NERVE GABA NEUROTRANSMITTER HEALTH LEVEL DETECTION SYSTEM

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ABSTRACT

Currently, neurological disorders are the primary global cause of illness and disability. Transcranial ultrasound stimulation in the deep brain has limited spatial resolution. However, ultrasound can enhance energy propagation resolution affected by tissue and bone dispersion. Among the non-invasive imaging methods in this category are biochemical assays that measure GABA levels and the highly expensive Magnetic Resonance Spectroscopy (MRS). Gamma-Aminobutyric Acid (GABA), a major neurotransmitter in the brain, contributes to 40% of inhibitory synapses in adult vertebrates. Biosensors such as piezoelectric sensors and the MPU6050 can accurately determine GABA levels in the nervous system. This system uses a Micro Processing Unit (MPU) and a piezoelectric pressure sensor to detect changes in GABA levels, which are essential for maintaining neurological health and balance. The system provides real-time data on GABA levels, and this high-accuracy information is displayed on an LCD panel.

Keywords: GABA, Piezoelectric Pressure Sensor, MPU6050 Sensor, Nerve Signal Transmission, GABA Receptors, Neurotransmitter Levels.

INTRODUCTION

The development of advanced health monitoring systems has seen significant progress, particularly in detecting neurotransmitter levels. One such initiative focused on creating a novel system for measuring Gamma-Aminobutyric Acid (GABA) neurotransmitter levels. This project leveraged a combination of piezoelectric sensors and the MPU6050 sensor, with the NodeMCU serving as the central processing unit, thanks to its built-in Wi-Fi capabilities. The piezoelectric sensor was employed for its sensitivity to changes in the nervous system's physiological conditions, allowing it to detect subtle vibrations and movements that could correlate with neurotransmitter activity. The MPU6050, known for its gyroscopic and accelerometric functions, was integrated to provide additional data that could help refine the detection process. This dual-sensor approach aimed to enhance the system's accuracy, offering a more comprehensive analysis of the subject's neurological state.

Data collected from these sensors were processed by the NodeMCU, which, due to its embedded Wi-Fi module, facilitated real-time transmission of the gathered information to a cloud-based application. This application was designed to analyze the data, providing insights into GABA neurotransmitter levels and enabling remote monitoring. The processed data were then displayed on an LCD screen, offering immediate feedback to the user. This innovative approach not only aimed to improve the accuracy of neurotransmitter detection but also sought to make the process more accessible and user-friendly. By utilizing a combination of advanced sensors and cloud technology, this system represented a significant step forward in the development of non-invasive health monitoring tools, particularly in the field of neurological health. There are many situations in which a patient may require medical imaging, and occasionally accuracy and timeliness are essential when making decisions.

1. Literature Review

1.1 Anxiety Disorders and GABA Neurotransmission: a Disturbance of Modulation

Nuss (2015) states that GABA is mediated by two distinct classes of receptors: ionotropic GABA A receptors, which are fast-acting chloride channels responsible for rapid inhibition, and metabotropic GABA B receptors, which are indirectly coupled to calcium or potassium channels to produce slow and prolonged inhibitory responses. Baclofen, a molecule that mimics the action of GABA at these GABAB receptors, has potent myorelaxant properties and has been proposed as a potential treatment for alcohol dependence.

1.2 The GABA Paradox Multiple Roles as Metabolite, Neurotransmitter, and Neurodifferentiative Agent

Waagepetersen et al. (1999) describe GABA as a neurotransmitter, neurotrophin, and metabolic enzyme distributed among various cellular pools in the brain. Its metabolic enzymes exhibit heterogeneity, with two isoforms displaying different subcellular distributions and regulatory properties. Recent evidence suggests a more pronounced regulatory role of the tricarboxylic acid cycle in GABA formation.

1.3 Detection and Evaluation of GABA Concentration in Anterior Cingulate Cortex and Occipital Cortex by MEGA- PRESS

Wen et al. (2015) show that the MEGA-PRESS pulse sequence can reliably detect GABA in both the ACC and OCC. Nevertheless, both CVws and ICC repeatability in the OCC are better than those in the ACC. The concentration of GABA+ in the OCC is higher than in the ACC, revealing its region-specific feature. However, the high variation of CVws in the ACC suggests that caution is needed when using MEGA-PRESS due to its sensitivity to motion.

1.4 Exploring the Therapeutic Potential of Gamma-Aminobutyric Acid in Stress and Depressive Disorders through the Gut–Brain Axis

Liwinski et al. (2023) suggest that the quantity of GABA reaching the brain may be too minimal to have clinical relevance, yet it might still produce an effect in a stop-change paradigm. Nonetheless, oral GABA obtained from supplements, probiotics, GABA-rich fermented foods, or fortified products may exert effects on the brain through complex peripheral mechanisms, primarily involving the Enteric Nervous System (ENS) and the gut–brain axis. We believe that Magnetic Resonance Spectroscopy (MRS) studies offer the most promising approach for directly evaluating the impact of GABA supplementation on GABA levels in the human brain.

1.5 GABA in Nervous System Function - An Overview

Roberts et al. (1976) discuss the discovery of GABA, its early history, basic neurophysiology, and provide a brief synopsis of its neurochemistry.

1.6 Non-invasive Brain Stimulation Modulates GABAergic Activity in Neurofbromatosis 1

Garg et al. (2022) state that Neurofibromatosis 1 (NF1) is a single-gene disorder linked to cognitive issues such as autism. GABAergic dysregulation is responsible for working memory impairments in NF1. A study involving 31 adolescents aged 11-18 years found that anodal transcranial Direct Current Stimulation (atDCS) can modulate GABA levels and working memory in NF1. The study revealed that higher baseline GABA+ in the left dorsolateral prefrontal cortex (DLPFC) was associated with faster response times on working memory measures. atDCS significantly reduced GABA+ and increased brain activation in the left DLPFC compared to sham stimulation. Task performance was worse in the atDCS group during stimulation, but no differences in behavioral outcomes were observed at the end of the stimulation period. Further research is needed to determine if repeated sessions of atDCS and strategies such as alternating current stimulation offer a better therapeutic approach.

1.7 Neurotransmitters as Food Supplements: The Effects of GABA on Brain and Behavior

Boonstra et al. (2015) state that Gamma-Aminobutyric Acid (GABA) is the main inhibitory neurotransmitter in the human cortex. The food supplement version of GABA is widely available online. Although many consumers claim to experience benefits from these products, it remains unclear whether these supplements confer advantages beyond a placebo effect. Currently, the mechanism of action behind these products is unknown. It has long been believed that GABA cannot cross the Blood–Brain Barrier (BBB), but the studies assessing this issue are often contradictory and vary widely in their methodologies. Accordingly, future research needs to establish the effects of oral GABA administration on GABA levels in the human brain, for example, using magnetic resonance spectroscopy. While there is some evidence supporting a calming effect of GABA food supplements, most of this evidence comes from researchers with potential conflicts of interest. We suggest that any genuine effects of GABA food supplements on brain function and cognition might occur through BBB passage or, more indirectly, via effects on the enteric nervous system. In conclusion, the mechanism of action of GABA food supplements remains unclear, and further work is needed to establish their behavioral effects.

2. Methodology

The paper aims to detect GABA levels non-invasively using a piezoelectric sensor and MPU6050 modules to monitor hand response movements. Initially, the piezoelectric sensor is affixed to the subject's hand to capture biomechanical vibrations, while the MPU6050, an Inertial Measurement Unit (IMU), tracks precise hand motions through its accelerometer and gyroscope capabilities. Commands are displayed on an LCD screen to prompt specific hand movements, ensuring consistent data collection. The NodeMCU microcontroller serves as the core processing unit, aggregating data from both the piezoelectric sensor and the MPU6050. It processes this input to quantify response characteristics associated with GABA levels, potentially by analyzing tremor intensity, frequency, and motion patterns. Once processed, the data is transmitted wirelessly to the ThingSpeak cloud platform via the NodeMCU's Wi-Fi capability. ThingSpeak facilitates real-time data storage, visualization, and analysis, providing accessible insights through its web interface. This data can then be accessed through a custom web application, enabling users to monitor GABA levels continuously. The methodology emphasizes real-time processing and remote monitoring, leveraging IoT technology for a seamless, non-invasive assessment of GABA levels, making it an innovative tool in neurochemical research and potentially aiding in the diagnosis and management of related disorders.

Figure 1 shows the system designed to monitor physiological signs that may be influenced by neurotransmitter activity, particularly GABA. The sensors gather data, which the NodeMCU processes, and the system then displays the information locally or sends it to the cloud for remote access and further analysis. This setup could be useful in applications such as remote health monitoring and preliminary diagnostic tools.

3. Hardware Description

3.1 Piezoelectric Pressure Sensor

A piezoelectric pressure sensor converts mechanical

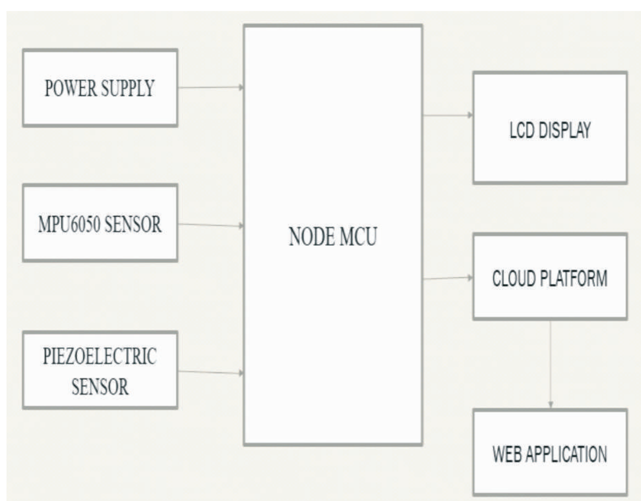

Figure 1. Block Diagram

stress into electrical charge using the piezoelectric effect. These sensors are ideal for measuring dynamic pressures and pulsations, offering high sensitivity and fast response times, but they are less suited for static pressure measurements. Figure 2 shows the piezoelectric pressure sensor.

3.2 MPU6050

The MPU6050 is an IMU device and a Micro Electro-Mechanical System (MEMS) that stands for Inertial Measurement Unit. It is a six-axis motion tracking device that provides data from a three-axis accelerometer and a three-axis gyroscope. Figure 3 shows the MPU6050.

3.3 NODE MCU

Because the Node MCU contains an integrated ESP8266 Wi-Fi module, it can connect to Wi-Fi networks and is therefore suitable for Internet of Things applications. For sensors that produce analog voltages, the Node MCU has a single ADC pin that can be used to read analog signals. Users can access and control the device through a web interface via a small web server that it can host. The Node MCU is also suitable for battery-powered applications since it can operate on various power sources and has functionality to manage power usage. Figure 4 shows NODE MCU.

3.4 LCD Display

An Liquid Crystal Display (LCD) is a flat-panel display technology that operates by manipulating liquid crystals with electric currents to modulate light and create images. LCDs consist of multiple layers, including a backlight, polarizers, and liquid crystal cells sandwiched between transparent electrodes. They offer benefits such as low power consumption, high resolution, and a slim design. Figure 5 shows an LCD display.

Figure 2. Piezoelectric Pressure Sensor

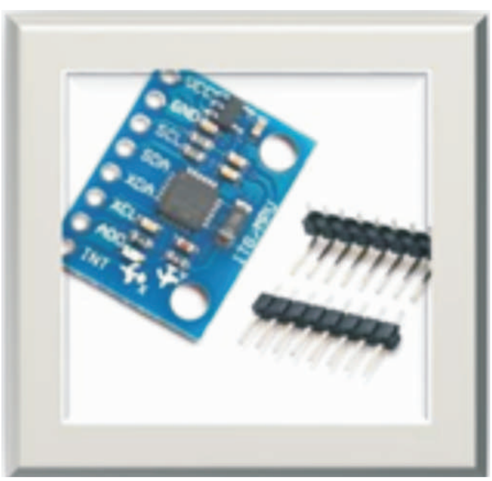

Figure 3. MPU6050

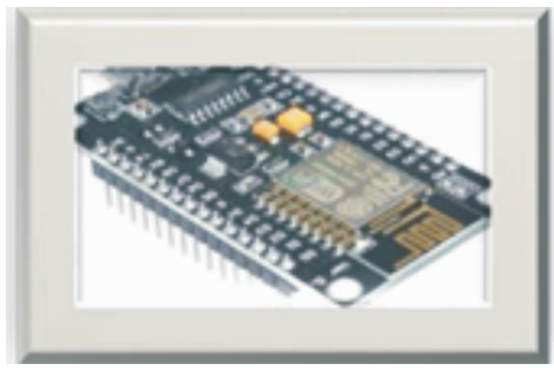

Figure 4. NODE MCU

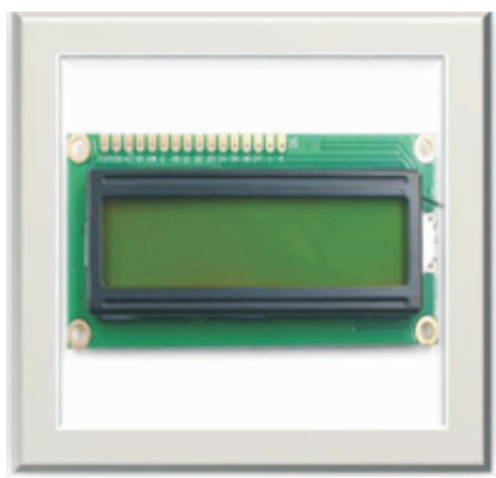

Figure 5. LCD Display

4. Software Description

4.1 Thinkspeak

An Internet of Things (IoT) platform called Thingspeak helps users gather, store, process, examine, display, and take action on data from sensors or devices. Because of its robust data analytics features, ease of use, and integration capabilities, it is frequently utilized in various IoT applications. Users can leverage the built-in charts and graphs to create historical and real-time visualizations of their data, facilitating the tracking and long-term analysis of trends. Users can also create dashboards that can be shared publicly or kept private, making it simple to convey data to stakeholders. When specific criteria are met (such as when sensor values surpass a threshold), users can configure triggers to send notifications via email, SMS, or other channels.

5. Results and Discussion

The measurement and monitoring of neurotransmitter activity is the goal of a GABA level detection system, which can shed light on various neurological and mental health issues. Accurate GABA level detection may aid in the diagnosis of conditions such as epilepsy, anxiety disorders, and certain mood disorders linked to GABA dysregulation.

The development of a non-invasive GABA detection system utilizing piezoelectric sensors and the MPU6050 represents a significant advancement in neurological health monitoring. This innovative approach capitalizes on the sensitivity of piezoelectric sensors to detect physiological changes related to neurotransmitter activity, while the MPU6050 enhances data accuracy through precise motion tracking. This dual-sensor configuration not only improves the reliability of GABA level measurements but also allows for real-time monitoring and analysis, crucial for timely medical decision-making.

The integration of the NodeMCU microcontroller facilitates seamless data transmission to the cloud via Wi-Fi, enabling continuous monitoring and remote accessibility. This is particularly beneficial in managing conditions linked to GABA dysregulation, such as anxiety disorders and epilepsy, where timely interventions can significantly impact patient outcomes. Furthermore, the LCD display provides immediate feedback, empowering users with real-time insights into their neurological state. This novel GABA detection system stands to transform the landscape of neurochemical research and patient monitoring. By enhancing accessibility and user-friendliness, it paves the way for broader applications in clinical settings and contributes to a deeper understanding of GABA's role in mental health and neurological disorders. Future studies should focus on validating this system's efficacy and exploring its integration into routine clinical practices to further bridge the gap between research and practical health applications.

Conclusion

The integration of these technologies into a cohesive system marks a unique contribution to the field of neurological health monitoring. It lays the foundation for future advancements in non-invasive, real-time health diagnostics, making it a valuable tool in both clinical and research settings. As the system evolves, it has the potential to significantly impact how neurological health is monitored and managed, ultimately improving patient outcomes and advancing the field of neurotechnology.

References

[1]. **Boonstra, E., De Kleijn, R., Colzato, L. S., Alkemade, A., Forstmann, B. U., & Nieuwenhuis, S. (2015).** Neurotransmitters as food supplements: The effects of GABA on brain and behavior. *Front Psychol.*, 6: 1520.

https://doi.org/10.3389/fpsyg.2015.01520

[2]. **Garg, S., Williams, S., Jung, J., Pobric, G., Nandi, T., Lim, B., & Stivaros, S. (2022).** Non-invasive brain stimulation modulates GABAergic activity in Neurofibromatosis 1. *Scientific Reports,* 12(1), 18297.

https://doi.org/10.1038/s41598-022-21907-9

[3]. **Liwinski, T., Lang, U. E., Brühl, A. B., & Schneider, E. (2023).** Exploring the therapeutic potential of gamma-aminobutyric acid in stress and depressive disorders through the Gut–Brain Axis. *Biomedicines*, 11(12), 3128.

[4]. **Nuss, P. (2015).** Anxiety disorders and GABA

neurotransmission: A disturbance of modulation. *Neuropsychiatric Disease and Treatment* (pp. 165-175).

https://doi.org/10.2147/NDT.S58841

[5]. Roberts, E., Chase, T. N., & Tower, D. B. (1976). *GABA in Nervous System Function.* Raven Press.

[6]. Waagepetersen, H. S., Sonnewald, U., & Schousboe, A. (1999). The GABA paradox: Multiple roles as metabolite, neurotransmitter, and neurodifferentiative agent. *Journal of Neurochemistry,* 73(4), 1335-1342.

https://doi.org/10.1046/j.1471-4159.1999.0731335.x

[7]. Wen, L., Liao, C., Chen, M., Zhu, D., Yan, X., Zhong, J., & Chen, S. (2015, November). Detection and evaluation of GABA concentration in anterior cingulate cortex and occipital cortex by MEGA-PRESS. In *2015 7th International Conference on Information Technology in Medicine and Education (ITME)* (pp. 80-84). IEEE.

https://doi.org/10.1109/ITME.2015.33

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