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MYSTERIES OF GAMMA BRAIN WAVES

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 brain waves 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 brain waves can be influenced by sensorial input. When we are exposed to an external stimulus vibrating at a rhythm that is within the range of brain waves frequencies, our brain has a tendency to fall in sync with this stimulus and starts to generate brain waves at a similar rhythm. This phenomenon called *brain wave entrainment* works with many of our senses, whether through sound, light or touch. Since each brain wave 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.

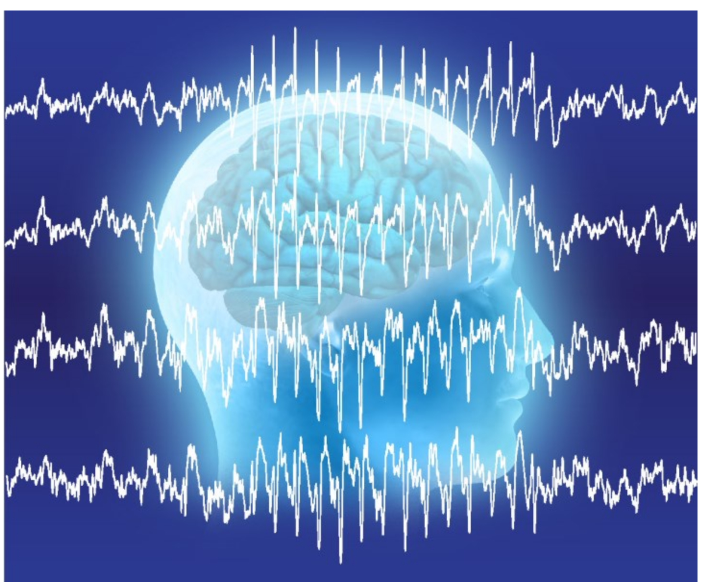


Figure 1 – Our brain emits EEG waves

A brief history of audiovisual stimulation

Photic brain wave 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 20^{th} 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 brain wave 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 *audiovisual stimulation,* or AVS. Several generations of AVS 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 AVS devices have been presented at various International Light Association conferences in recent years: the DAVID, created by Canadian Dave Siever, 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 AVS 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 AVS. This enables more sophisticated applications involving properties of peripheral vision and brain laterality, as realized in the Sensora multisensory system and more recently in the portable SensoSphere light device.

Clinical studies have validated therapeutic applications of AVS 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. Siever).

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 altered states such as trance mediumship.

Table 1 – EEG Brain waves Bands

Sync and Resonance

What could be the operating principle behind brain wave 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, brain waves 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 AVS, 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 brain waves

For most of the past century it was considered that all significant brain waves were contained within the four classical bands—delta (deep sleep), theta (hypnagogic states), alpha (resting state), and beta (mental activity)—spanning the range of 1 to 30 Hz. Only recently have we begun to recognize the band above this range, known as the gamma band, commonly considered to extend from 30 to 100 Hz. This is because its levels remain usually very low and its function remains elusive.

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

Other studies have confirmed the prevalence of gamma brain waves in practitioners of long-term meditation, compared with the human average. High-amplitude gamma and phase synchronization appear not only during meditation activity but also in the resting brain wave baseline of experienced meditators (Lutz 2004; Braboszcz 2017).

While these findings were intriguing, no clear clinical role could emerge for gamma brain waves.

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 with the Broad Institute of Harvard and MIT) and her team found that light flashes in the gamma brain wave range could reverse the neurological degeneration brought about by Alzheimer's disease (AD). This was demonstrated in mice genetically engineered to develop AD. Dr. Tsai knew that gamma brain waves are among the first to disappear as AD develops, and she reasoned that perhaps stimulation at that frequency through photic entrainment would exert influence. But even she never expected such a dramatic outcome: daily one-hour sessions of gamma light pulses (administered through flashing white LEDs in the animals' cages) 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 that accounts for 10-15% of all cells found within the brain. Microglia are resident macrophage cells and constitute the first and main form of immune defence in the central nervous system. As AD progresses, microglia gradually cease their protective work. Somehow, gamma stimulation restores their vitality and allows them to clear the plaque buildup.

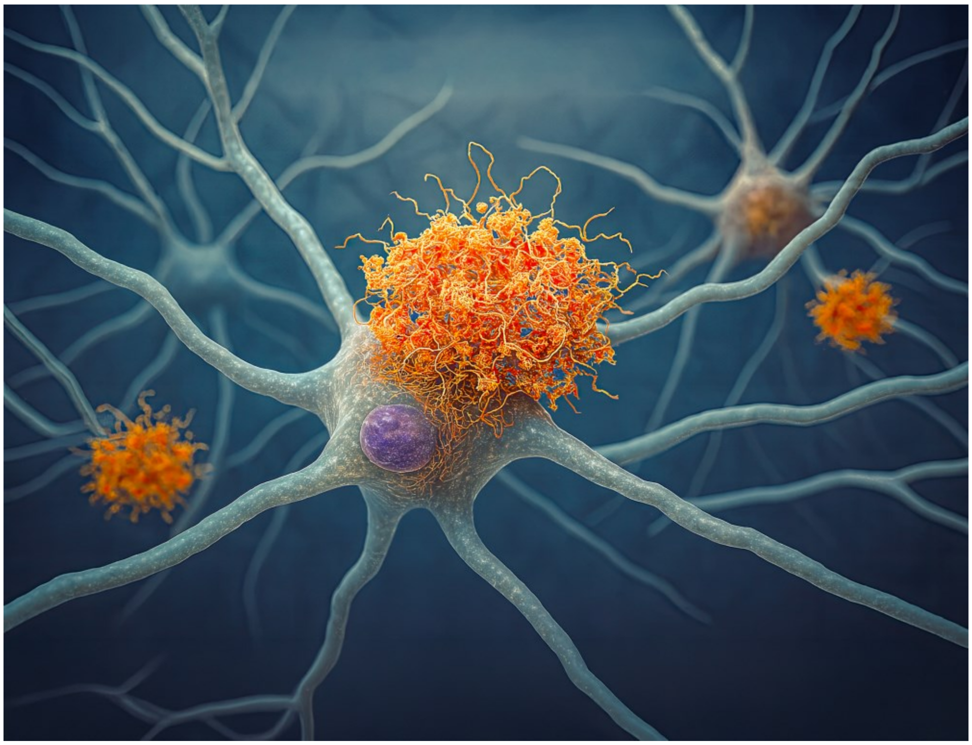


Figure 3 – Amyloid plaque build-up in neurons

This amyloid clearing occurred mostly in the visual cortex and only when the light flashing frequency was 40 Hz; 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 twelve hours after the light treatment was interrupted.

A further study published by Tsai's team (Adaikkan 2019) sought to better understand the mechanisms involved in this neuroprotective approach, now designated as Gamma Entrainment Using Sensory Stimulation (GENUS). Here, 40 Hz gamma light prevented neurodegeneration in mice given highly neurotoxic proteins typically resulting in rapid brain damage. Gene data suggest 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 responses 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."

A subsequent study (Garza 2020) sought to gain better insight into neuronal intracellular signaling changes within the brains of healthy mice after gamma visual stimulation. The Georgia Tech researchers found that 40 Hz light pulses induced a specific cytokine neuroimmune signaling profile, distinct from profiles typically seen during neuroinflammation, highlighting both the unique nature and therapeutic potential of this treatment. (Cytokines are signaling proteins of the immune system, serving as the main communication signal between neurons and immune cells.) Remarkably, a significant effect appeared after only fifteen minutes of visual stimulation. The study authors concluded: "Due to the multifunctional nature of these pathways and the broad range of cytokines expressed, the effects of visual flicker likely extend beyond neural immune activity to changes in neuronal health, synaptic plasticity, and other functions."

While the brain pathology of mice may differ considerably from ours, as the researchers are the first to point out, these results still hold the promise of alleviating symptoms of AD in humans through the completely non-invasive approach that characterizes most light therapies. Dr. Tsai has established a private corporation (Cognito Therapeutics) to test this, though ongoing human studies are expected to require many years. Early unofficial results in 2017 seemed positive, as participants in a first pilot study with five AD subjects showed memory and cognitive improvements—although their condition reverted after treatment was discontinued at the trial’s end. A study from another group published in 2018 found no significant amyloid removal in subjects with early AD exposed to 10 days of 40 Hz light, which indicates that longer treatment periods may be required for humans than for mice (Ismail 2018).

Adding to the suspense, a later study conducted with mice did not manage to reproduce the high amyloid plaque reduction rates observed in Dr. Tsai's original study (Soula 2023)—although Tsai subsequently countered that the study employed nonstandard methodologies that may have compromised its results (Blanco-Duque 2024). Other research teams have since reconfirmed the positive results, such as Wu et al. (2025) in China.

Multisensory Gamma Modalities

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

Although 40 Hz is a frequency too low to be properly heard by our auditory system, it proves 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 as early as 2015 he found that 40 Hz 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 produced positive effects in patients with AD, especially those with mild and moderate symptoms (Clements-Cortes 2016).

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

Pursuing their exploration of multisensorial gamma stimulation, Tsai's team recently studied the effects of vibrotactile stimulation on mice as a third sensory modality (Suk 2023). They tested this by vibrating the rodents' cages at 40 Hz using a speaker for one hour a day over periods of three and six weeks. They found the same beneficial effects as with audio and visual modalities: reducing the levels of the characteristic Alzheimer's protein phosphorylated tau, preventing neurons from dying or losing their synaptic connections, and reducing neural DNA damage. Intriguingly, they also observed a novel effect not seen with the other modalities: an enhancement of motor abilities.

Yet another modality of gamma stimulation involves transcranial infrared therapy using 40 Hz-pulsing LEDs shining on the head. A proportion of their light penetrates the cranium and can directly stimulate neurons. Various transcranial devices are now available, and their use is being explored for AD alleviation (e.g. Rashidi-Ranjbar et al. 2024). A recent study also found significant benefits for children with autism spectrum disorder (ASD) (Fradkin 2025).

In parallel with this work, other teams are evaluating whether the 40 Hz commonly used for gamma stimulation represents the optimal frequency. Petro et al. (2024) tested 32 Hz, 40 Hz, and 48 Hz light flicker; they confirmed that while both 32 Hz and 40 Hz provide the highest entrainment of the visual cortex, 40 Hz has the added advantage of most efficiently spreading the entrainment to wider regions of the brain, such as the prefrontal cortex. Since the whole purpose of multisensorial stimulation is to activate as much of the brain as possible, 40 Hz does seem to be a sweet spot for gamma stimulation.

A Bright Future for Gamma Stimulation

In a recent essay, Dr. Tsai's team summarizes the current understanding of the effects of gamma stimulation as follows: "At the molecular and cellular level, we are beginning to understand how gamma oscillations can promote amyloid clearance via the glymphatic system. At the circuit level, GENUS promotes robust rhythmic firing in the corresponding sensory cortices. Critically, gamma oscillations synchronize to other regions important for learning, memory, and higher-order functions such as the hippocampus and prefrontal cortex. We also find decreased synaptic loss coupled with increased neuroprotection and blood flow" (Park and Tsai 2025).

Clinical trials using gamma stimulation for humans with Alzheimer's disease have been underway since 2017, and preliminary results have gradually emerged: a study with fifteen patients suffering from mild Alzheimer's showed reduced brain atrophy and increased cognitive performance after daily one-hour light-and-sound sessions for three months (Chan 2022), while a 69% reduction in brain volume loss after daily 1-hour treatments at home for 6 months using Cognito Therapeutics' audiovisual stimulation device was later reported (Hajòs et al. 2024; Da et al. 2024). Approval for FDA Phase III trials was granted.

I have been well aware of the advantages of multisensory stimulation long before the recent gamma studies demonstrated its value, 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. Later on, I designed special methods of modulating the audio signal in order to perform brain waves stimulation through this vibroacoustic transduction. 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 brain waves. Since my instruments had been designed to operate across the classic 1-20Hz brain waves 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 multisensory programs implementing gamma frequencies and have now started to explore their use. This way of entraining gamma brain waves through an immersive experience of simultaneous light, sound and vibroacoustic pulsations is uniquely powerful.

Gamma stimulation holds the tantalizing possibility of 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 best be administered. Current studies indicate that its beneficial effects remain temporary and that daily stimulation is needed to ensure sustained results. It is difficult to imagine elderly patients suffering from AD wearing pulsing-light goggles for an hour every day, as occurs in some clinical trials. Hence, new methods to apply gamma stimulation in more practical ways need development.

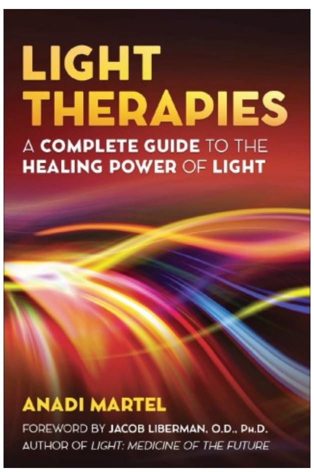
I am pursuing one approach with the SensoSphere and SensoLight, which I have adapted to emit 40 Hz gamma light pulsations. These globe-shaped lamps are designed for use in everyday environments, where they unobtrusively emit beautiful colored light patterns. It remains to be seen whether such low-level but continuous gamma stimulation can act as a gentle cognitive prophylactic, but we have been surprised to see many of our users report that the new gamma program quickly became their favorite. Clearly, gamma stimulation can be enjoyed by all and is not exclusively reserved for AD patients.

Figure 4 – The SensoSphere
as a source of gamma brain waves modulation

The exploration of gamma brain waves is still in its early stages. But whatever form it eventually takes, gamma stimulation has already achieved a significant result: it has elevated the technique of audiovisual stimulation (AVS) —hitherto mostly relegated to the alternative-medicine realm— into the mainstream medical world and brought it both recognition and renewed interest.

About the author

Anadi Martel is a physicist working in novel ways with sound, light, and brain waves. 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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References

Adaikkan C et al, Tsai LH: *Gamma Entrainment Binds Higher-Order Brain Regions and Offers Neuroprotection.* Neuron, https://doi.org/10.1016/j.neuron.2019.04.011, 7 May 2019

Blanco-Duque C, Chan D, Kahn MC, Murdock MH, Tsai LH: *Audiovisual gamma stimulation for the treatment of neurodegeneration.* J Intern Med. 2024 Feb;295(2):146-170. doi: 10.1111/joim.13755. Epub 2023 Dec 19. PMID: 38115692; PMCID: PMC10842797.

Braboszcz C, Cahn BR, Levy J, Fernandez M, Delorme A: *Increased Gamma Brain wave Amplitude Compared to Control in Three Different Meditation Traditions.* PLOS ONE, https://doi.org/10.1371/journal.pone.0170647, 24 Jan 2017

Chan D, Suk H-J, Jackson BL, Milman NP, Stark D, Klerman EB, et al.: *Gamma frequency sensory stimulation in mild probable Alzheimer's dementia patients: results of feasibility and pilot studies*. PLoS ONE. 2022;17:e0278412.

Clements-Cortes A, Ahonen H, Evans M, Freedman M, Bartel L: *Short-Term Effects of Rhythmic Sensory Stimulation in Alzheimer's Disease: An Exploratory Pilot Study.* Journal of Alzheimer's Disease 52, 651–660 https://doi.org/10.3233/JAD-160081, 2016

Da X, Hempel E, Ou Y, Rowe OE, Malchano Z, Hajós M, et al.: *Noninvasive gamma sensory stimulation may reduce white matter and myelin loss in Alzheimer's disease.* Journal of Alzheimer's Disease. 2024;1–14.

Fradkin Y, Anguera JA, Simon AJ, De Taboada L and Steingold E. 2025. "Transcranial photobiomodulation for reducing symptoms of autism spectrum disorder and modulating brain electrophysiology in children aged 2–7: an open label study." Front. Child Adolesc. Psychiatry 4:1477839. doi: 10.3389/frcha.2025.1477839

Garza K, Zhang L, Borron B, Wood LB, Singer AC: *Gamma visual stimulation induces a neuroimmune signaling profile distinct from acute neuroinflammation*. The Journal of Neuroscience, 40(6):1211–1225, Feb 2020.

Hajós M, Boasso A, Hempel E, Shpokayte M, Konisky A, Seshagiri CV, et al.: *Safety, tolerability, and efficacy estimate of evoked gamma oscillation in mild to moderate Alzheimer's disease.* Front Neurol. 2024;151343588. https://doi.org/10.3389/fneur.2024.1343588 PMID: 38515445

Iaccarino HF et al, Tsai HL: *Gamma frequency entrainment attenuates amyloid load and modifies microglia.* Nature, 540(7632): 230–235. https://doi.org/10.1038/nature20587, 7 Dec 2016

Ismail R, Hansen AK, Parbo P, Brændgaard H, Gottrup H, Brooks DJ, BorghammerP: *The Effect of 40-Hz Light Therapy on Amyloid Load in Patients with Prodromal and Clinical Alzheimer's Disease.* Hindawi International Journal of Alzheimer's Disease, Article ID 6852303, https://doi.org/10.1155/2018/6852303, 2018

Lee J, Ryu S, Kim HJ, Jung J, Lee B, Kim T: *40 Hz acoustic stimulation decreases amyloid beta and modulates brain rhythms in a mouse model of Alzheimer's disease.* bioRxiv preprint, http://doi.org/10.1101/390302, 20 Aug 2018

Llinas R, Ribary U: *Coherent 40-Hz oscillation characterizes dream state in humans*. Proc. Natl. Acad. Sci. USA (Neurobiology), Vol. 90, pp. 2078-2081, March 1993

Lucia No3 hypnagogic light experience: www.gesund-im-licht.at

Lutz A, Greischar LL, Rawlings NB, Ricard M, Davidson RJ: *Long-term meditators self-induce high-amplitude gamma synchrony during mental practice.* PNAS, Vol.101 no. 46 16369–16373, 16 Nov 2004

Martorell AJ, Paulson AL, Suk HJ, Boyden ES, Singer AC, Tsai HL: *Multi-sensory Gamma Stimulation Ameliorates Alzheimer's-Associated Pathology and Improves Cognition.* Cell 177, 1–16, 4 April 2019

Miltner WH, Braun C, Arnold M, Witte H, Taub E: *Coherence of gamma-band EEG activity as a basis for associative learning.* Nature. 397(6718):434-6. 4 Feb 1999

Naghdi L, Ahonen H, Macario P, Bartel L: *The effect of low-frequency sound stimulation on patients with fibromyalgia: A clinical study.* Pain Res Manag, Vol 20 No 1, Jan/Feb 2015

Park JM, Tsai L-H: *Innovations in noninvasive sensory stimulation treatments to combat Alzheimer's disease.* PLoS Biol 23(2): e3003046. https://doi.org/10.1371/journal.pbio.3003046, 2025

Petro NM, Webert LK, Springer SD, Okelberry HJ, John JA, Horne LK, Glesinger R, Rempe MP, Wilson TW. *Optimal gamma-band entrainment of visual cortex*. Hum Brain Mapp. 2024 Jul 15;45(10):e26775. doi: 10.1002/hbm.26775. PMID: 38970249; PMCID: PMC11226544.

PSiO light and relaxation technologies: www.psio.com

Rodriguez E, George N, Lachaux JP, Martinerie J, Renault B, Varela FJ: *Perception's shadow: long-distance synchronization of human brain activity.* Nature, 397(6718):430-3, 4 Feb 1999

Rashidi-Ranjbar, N. et al. 2024. "A pilot study evaluating the feasibility, safety, and efficacy of transcranial photobiomodulation (tPBM) for the treatment of mild cognitive impairment (MCI): preliminary findings." Alzheimer's Dement., 20: e095049. https://doi.org/10.1002/alz.095049

Siever D: multiple audiovisual stimulation studies are available at www.mindalive.com

Sensora multisensory system, SensoSphere: www.sensora.com

Soula M, Martín-Ávila A, Zhang Y et al.: *Forty-hertz light stimulation does not entrain native gamma oscillations in Alzheimer's disease model mice*. Nature Neuroscience **26**, 570–578, https://doi.org/10.1038/s41593-023-01270-2, 2023

Srinivasan R, Russell DP, Edelman GM, Tononi G*: Increased Synchronization of Neuromagnetic Responses during Conscious Perception.* Journal of Neuroscience, 19 (13) 5435-5448, 1 July 1999

Suk HJ, Buie N, Xu G, Banerjee A, Boyden ES, Tsai LH: *Vibrotactile stimulation at gamma frequency mitigates pathology related to neurodegeneration and improves motor function*. Frontiers in Aging Neuroscience, Sec. Parkinson's Disease and Aging-related Movement Disorders Volume 15 - 2023, https://doi.org/10.3389/fnagi.2023.1129510, 18 May 2023

Wu W, Zhao Y, Cheng X et al.: *Modulation of glymphatic system by visual circuit activation alleviates memory impairment and apathy in a mouse model of Alzheimer's disease.* Nat Commun 16, 63 (2025). https://doi.org/10.1038/s41467-024-55678-w

