Stimulating Gamma Brain Waves Via the Visual System Using Flashing LED Lights: Optimizing a Potential Treatment for Alzheimer's

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ABSTRACT

Recent studies with a mouse Alzheimer's disease model show that inducing gamma brain waves at 40 Hz causes microglia in the brain to remove plaque-forming proteins, actually treating the disease, not just the symptoms. In my study, an electroencephalogram (EEG) device and a flashing LED light circuit were designed and built in order to test how best to induce gamma waves in the human brain. Data were analyzed with a Fast Fourier Transform. Nine adults were tested, ranging in age from 18 to 90, including an Alzheimer's patient. 40 Hz brain waves were readily induced in every subject. At 30, 35, and 40 Hz there was a striking peak in the brain wave at the test frequency during stimulation. No response was detected in control trials with the lights on but blocked by cardboard, demonstrating that the effect was not due to electronic crosstalk artifact. The effect was weak at 45 and absent at 50 Hz. The response was strongest at a 50% duty cycle. Occasionally there was no response at 20% and 80%. Response increases with brightness. However, there was occasionally a strong response at low luminance, especially in the older subjects. Red and white worked better than green and much better than blue. One subject commonly had a response at exactly half the stimulation frequency, implying the neurons are responding to every other light stimulus. This study provides guidance on how best to induce 40 Hz gamma brain waves in humans to potentially treat Alzheimer's disease.

1 INTRODUCTION

A recent study conducted in 2016 on a strain of mice genetically at risk for Alzheimer's disease revealed that inducing Gamma brain waves stimulates microglia in the brain to clean up Beta Amyloid plaques, which are associated with Alzheimer's. This is an extraordinary finding, as it demonstrates that inducing Gamma brain waves could be a treatment for Alzheimer's, not just for its symptoms. Human clinical trials are currently underway, however no results have been released.

In my study, I wanted to see if I could stimulate Gamma brain waves in humans with flashing lights, and, if so, how best to induce them. I did this by testing the effects of varying frequency, duty cycles, brightness, and color on nine test subjects.

2 METHODS

I began by building an electroencephalogram, or an EEG, to read brain wave responses. Because electroencephalogram signals are very weak, in the 2 to 30 microvolt range, it was essential to use a large gain. Total circuit gain, using op-amp circuits, was about 20,000 to 120,000. A special form of op amp with extremely high common mode rejection, called an instrumentation amplifier, was needed at the front end. Three filters were also used: a high pass filter, used to get rid of the direct current (below 0.9 Hertz), a low pass filter, to remove unwanted signals above 88 Hertz (such as radio and extra noise), as well as a 60 Hertz notch filter, to reduce 60 Hertz artifact from utility power in the walls. Ultimately, this notch filter did not eliminate the signal completely, however it did greatly reduce the 60 Hertz peak so that the important signals were not masked or distorted.

The next step was to build a flashing LED circuit. To do this, I used a 7555 timer integrated circuit. In order to fulfill the engineering requirements, I ensured that the frequency could range from 30 Hertz to 50 Hertz, the duty cycle could range from 20% to 80%, the brightness could range from 30 to 300 lux, and the colors could be white, red, green, or blue (the colors were manipulated within the goggles that held an LED circuit board).

2.1 Data Collection

To acquire data, the test subject put on the goggles, sat down in a comfortable chair, and relaxed as much as possible, since any muscle movement would show up on the brain wave readings. Using the computer, I recorded three sequential acquisitions, each eight seconds in length. The first one was before the lights were turned on, the second one was with the lights on and flashing, and the third one was after the lights were turned off again. In some trials, I also added a fourth acquisition in which the lights were on and flashing, but were blocked from the view of the subject by a piece of cardboard placed inside the goggles. In doing this, I was able to prove that the response I was receiving was not due to crosstalk artifact (unwanted capacitive or inductive coupling) between the circuits. That is to say, the response I was receiving was the brain wave signal. Data were later analyzed with a Fast Fourier Transform.

3 SAFETY

In both of the previously mentioned circuits, there are safety considerations. Therefore, everything was battery powered and electrodes were connected via 4.7kΩ resistors. These safety precautions were taken to eliminate possible burns or electrocution. Shielding was also very important to reduce crosstalk between the flashing light circuit and the EEG, so I used coaxial cable between circuits and aluminum boxes to enclose both devices. The largest safety consideration was photosensitive epilepsy, which is most common in young children and it usually occurs at frequencies between 5 Hertz and 30 Hertz, more common at the lower end of that range. Therefore, all test subjects were between the ages of 18 and 90 with no history or family history of epilepsy. I only tested frequencies between 30 Hertz and 50 Hertz.

4 RESULTS

Data were analyzed with a Fast Fourier Transform. Below, the first panel shows the first trial of the 54 year old female subject. The second panel shows the test results for all three trials for all nine test subjects, including the 90 year old Alzheimer's patient. The graph was made by finding the ratio of the peak during the stimulus at the test frequency to that prior to the stimulus. If no significant peak was detected, then no value was plotted.

4.1 Frequency

Figure 1

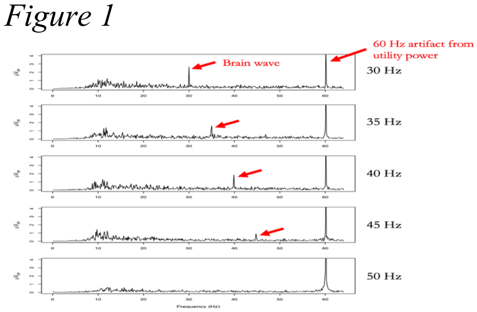
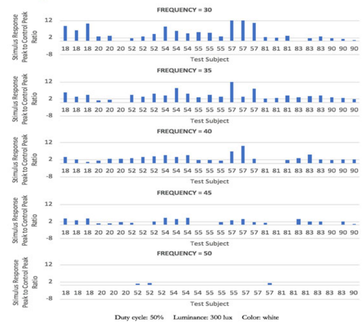


Figure 2



At 30, 35, and 40 Hz there was a striking peak in the brain wave at the test frequency during stimulation. The effect was weak at 45 and absent at 50 Hz. Because the previously mentioned mouse experiments were conducted at 40 Hertz, I used that frequency for the other trials.

4.2 Brightness/Luminance

Figure 3

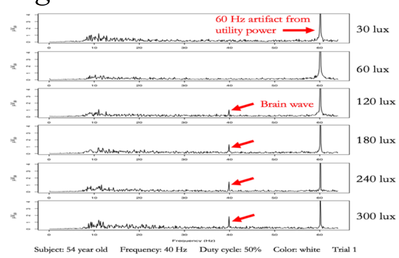
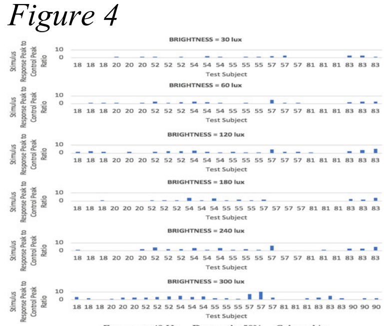


Figure 4



Response increases with brightness. However, there was occasionally a strong response at low luminance, especially in the older subjects. Because the response was the most consistent at 300 lux, I used that for the other trials.

4.3 Duty Cycle

Figure 5

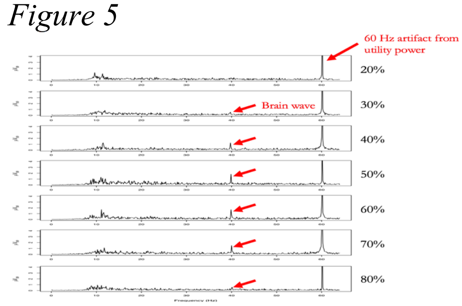
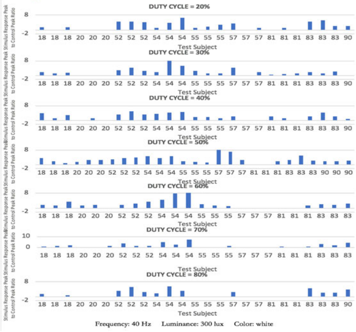


Figure 6



The duty cycle had a surprisingly large impact on the results. The response was strongest at a 50% duty cycle. Occasionally there was no response at 20% and 80%. 50% was used for the other experiments.

4.4 Color

Figure 7

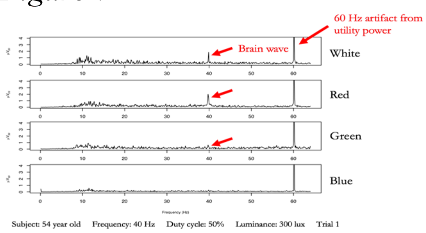
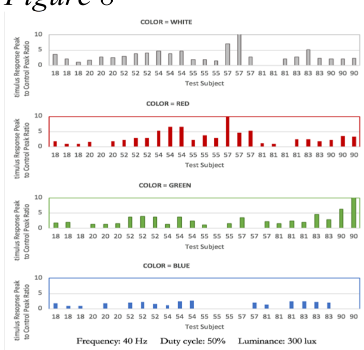


Figure 8



Red and white worked better than green and much better than blue. White was used in all the other experiments.

4.5 Alzheimer's Patient

The subject with Alzheimer's was clearly able to produce strong gamma brain waves, including at 40 Hertz. He also generally showed the same trends as other subjects.

4.6 Half-Frequency Peaks

In testing, one subject commonly had a response at exactly half the stimulation frequency, implying the neurons are responding to every other light stimulus. This happened at least once with most of the subjects. This does have implications for the application of this treatment because the patient could be looking into 40 Hertz flashing lights, however they could be responding at exactly half of the frequency. So, the question is, will this still produce the desired treatment effects?

4.7 Individualization

Throughout the experiments, I noticed that almost everyone responded slightly differently to different variables. For example, the 81 year old female had a stronger response to green and blue lights than to white and red. Therefore, it would be beneficial in the application of this treatment to individualize each subject's settings in order to optimize how best to induce the Gamma waves in their unique brain.

5 CONCLUSIONS

Ultimately, this study provides guidance on how to optimally produce 40 Hertz gamma brain waves in humans, serving as a potential treatment for Alzheimer's disease. In the end, the best settings generally were at 40 Hertz, 300 lux, 50% duty cycle, and white or red lights.

6 FURTHER RESEARCH

I noticed significant 60-cycle noise during the study (which improved substantially by turning off the circuit breakers to that part of the house). I would like to add another 60-Hz notch filter. I would like to add additional electrodes and try different electrode placement positions as well.

I would also like to test whether this has therapeutic effects on Alzheimer's patients. Cognitive tests would need to be applied before and after treatment. However, this requires safety experiments first, which would take a long time and require a high level of sophistication.

To be practical, the flashing light would need to be applied during daily activities. So, I could test special glasses or lights in a room.

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