ISSN 2395-8618

Electric Buzz Wire Game, a Possible Indicator of Brain Activity through EEG Analysis

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Abstract—**The physiology of several neurological diseases remains a mystery. This study aims to incorporate a research tool that identifies brain areas activated during the buzz wire experience, designed to induce states of concentration accompanied by fine motor tasks and auditory stimuli. During the game, the participant's electroencephalographic activity is recorded using a sensor placed on the left frontal lobe. This activity reveals changes in the high beta, low gamma, and theta bands.**

Index Terms—**Buzz wire game, brain activity, EEG analysis.**

I. Introduction

This work stems from an interest in exploring brain activity through EEG signals. For this purpose, the Neurosky TGAM sensor was used, adapted to a headband that records activity in the frontal lobe. To induce brain activity, two games were incorporated into the research. The first involves performing simple mathematical operations using the Quick Brain application. The second game focuses on maintaining a steady pulse and has been adapted to ensure replicability in future research.

The results indicate that brain activity can be induced using the buzz wire game. Specifically, it generates an increase in high beta and low gamma oscillations while inhibiting the theta band. These findings highlight the relevance of assessing these oscillations when diagnosing or evaluating treatments for neurological conditions.

Gamma activity is a complex phenomenon associated with multiple cognitive functions. A distributed gamma system in the brain suggests that gamma activity may involve multiple brain structures rather than being confined to specific areas [1]. The findings from the buzz wire game are significant because the modulation of gamma oscillations is being studied as a therapeutic strategy for treating neurological disorders. By restoring or improving neuronal synchronization through targeted interventions, symptoms of diseases like Alzheimer's and schizophrenia may be mitigated, offering hope for patients [2].

Additionally, oscillations in the high beta band are linked to experiences of anxiety or stress [3]. They may also guide the placement of electrodes used in deep brain stimulation treatments for Parkinson's patients [4].

Finally, alterations in theta oscillations are associated with various neurological disorders. Research on theta oscillations holds significant implications for understanding and treating such conditions. As studies progress, it is anticipated that new therapeutic strategies based on theta modulation will emerge [5].

II. Materials and Methods

A. Description of the Buzz Wire

The buzz wire game involves guiding a small-diameter conductive ring along an irregular path defined by a conductive wire connected to a voltage source. The objective of the game is to avoid contact between the wire and the ring, which is connected to the opposite terminal of the source. If contact occurs, a buzzer connected in series is activated. The game aims to stimulate brain areas associated with concentration, motor activity, and visual and auditory processing. Adjustments have been made to the game, including changes to its dimensions, route regularity, and stability, to increase its difficulty and ensure replicability. Figure 1 illustrates the assembly.

Figure 2 illustrates the dimensions used in constructing the assembly. The curves follow ellipsoidal trajectories and, analogous to the model of a transverse wave, the setup consists of six valleys and five crests. The power supply provides 9 V, the conducting wire has a diameter of 1.25 mm, and the buzzer operates at a frequency of 3,600 Hz with a sound intensity of 75 dB. The ring has a diameter of 0.8 cm, and the wire length from the buzzer to the handle's base is 70 cm, facilitating maneuverability.

Figure 3 illustrates the sensor used for measurement, a TGAM with a sampling frequency of 512 Hz. It is a non-invasive sensor with a high degree of reliability [6]. To ensure efficient measurement, the sensor requires three connection points [7]: the first is a detection point located on the frontal lobe, the second is a reference point attached with a clip to the left earlobe, and the third is a ground point clipped to the right earlobe. To facilitate these connections, a headband was designed to support the sensor and the power supply needed for its operation. Figure 4 shows the headband placed on the head of one of the participants.

After obtaining the signal, it is amplified and filtered. Then, using a Fourier transformation, the signal is separated into different frequencies [8]. This process is used to create graphs that identify the signal power for each band, thereby determining which part of the spectrum represents the greatest activity.

Manuscript received on 14/12/2023, accepted for publication on 03/02/2024.

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ISSN 2395-8618

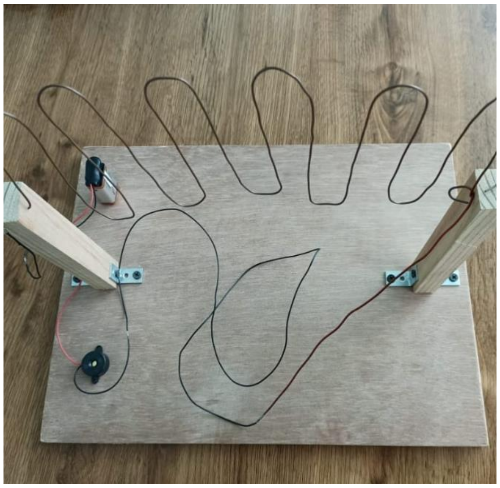

Fig. 1. The assembly

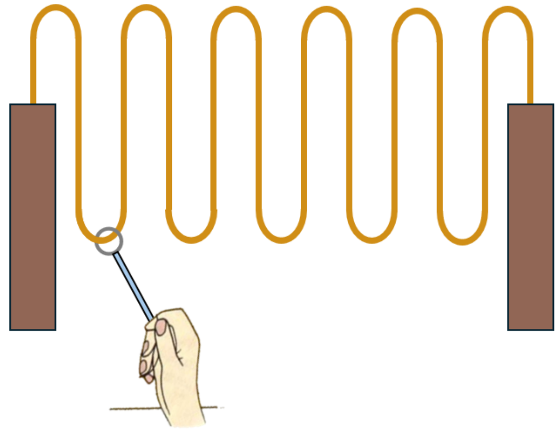

Fig. 2. Dimensions used in constructing the assembly

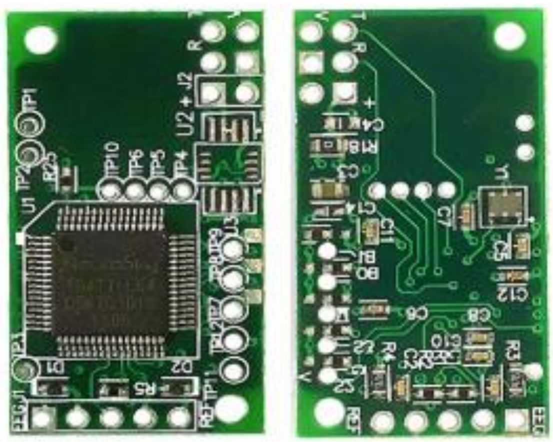

Fig. 3. Sensor used for measurement

Fig. 4. Headband on the head

B. Procedure

The local health research committee 1001, part of the Mexican Social Security Institute (IMSS), has approved the test. Bioethics registration: 11 CEI 003 2018080. Institutional registration number: R-2024-1001-122.

The participant is asked to sit ergonomically at a desk while the headband is placed on them, and instructions are provided. The measurement is conducted in three stages:

1. A reference recording is taken for two minutes, during which the participant is instructed to remain idle.

2. The Quick Brain application is presented on a cellphone, and the participant is asked to play.

3. The buzz wire is placed on the table, and the participant is instructed to guide the ring along the path without making contact with the wire. If contact occurs, a buzzer will sound, and they must continue to avoid further activation of the buzzer.

III. Results

For each measurement, a Fourier transformation was applied to decompose the EEG signal into frequency bands. Subsequently, 100% of the signals obtained from each participant was distributed across bands, so the values presented below indicate the percentage of the signal corresponding to each band. Three measurements were taken per participant: one as a reference or baseline, another during the pulse game, and a third while performing mathematical operations. The results are shown in tables 1, 2, and 3.

After processing and organizing the EEG signals by frequency bands, a comparative statistical analysis was performed for the following pairs: Buzz Wire vs. Reference, Math vs. Reference, and Buzz Wire vs. Math.

All box-and-whisker diagrams are shown in Figure 5, where variations in the Theta, Low Gamma, and High Beta bands can be observed. To validate whether these changes are statistically significant, T-student tests were conducted. The consolidated results are presented in Table 4.

From the graphs and tables presented above, the following can be concluded:

1. The math test did not induce statistically significant changes in the brain activity of the participants.

2. Measurements taken during the Buzz Wire practice showed statistically significant changes in the Low Gamma and Theta bands.

ISSN 2395-8618

TABLE I
RESULTS (PART 1)

Buzz Wire								
Participant 1	30.84	16.20	3.32	14.66	6.53	3.29	0.05	25.12
Participant 2	26.24	11.94	10.34	11.96	9.56	8.75	1.62	19.60
Participant 3	12.19	12.95	10.40	20.68	2.67	10.40	0.93	29.78
Participant 4	11.49	12.25	12.26	10.33	8.21	26.39	5.13	13.94
Participant 5	3.00	10.14	13.83	8.90	18.74	18.75	16.69	9.95
Participant 6	12.74	15.93	6.99	23.89	14.94	5.98	0.02	19.51
Participant 7	17.50	5.45	23.18	12.50	7.24	10.77	0.08	23.28
Participant 8	7.17	16.56	8.29	15.57	16.51	9.30	4.14	22.46
Participant 9	9.81	17.75	5.96	21.72	6.95	4.96	0.03	32.82
Participant 10	11.71	7.28	13.29	3.68	18.10	8.47	6.02	31.46
Participant 11	6.86	13.50	11.44	13.56	9.35	13.48	6.24	25.58
Participant 12	20.95	8.84	9.72	21.98	14.95	5.34	0.92	17.30
Participant 13	23.51	10.40	6.99	12.72	9.28	1.21	2.33	33.57
Participant 1	30.84	16.20	3.32	14.66	6.53	3.29	0.05	25.12

TABLE II
RESUTLS (PART 2)

Math								
	Delta	**High Alpha**	**High Beta**	**Low Alpha**	**Low Beta**	**Low Gamma**	**Mid Gamma**	**Theta**
Participant 1	9.86	19.90	3.19	24.11	9.47	5.26	4.20	24.03
Participant 2	33.55	8.32	0.06	15.18	1.45	1.40	12.38	27.66
Participant 3	10.10	10.90	2.47	14.50	15.68	6.05	7.23	33.08
Participant 4	46.64	5.56	1.94	5.61	9.13	1.89	3.64	25.59
Participant 5	13.76	4.22	11.65	6.31	11.58	15.73	19.92	16.82
Participant 6	6.40	17.66	9.66	18.47	12.07	6.43	5.62	23.69
Participant 7	59.46	0.29	5.12	5.07	0.24	0.16	4.90	24.77
Participant 8	12.03	17.63	6.26	21.84	15.52	2.11	4.15	20.45
Participant 9	11.60	16.40	3.14	26.62	2.13	1.05	0.02	39.06
Participant 10	9.52	10.69	10.69	15.53	23.27	3.94	0.98	25.38
Participant 11	12.14	10.72	15.06	16.93	12.47	9.78	3.56	19.33
Participant 12	38.37	4.05	1.41	10.68	4.03	1.39	1.36	38.71
Participant 13	29.14	6.57	0.07	11.99	3.32	1.11	3.26	44.54

TABLE III
RESULTS (PART 3)

Reference								
	Delta	**High Alpha**	**High Beta**	**Low Alpha**	**Low Beta**	**Low Gamma**	**Mid Gamma**	**Theta**
Participant 1	4.18	5.62	19.55	2.13	18.17	17.46	5.63	27.25
Participant 2	31.43	16.71	1.46	8.44	0.09	1.42	2.79	37.67
Participant 3	10.81	8.33	11.86	11.85	16.59	3.60	2.38	34.59
Participant 4	14.02	14.29	17.61	14.26	11.01	3.39	2.23	23.19
Participant 5	9.71	23.15	6.64	10.01	11.06	1.13	5.52	32.78
Participant 6	10.47	5.70	14.72	9.06	20.35	6.82	3.40	29.47
	Delta	**High Alpha**	**High Beta**	**Low Alpha**	**Low Beta**	**Low Gamma**	**Mid Gamma**	**Theta**
Participant 7	31.57	5.76	2.96	8.57	0.17	0.12	0.05	50.80
Participant 8	10.35	14.85	15.74	16.75	9.30	10.21	0.96	21.83
Participant 9	25.30	9.31	3.53	7.06	5.85	3.51	2.33	43.11
Participant 10	12.28	3.93	12.72	5.85	13.66	11.65	12.60	27.30
Participant 11	23.08	19.55	5.37	15.15	3.61	1.80	2.68	28.75
Participant 12	26.59	11.14	6.22	18.56	3.76	2.52	3.72	27.48

ISSN 2395-8618

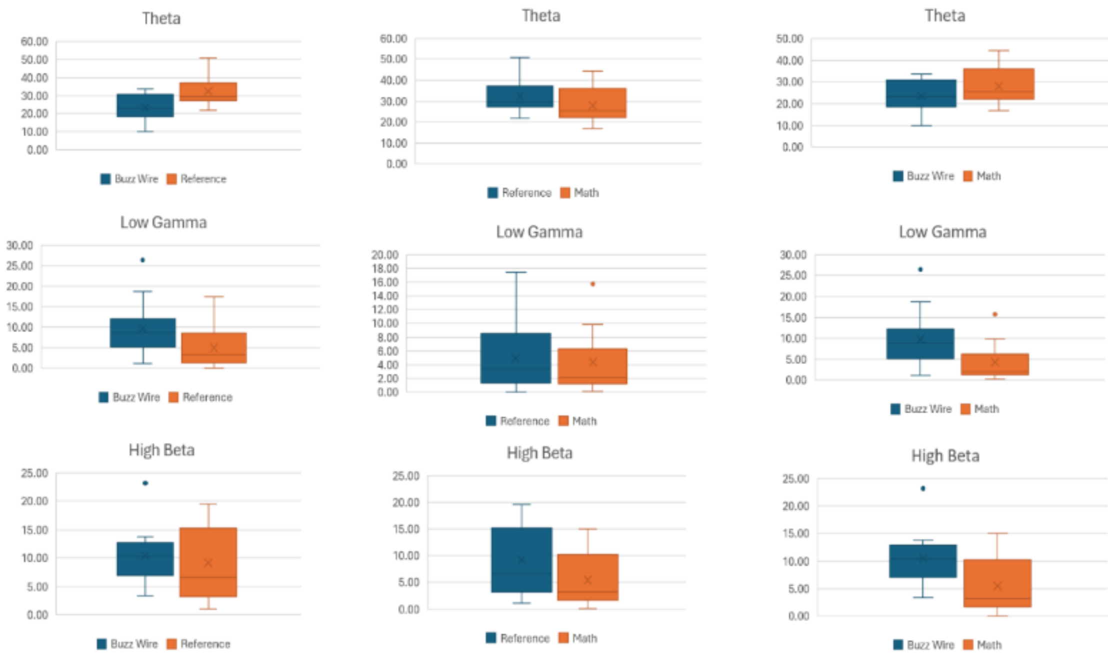

Fig. 5. Box-and-whisker diagrams

TABLE IV
CONSOLIDATED RESULTS

Comparison	High Beta	Low Gamma	Theta
Buzz Wire - Math	**BW↑ M↓**	**BW↑ M↓**	**BW↓ M↑**
0.05 - P(T<=t)	0.04266704*	0.03858542*	-0.02855083
Buzz Wire-Reference	**BW↑ R↓**	**BW↑ R↓**	**BW↓ R↑**
0.05 - P(T<=t)	-0.23859813	0.02473093*	0.04642093*
Math-Reference	**M↓ R↑**	**M↓ R↑**	**M↓ R↑**
0.05 - P(T<=t)	-0.00292601	-0.33424178	-0.04367883

3. Comparing the measurements obtained during the Buzz Wire practice with those from the math test revealed statistically significant changes.

Based on these assessments, the general conclusion is that practicing with the Buzz Wire induces activity in the High Beta and Low Gamma bands, while inhibiting oscillations in the Theta band.

IV. Discussion

Previous research indicates that math tests induce variations in everyday brain activity and that the brain's response to the effort involved in mathematical reasoning can be observed through EEG signal analysis [9]. However, an analysis of the obtained results revealed that practicing with the Quick Brain application does not show significant changes in brain activity compared to reference states. While changes are evident across all bands, they do not represent a consistent trend among all test participants.

One consideration regarding this outcome in the math operations test could be related to the low difficulty level encountered by participants when using the application, as the proposed operations were simple. This aligns with the findings reported by[9], which emphasize that low difficulty does not induce significant changes, in contrast to operations requiring greater cognitive effort [9].

Low gamma oscillations and their relation to neurological conditions:

Gamma waves, including low gamma waves (typically in frequencies of 30 to 50 Hz), are associated with complex cognitive processes such as attention, memory, and perception. Evidence suggests that some of these waves can be induced by the buzz wire. It is important to note that gamma waves can be produced in various areas of the brain, with low gamma oscillations reflecting intense and coordinated brain activity. The dynamics of gamma activity can occur spontaneously or be induced. Practicing with the buzz wire appears to be an effective method for inducing gamma oscillations.

A key aspect of low gamma oscillations is their role in neuronal synchronization, which is crucial for effective communication between different brain areas. Gamma oscillations enable neurons to activate in a coordinated manner, a process essential for information processing and the execution of complex cognitive tasks. Without this synchronization, communication between neurons could become chaotic, negatively impacting brain function [10].

ISSN 2395-8618

Variations in the gamma band may indicate neurological disorders. For example, in patients with Alzheimer's disease, a decrease in gamma oscillations has been linked to the severity of cognitive symptoms [2]. Similarly, alterations in gamma oscillations in patients with schizophrenia may contribute to cognitive dysfunction and symptom development. Regarding Parkinson's disease, gamma oscillations are associated with motor control and coordination. Dysfunction in these oscillations can result in movement difficulties and impairments in performing motor tasks effectively [2].

High beta waves and their relevance to stress assessment and optimal treatment delivery in Parkinson's patients

Beta band activity has been observed in the motor areas of the brain and is associated with the preparation and execution of movements, as well as attention [11]. Beta oscillations, which range from 15 to 40 Hz, could be a useful marker for stress, although the relationship between these factors may be somewhat complex [3]. Significant differences in beta wave activity were observed between participants assessed for anxiety and stress under resting conditions, suggesting variability in how individuals experience stress and anxiety. This variability may be related to differences in brain connectivity and each person’s ability to regulate their emotional state. Understanding these differences is crucial for developing personalized approaches to stress management [3].

The therapeutic effect of deep brain stimulation (DBS) of the subthalamic nucleus for Parkinson’s disease is related to the modulation of pathological neuronal activities, particularly the synchronization of high beta oscillations in the subthalamic nucleus. High beta oscillations, but not low beta oscillations, can provide insight into stimulation-induced improvements in patients. These high beta oscillations can also help refine electrode targeting and inform contact selection for stimulation therapies [4].

V. Conclusions

Performing simple mathematical operations does not induce activity in low gamma, high beta, and theta oscillations in healthy individuals. However, using the buzz wire can induce activity in these bands, opening up potential applications. One such application could involve using the buzz wire with patients who have various neurological conditions, allowing researchers to identify which oscillations are more or less influenced. This approach could help explore how brain activity is affected by these diseases. Different recording methods could also be employed by placing electrodes in other areas of interest. Finally, the measurement system, along with the buzz wire, could be used according to the needs of research groups that deem it pertinent.

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