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MYSTERIES OF GAMMA BRAINWAVES

By Anadi Martel

It has been known since 1924 that our brain emits electromagnetic waves, when neurologist Hans Berger was first to detect their tiny electric field of around 10 microvolts. It did not take long for medicine to explore the properties of these, known as *electroencephalographic* (EEG) waves, and to realize that their frequency is related to our mental state. By now all of us have heard about the main brainwaves bands, such as alpha, theta and beta, ranging from 1Hz (or cycle per second) to about 20Hz; a short description of each band is given in Table 1.

As early as 1934 electrophysiologists Adrian and Matthews had found that brainwaves can be influenced by sensorial input. When we are exposed to an external stimulus vibrating at a rhythm that is within the range of brainwaves frequencies, our brain has a tendency to fall in sync with this stimulus and starts to generate brainwaves at a similar rhythm. This phenomenon called *brainwave entrainment* works with many of our senses, whether through sound, light or touch. Since each brainwave frequency band corresponds to a specific mental landscape, this provides us with a remarkable way to influence our inner state through these natural sensory gateways.

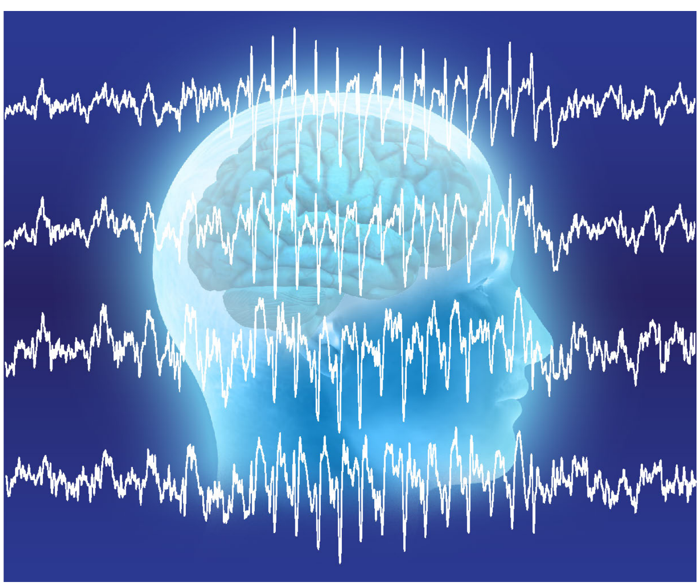


Figure 1 – Our brain emits EEG waves

A brief history of audio visual entrainment

Photic brainwave entrainment (the kind operating through light pulses) was intuitively recognized long ago. As early as 300AD Ptolemy, a disciple of Aristotle, described the sensation of contentment induced by the observation of the sun rays flashing through a rotating wheel. And at the very beginning of the 20th century Dr. Pierre Janet, a colleague of Sigmund Freud working at the Salpêtrière Hospital in Paris, reproduced the same sort of effect. By focusing on pulsating light from a kerosene lamp placed behind a wheel, his patients found relief from their states of depression, tension and agitation.

Closer to us, a classic example of photic entrainment is the *Dream Machine* created by British artist Brion Gysin. It consisted of a simple cylinder with a central light placed on a revolving turntable. The cylinder was pierced in such a way as to generate stroboscopic pulsations in the alpha EEG wave band. Starting in the 1960s, Gysin and American poet William Burroughs together explored and popularized altered states of consciousness induced through contemplating this device.

Audio brainwave entrainment can be realized through sound pulsating at the sought after frequency, such as with *binaural beats* where each ear is presented with a tone of slightly different frequencies (for example using 300 Hz and 310 Hz to generate a 10 Hz beat frequency in the alpha range). Their exploration started in the 1960s, notably by Robert Monroe and his institute.

One of the most interesting variations is obtained by the stimulation of both auditory and vision senses, in *audio visual entrainment,* or AVE. Several generations of AVE devices have come on the market since the 1970s. For the most part these consist of goggles equipped with pulsating light sources and a set of earphones. Some of the best AVE devices have been presented at various International Light Association conferences in recent years: the DAVID, created by Canadian Dave Seiver (who was the recipient of the ILA's first *Frances McManemin Award* in 2011), the PSiO, presented by its Belgian designer Stéphane Krsmanovic, and the Lucia No3 from Austrians Drs. Englebert Winkler and Dirk Proeckl.

Figure 2 – DAVID, PSiO and Lucia No3 AVE devices

I have myself long explored visual stimulation as I developed a technique called *light modulation* in which light is pulsed in subtler ways than the stroboscopic flashes commonly used in AVE. This enables more sophisticated applications involving properties of peripheral vision and brain laterality, as realized in the Sensora multisensorial system and more recently in the portable SensoSphere light device.

Clinical studies have validated therapeutic applications of AVE in areas as varied as PTSD, affective disorders (seasonal and others), concussions, hypertension, chronic pain and fibromyalgia, attention and learning issues, among many others (see e.g. Seiver).

EEG Band	Frequency Range	Associated Properties
Gamma	30 to 100 Hz	Gamma waves are related to higher cognitive activity, appearing in states of meditation or in moments of conscious focus. Like the conductor of the brain, they keep the rest of the brain in sync
Beta	14 to 30 Hz	Brain waves in this range indicate the normal waking state. This is a state of mental activity and attention turned out towards the world. Most of us spend the majority of our waking hours in this state.
Alpha	8 to 13 Hz	Alpha waves are the natural resting rhythm of the brain and accompany relaxation. This state indicates attention turned inward, as in deep unwinding and let-go.
Theta	4 to 7 Hz	The hypnagogic state just before falling asleep. This state plays an important role in visualization, creativity and learning.
Delta	1 to 4 Hz	Delta waves appear during the deepest portions of sleep. They are also associated with states such as trance mediumship.

Table 1 – EEG Brainwaves Bands

Sync and Resonance

What could be the operating principle behind brainwave entrainment? It is none other than the universal phenomenon of *resonance*. Resonance is the natural tendency of any system susceptible to oscillation (and this is the case for most systems in our world) to react to an external field vibrating at a frequency similar to its own. When frequencies match and synchronize, energy can be transferred and amplified with near perfect efficiency. This operates at all levels of the universe, from the microscopic quantum scale (as with the electron orbitals in the atom which resonate at highly specific frequencies) all the way to the cosmic scale (the Moon's tidal locking, the perfect ordering of Saturn's rings, or the shape of spiral galaxies all result from resonant energy exchanges).

Closer to us, brainwaves in themselves are one of most exquisite examples of resonance. They are produced when millions of individual neurons, each emitting a tiny electric pulse every time they fire, start to operate in synchrony. Instead of cancelling each other in chaotic noise, their fields fall in sync and neatly add up until their sum becomes large enough to be detected through the cranium as the EEG wave.

Is it then surprising that these vast assemblies of synchronized neurons would in turn be susceptible to interaction with the rhythmic neural energy pulses generated by the sensorial stimulation of AVE, and adapt their firing frequency to that stimulus? This sensory resonance typically originates from the thalamus region of the brain, and from there gradually expands to other brain areas within minutes.

Enter gamma brainwaves

For most of the past century it was considered that all significant brainwaves were contained in the four classical bands of delta (deep sleep), theta (hypnagogic states), alpha (resting state) and beta (mental activity) spanning the range of 1 to 20Hz. Only recently have we taken notice of the band above this range, known as the *gamma band*. This is because its levels are usually very low and its function remains elusive. It is still so little understood that even its frequency range is not well delineated: depending on references, it is stated as starting anywhere from 20Hz to 30Hz and extending up to about 100Hz.

There are clear indications linking gamma brainwaves to cognitive functions. An early study in 1993 looked at 40Hz gamma brainwaves during sleep and found them active during rapid-eye-movement (REM) sleep where dreams take place (Llinas 1993). The authors concluded: "we propose 40Hz oscillation to be a correlate of cognition". Further studies reinforced this assertion. One found a relation between gamma-band EEG and associative learning (Miltner 1999); another looked at the role of gamma brainwaves in establishing long-distance synchronization of brain activity (Rodriguez 1999). A third one linked an increased synchronization of gamma brainwaves with conscious perception (Srinivasan 1999).

Other studies have confirmed the prevalence of gamma brainwaves in people who have practised long-term meditation, compared with the human average. High-amplitude gamma and phase synchronisation are apparent not only during meditation activity, but also in the resting brainwave baseline of experienced meditators (Lutz 2004, Braboszcz 2017).

While these findings were intriguing, no clear clinical role could still be found for gamma brainwaves.

Gamma and Alzheimer's

This is where things stood when in 2016 an original article sent shockwaves through the medical community. Dr. Li-Huei Tsai (affiliated to the Broad Institute of Harvard and MIT) and her team found that light flashes in the gamma brainwave range could reverse the neurological degeneration brought about by Alzheimer's Disease (AD). This was done on mice genetically engineered to develop AD. Dr. Tsai knew that gamma brainwaves are among the first to disappear as AD develops, and she reasoned that perhaps stimulation at that frequency through photic entrainment would have some influence. But even she never expected such a drastic outcome: daily one-hour courses of gamma light pulses (administered through flashing white

LEDs in the animals' cage) actually reduced the amyloid plaque load in the mice's brains by 40-50% within a week (Iaccarino 2016). Amyloid plaques are sticky protein deposits that invade and eventually kill neurons in AD. In a healthy brain they are normally kept in check by the action of *microglia*, a type of glial cell which accounts for 10-15% of all cells found within the brain. Microglia are resident macrophage cells, and they constitute the first and main form of immune defence in the central nervous system. As AD progresses, microglia gradually stop their work. Somehow, gamma stimulation restores their vitality and allows them to clear the plaque build-up.

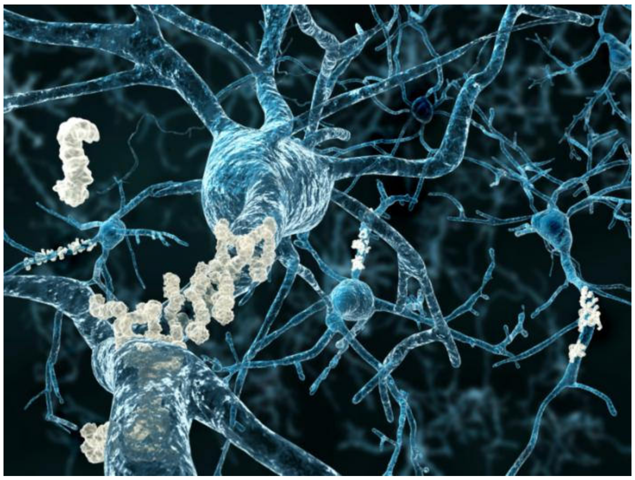


Figure 2 – Amyloid plaque build-up in neurons

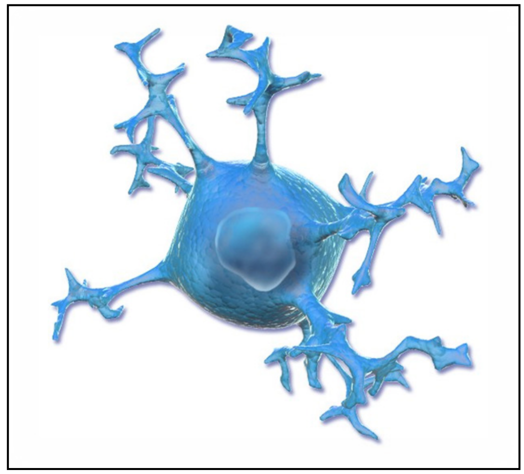


Figure 3 – Microglia cell

This amyloid clearing happened mostly in the visual cortex and only when the light flashing frequency was 40Hz; other frequencies or random pulses had no significant effect. It was accompanied by a halting of the cognitive decline experienced by the AD mice. Conversely, the amyloid plaques rebounded within 12 hours after the light treatment was interrupted.

A further study published recently by Tsai's team (Adaikkan 2019) sought to better understand the mechanisms involved in this neuroprotective approach, now designated as *Gamma entrainment using sensory stimulus* (GENUS). Here, the 40Hz gamma light prevented neurodegeneration in mice that were given highly neurotoxic proteins usually resulting in rapid brain damage. Gene data suggests that chronic GENUS shifts neurons to a less degenerative state, improving synaptic function, enhancing neuroprotective factors, and reducing DNA damage in neurons while also reducing inflammatory response in microglia. Dr. Tsai herself noted in an interview: "I haven't seen anything like that. It's very shocking (...) After all, oscillations are initiated by neurons, and I still like to think that they are the master regulators. I think the oscillation itself must trigger some intracellular events, right inside neurons, and somehow they are protected."

While the brain pathology of mice may be quite different from ours, as the researchers are the first to point out, these results still hold the potential promise of alleviating symptoms of AD in humans in the completely non-invasive way that is a hallmark of most light therapies. Dr. Tsai has established a private corporation (Cognito Therapeutics) to test this, though ongoing human studies are expected to take at least 5 years and as of today no conclusive outcome is yet available. Unofficial results in 2017 seemed positive, as participants in a first pilot study with five AD subjects saw memory and cognitive improvements – although their state reverted after treatment was discontinued at the end of the trial. A study from another group published in 2018 found no significant amyloid removal for subjects with early AD exposed to 10 days of 40Hz light, which indicates that longer treatment periods may be required for humans than for mice (Ismail 2018).

Multisensory gamma modalities

In parallel with these visual entrainment trials, other modalities of gamma brainwave stimulation have recently been explored. For example, positive amyloid-reducing effects have been reported in mice AD models using stimulation with sound modulated at 40Hz (Lee 2018).

Although 40Hz is a frequency too low to be properly heard by our auditory system, it is ideal as a source of kinesthetic stimulation when converted through acoustic transducers. Dr. Lee Bartel from the University of Toronto has been studying this type of stimulation using vibroacoustic reclining chairs and already in 2015 he had found that 40Hz gamma *low-frequency sound stimulation* (LFSS) reduced symptoms in patients with fibromyalgia (Naghdi 2015). He wrote: “The present study premises that thalamocortical dysrhythmia is implicated in fibromyalgia and that LFSS can play a regulatory function by driving neural rhythmic oscillatory activity.” In a further study he found that the same LFSS has positive effects on patients with AD, especially for those with mild and moderate symptoms (Clements-Cortes 2016).

Furthermore, by combining both sound and light stimuli Dr. Tsai’s team have obtained better results on AD mice than when using either method separately (Martorell 2019). Interestingly, while sound stimulation affects primarily the auditory cortex and light stimulation the visual cortex, effects of their combination appear to spread across multiple brain areas: such multisensory stimuli produced widespread reduction of amyloid plaque throughout the neocortex within a few days.

A new frontier in audio visual stimulation

I have been well aware of the advantages of multisensory stimulation, as we integrated it into our Sensora system early in our research from the 1990s. For this purpose I developed a method called *dynamic sound transduction* where low-frequency vibroacoustic signals are distributed over an array of 8 transducers in a reclining chair or table, resulting in kinesthetic sensation perceived as patterns or waves gently moving across the surface of the whole body. We’ve always considered that this physical sensation acts as an anchor allowing a deeper integration of the transformative effects of complementary audio and visual stimulation in our system.

Thus it was with great interest that I surveyed these new findings regarding 40Hz gamma brainwaves. Since my instruments had been designed to operate across the classic 1-20Hz brainwaves frequency range, I undertook in 2018 to modify both my light projectors and kinesthetic transducers to enable their operation at 40Hz in the gamma band. We've developed AVE programs implementing gamma frequencies and have now started to explore their use.

Gamma stimulation holds the tantalizing possibility of contributing to both preventing and alleviating dementia symptoms in humans through non-invasive means using our natural sensory channels. But one may wonder how it would eventually be best administered. Current studies indicate that its beneficial effects are temporary and thus that daily stimulation is needed to ensure sustained results. It is hard to imagine elders suffering from AD wearing pulsing-light goggles for an hour every day, as is the case in current clinical trials. Hence new methods to apply gamma stimulation in more practical ways need to be developed.

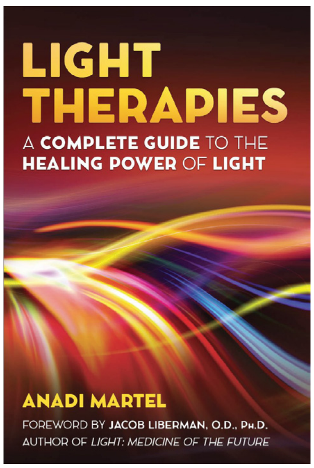
I am pursuing one approach with the SensoSphere, which I've adapted to emit 40Hz gamma light pulsations. This globe-shaped lamp is designed to be used in the everyday environment, where it unobtrusively emits beautiful coloured light patterns. We now have to find out if such low-level but continuous gamma stimulation can act as a gentle cognitive prophylactic. We have been surprised to see many of our users report that the new gamma program quickly became their favourite, so clearly gamma stimulation can be enjoyed by all and is not exclusively reserved to AD patients.

Figure 4 – The SensoSphere
as a source of gamma brainwaves modulation

The exploration of gamma brainwaves is still in its early days. But whatever form it eventually takes, gamma stimulation has already achieved a significant result: it has taken the hitherto relatively alternative technique of AVE into the mainstream medical world, and brought it recognition and renewed interest. It will undoubtedly be a significant part of the medicine of the future.

About the author:

Anadi Martel is a physicist working in novel ways with sound, light, and brainwaves. His Spatial Sound Processors have been used worldwide by professionals in psychoacoustics, multimedia and cinema. His work has led to patents in the field of light modulation and in LED-based design. He served as president of the International Light Association from 2011 to 2018. He recently published the book *Light Therapies – A Complete Guide to the Healing Power of Light* (Healing Arts Press, 2018).



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