Paralysis. It happens when your muscles are unable to move on their own. Your body's mechanism for controlling and communicating is called the Nervous System. The brain instructs your body on what to perform by sending messages throughout it. Any part of the body can be rendered immobile. Total paralysis implies you have no control over any forces, while partial paralysis means you can control some muscles but not all. Paralysis can also be categorized as flaccid or spastic depending on where in the nervous system the damage occurred. Stroke, brain damage, spinal cord injury, broken necks, and multiple sclerosis are among the most common causes of paralysis [5,6]. Additional causes of paralysis include Bell's palsy, which affects the facial muscles, Guillian- Barre syndrome, the polio virus, and other nerve diseases [7]. The various forms of paralysis and their associated symptoms are illustrated in the table below.

Table 1 Categories of paralysis

Types	**Symptoms**
Hemiparesis or hemiplegia	Weakness on one side of the body, particularly in the face, arm, or leg.
Paraplegia	Weakness below the waist may include loss of bowel and bladder control.
Quadriplegia	All four limbs are weak.
Monoplegia	Weakness in one or more limbs.
Gastroparesis	Slowed digestion can result in vomiting or constipation.
Bell's palsy	Kind of facial paralysis that typically affects one side of the face.

IV. ETIOLOGY

A stroke which is a blockage in a brain artery can damage regions of the brain that regulate motor action [8]. Cardiovascular disease risk factors include uncontrolled diabetes, excessive blood sugar, high blood pressure, and high cholesterol. Due to demyelination (damage to the protective coating of nerve fibers) in the brain and spinal cord, multiple sclerosis is an inflammatory disease that frequently results in periods of weakness, abnormalities in coordination, and other symptoms. The rare condition known as ALS (amyotrophic lateral sclerosis) results in the deterioration on a particular area of the spine. It typically affects those over 50 and progresses over a short period. Guillain-Barre syndrome: Usually beginning in the legs and progressing up the body, this condition weakens a person owing to inflammatory demyelination of the peripheral motor neurons. A herniated spinal disc is when a disc of cartilage in the spinal column bulges out of its normal position, typically because of degenerative illness or trauma [9].

V. SYMPTOMS

Tingling or discomfort in the afflicted muscles, Muscle tremor, Confusion, Stiffness, Unwilled twitches or spasms, Muscle pain, the loss of muscle in plain sight (muscle atrophy), talking or comprehending problems, Walking problems, dizziness, loss of coordination and balance, severe headache [10].

VI. BIOSIGNAL – BASED COMMUNICATION DEVICES

6.1 ELECTROMYOGRAPHY

The EMG signal is used to capture a muscle's electrical activity. When a muscle fiber is stimulated, the central nervous system produces little electrical currents in the form of ion fluxes. Since body tissue acts as a resistance to electrical current, an electrical field is produced. The ensuing potential differences between certain areas of the body's surface can be monitored [11]. When a muscle is instructed to contract by the brain, motor neurons receive the signal, which controls many fibers. As the fiber membrane depolarizes, an electrical potential with a duration of around 8 ms is created close to the muscle fibers. A motor unit's motor unit action potential (MUAP) is produced by adding the action potentials that are propagating through its fibers. The MUAPs are fired regularly at frequencies between 7 and 20 Hz to maintain the muscle's force [12]. The electrical field is produced by each motor units are recorded by an electrode that records the activity of the muscle. Muscle signal collection is done by the usage of two different surface and intramuscular types of electrodes. The EMG signal is made up of this group of MUAPTs. The signal, which is captured from the surface of the skin, can have peak-to-peak amplitude values of 20–2000 V [13]. It is possible to reliably gather data from motor units or fibers. The mechanical activity of the muscle, on the other hand, could lead to sores and infections. Since communication aid devices would likely be utilized for several hours per day, the decision to employ surface electrodes is ideal for such procedures [14]. Numerous neuromuscular and neurological problems have been frequently diagnosed using this diagnostic technique. EMG is an intrusive method that calls for training. Because of this, it has only seen limited application in the detection and treatment of voice disorders, particularly in young children [15].

6.1.1 APPLICATION

Switch-based mouse - The human face provides the EMG signal that the EMG human-computer interface uses to direct the computer cursor. The impaired subject can use the facial EMG cursor to interact with the software by tensing their facial muscles. Utilizing Labview, a graphical development environment, the full signal processing method is created. Ultimately, the recognition of the pattern system introduces the appropriate computer mouse function by the pattern of muscle action [16]. A human can engage in sensory and cognitive activity in a digitally produced artificial world called virtual reality. This world can be fictitious, symbolic, or a mimic of some features of the authentic world. When the user presses buttons scanned using Arduino (with the right hand, left hand, or both at once) or while the person contemplates pressing the buttons, they can view the genuine outcomes of their interaction with the world in a virtual world (Unity3D or NeoAxis) [17].

Patients who can still move their heads or have some use of their limbs may use a pressure device. A similar idea can be used in the substitution of the action of pressure in EMG signals with the contraction of a muscle. Electromyogram has been utilized before to evaluate patients with consciousness issues, demonstrating their potential as a communication tool. Binary signals can be produced using computational solutions, with '1' denoting muscle activation and '0' otherwise [18]. Depending on the length of the contraction, the user shifts their chin to convert the Masseter muscle signal into "dot" or "dashes". Characters from the sequence are decoded and sent into a voice synthesizer. This work addresses a critical issue with using EMG— failure to adapt to exhaustion. The main qualification was that, despite figures not being provided, the information transfer rate was low since people cannot chew and pause quickly [19].

Another objective was to create a pointing device that could be operated by facial muscles. Each muscle's level of activation was assessed using a continuous Wavelet transform, which produces displacements in four directions linked to both sides of the mentalis, masseter, and orbicular muscles. The simultaneous execution of the opposite directions for left and right click operations was designated as UpDown for the right click and LeftRight for the left click. The wavelet mother and MUAPs' comparable shapes are justified using the wavelet transform. However, as the system's performance was not measured against conventional signal characteristics, this tactic raises some doubts (e.g., the RMS value) [20]. Additionally, compared to a traditional mouse, directing a cursor using face muscles feels odd. When employing EMG signals as the source of control, for instance, diagonal movements typically involve horizontal and vertical movements [21]. On the other hand, the movement of the head [22] is comparable to using a joystick.

EMG data from the Sternocleidomastoid muscle were interpolated linearly, and the head's angle was determined. The EMG signal is insufficient to yield any good data for small angle rotations, thus a photo camera was used instead, and the determination of the angle was done by the pupil's location about one another. The camera-based option, which only requires a standard webcam and software that is already accessible for download, looks more acceptable if the person has adequate control of their neck and head [23].

Since the lips and mouth shapes were fixed, only vowels were employed [24]. Since the Masseter, Mentalis, and Depressor anguli oris muscles are the ones that are most engaged when pronouncing vowels, three channels were employed to record data. The EMG signal's RMS was connected to the vowels using a back-propagation algorithm-based ANN (artificial neural network). Single-word recognition and a speech impediment are covered in other studies [25–27]. Electrodes were inserted into a pilot's oxygen mask [27] to identify pilot speech that could be mistaken for directives. While performing the task the error rate for identifying the speech of the numerals "zero" to "nine" was comparatively low, varying from 0% to 10.4%.

6.2 ELECTROOCULOGRAPHY

Eye signal is produced by the deviation of potential between the retina and the cornea [28]. It varies between 2 and 20 Mv. However, data recording often falls between 15-20 mV. This possibility arises from the retina's higher concentration of active nerves than the front of the eye [29]. On comparing with other methods of measuring eye movement, the EOG has an advantage because head and torso motions do not interfere with recording. The EOG is frequently used to quantify blinking, nystagmus, smooth pursuit eye movements, and saccadic eye movements [30]. With an average accuracy of 1.5 to 2.0, the EOG can capture eye movements up to ±70 [31]. To capture, 5 Ag/AgCl self-adhesive electrodes are typically positioned for EOG recordings: (i) a pair - above and below the eye to capture movements of vertical; (ii) a pair - close to the lateral canthus to capture movements of horizontal; and (iii) one in a neutral site to serve as a reference. A constant electrical dipole with a negative pole at the fundus (retina) and a positive pole at the cornea can be used to describe this potential. As a result, it is possible to assume that the retina is negative and the corneal center is positive in a human eyeball [32]. It is conceivable to think of the battery in this way—as being lodged in the socket of an eye and rotating near to the torus of the eye through the conductive tissue surrounding the orbit, microcurrents flow radially from the battery's positive to the negative poles. Thus, standing potentials around the eye are produced by these currents and that is estimated with the help of electrodes placed [33].

6.2.1 APPLICATION

A couple of EOG channels and an EMG channel make up the virtual keyboard writer system proposed by Dhillon et al. [33]. The angular displacement of the gaze in the vertical and horizontal directions was linked to the cursor movement, and the letter was chosen using an "EMG click" recorded from the brow. The authors cited the system's simplicity and reduced cost as advantages over more advanced techniques like videooculography (VOG) and infraredoculography for detecting eye movements (IROG). Considering the eyelid movements of the patient as a source of signal, our technology uses Morse code to translate the eye blink's duration and pattern into the standard English alphabet. Before, Nicolaou et al. in 2008 [34] and Luna et al. in 2002 [35] employed this code as a communication tool. Blinking takes the human eye around a third of a second on average. During a blink, more light is reflected for a duration and the sensor gives an exceptional output than for an open eye. A microcontroller called an Arduino Uno receives readings at a rate of 10 per second continually. Here, to identify whether the eye was open or closed, they are contrasted with a previously fixed value. The patient can then communicate and form complete words and sentences in this way. [36].

In comparison to the EEG, EOG signals exhibit the following qualities: a relatively high amplitude, a linear correlation between the signal and movement of an eye, and a waveform that is simple to identify [37]. Given that EOG is simpler than EMG, it is also simpler to categorize. These factors have made EOG-based HCI systems a particularly intriguing area of study in recent years. In addition, most patients with significant motor impairments can nevertheless control their eye movements. Recent research has demonstrated the feasibility of the application of EOG in assistive communication systems in this way. Using infrared cameras [38], which make use of the eye structures' reflections and their spatial correlation, is the most common technique for estimating gaze. Since the technical issue faced by the devices based on eye gaze is the loss of reference whenever the patient shifts their head, people with severe motor impairments who are unable to move their head may be the greatest candidates for gaze-based devices. Absolute coordinates (gaze) [38,39] or movement direction [40,41] can both be used to control the cursor.

6.3 ELECTROENCEPHALOGRAPHY

One important component of people is their brain, which has complete control over various body systems. Human behavior is controlled by the brain, which can be seen as a network of interconnected neurons [42]. EEG's nondestructive, painless, adverse-effectfree, and correct interpretations for several brain disorders including epilepsy, memory loss, autism, and Alzheimer's disease, are important features [43-47]. These signals have certain frequency bands between 0 and 100 Hz assigned to them. Some have frequencies greater than 100 Hz. Medical researchers can better comprehend the functional and behavioral traits of complex brain regions thanks to this signal-based analysis of various states.

A promising possibility for the creation of a BCI (brain-computer interface) is electroencephalography (EEG), a non-invasive technology for assessing brain activity. Muscle control and communication become frequently impossible for those with severe motor disabilities like locked-in syndrome. However, these individuals typically retain their cognitive and sensory abilities. Electroencephalography, which measures cerebral activity, is considered a potential remedy to overcome this disability. Typically referred to as a brain-computer interface, this sort of interface uses cerebral waves [48].

6.3.1 APPLICATION

A computer-based system called a BCI (brain-computer interface) converts brain impulses into instructions that are sent to an external program or device to carry out the user's intention. People can communicate with their surroundings while not using their muscles or peripheral nervous system [49]. For persons with poor speech or movement, the concept of controlling an external gadget with their thoughts is a very intriguing one. Numerous clinical studies in the research field of BCI have demonstrated not only the integration and the potential utilities of these cutting-edge approaches to technology in the lives of humans with disabilities in the motor but also the beneficial effect that takes place by converting knowledge of science and design of experiments into clinical benefits by allowing the person to communicate with the outside world in a revolutionary genuine manner [50].

The thought translation device (TTD)-Users using slow cortical potentials-EEG-based BCI devices must be trained to change the polarity of the SCPs [51]. The subjects had to create either a negative or positive greater than a predetermined amplitude during the response interval. The patients had been trained to generate SCPs that lasted between 2 and 4 seconds willingly. Afterward, a TTD was created. The participants received a training process that taught them how to regulate their SCPs on their own in the "Language Support system," allowing them to converse verbally [52], which is an alphabet split into halves that are successively displayed at the screen's bottom for many secs. By causing an SCP shift, the subject can choose which letter bank is displayed. If the subject chooses that letter bank, it will divide into two additional halves, and so on, until just one letter contains in each of the two letter banks [52]. In general, motor-disabled participants use this strategy to learn how to write using their mental strategies for cursor movement (training in basics). After a practice of six months, the user was able to maintain their SCP on their own by eliciting two distinct responses from the brain. Despite the speller's output of one letter per minute, he managed to reproduce 454 German words (a full written text by the user while maintaining of SCPs on his own is represented in the article which is published). Nonetheless, the participant expressed satisfaction with the system operation [53].

Control of external device - A recent study developed and tested a BCI system on two groups of participants. They discovered [54] differences in amplitudes of P300 between people with and without impairment. Both groups performed a successful examination without any coaching, and no progress was detected after training. Most disabled folks did poorly than others, demonstrating that P300 is compromised when there is a substantial impairment. However, it should be noted that the group of participants wasn't homogeneous, as the authors examined five participants who are paralyzed with varying impairments. This study demonstrates that proper response without coaching is possible using the modulation of P300. A recent study in this area tested a BCI system based on P300 on participants with various cognitive and motor restrictions, to manage eight real domestic devices using 113 control instructions [53]. 10 of the fifteen participants were able to deliver the suggested apparatus with greater than 75% precision.

Speller system - The primary applications of BCI that make use of the modality of P300 are called speller systems [54]. Whether BCI P300 may be employed as a substitutive EEGbased BCI communication modality in the denizen with ALS was the subject of a seminal study. By testing persons with and without ALS and by using four random stimuli (YES, NO, PASS, and END), they were able to assess the BCI system's effectiveness. It was the responsibility of the individual to concentrate on one stimulus while disregarding the alternatives. For a point, a mission involved concentrating on the target impulse (i.e., YES or NO as determined by the instructor at the start of each run), whereas the alternative job involved concentrating on the impulse (YES or NO) that answered the researcher's query correctly. ALS and non-ALS, healthy users can both benefit from BCI based on P300 as a potent and affordable communication method without muscle action. The ITR (bits/selection) ranges 0.43 - 1.80 in this study, which is low in comparison to other alternatives and contemporary BCI based on P300 investigations [52]. Additionally, the conditions of the people with the most severe ALS impairments were worse than those of the other participants, reflecting the P300's inability to serve as an effective communication option for those with more serious impairments.

VII. CONCLUSION

Paralysis may alter a person's whole existence. Disabilities can range from slight, sporadic weakness to chronic muscular loss, inability to do routine occupations, and the usage of a motorized chair, with most people performing reasonably well owing to medicine and lifestyle. Currently, in addition to the identification of medications that aid in the restoration of paralyzed nerves, several alternative therapies with the same purpose are being investigated. The lack of basic methods has hindered experiment testing and assessment, contributing to the sluggish pace of advancement in this field of study. Paralysis is a lifealtering illness. Even brief paralysis might impair your ability to perform the activities you like. When paralysis strikes unexpectedly, adjusting to big changes in your lifestyle can be difficult. Many persons with paralysis lead busy lives thanks to mobility aids and the support of loved ones. Emotional and social support can also be beneficial in a person's therapy.

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