BRAINVIEW

Science & Technology Overview

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BrainView System

The BrainView system is a cutting-edge hardware and software system that allows for an objective measure of cognitive function assessment using EEG, electrocardiogram activity (ECG), visual and auditory processing speeds (evoked potentials), and a subjective neuropsychological survey.

The BrainView system is designed to help the physician effectively diagnose biomarkers related to seizures, memory loss, cognitive impairment, and other stress-related neurological conditions. In addition, a neuro-functional physiology report of the results is provided, including a data summary, raw data, and images.

The BrainView system is portable, easy to use, and noninvasive.

The BrainView system enables a physician to collect the patient's neuro-physiological biomarkers, which profile the patient's neurological function. The system allows the physician to gain additional clinical information vital to making a well-informed patient-care decision.

What do we do?

BrainView offers healthcare providers an understanding of EEG/ERP associated with various neurological disorders and explains how they correlate to brain performance and behavior.

BrainView offers in-depth analyses, including comparing normative databases, ERP interpretation, and Low-Resolution Electromagnetic Tomography (LORETA).

BrainView assists healthcare providers in understanding what the brain's activity means to their patients in terms of everyday function and behavior. In addition, we provide recommendations of ways that neuroscience can improve and optimize brain function. This deep comprehension is essential for the referring treatment team to understand the patient's EEG and ERP data, clinical presentation, and the best treatment options available.

Frequency-based analysis of EEG data

The brain is a continuous oscillator and generates rhythmic activity even in the complete absence of stimuli - during sleep, for example. Therefore, for the brain activity that drives our behavior, thoughts, motivations, and emotions, a different analytic approach is required based on the analysis of frequencies.

What are the significant frequencies that are contributing to the brain mix? How do these frequencies vary depending on internal state changes or environmental factors?

The brain generates primarily low frequencies between 1 and 80 Hertz. Specific frequency bands are classified as delta, theta, alpha, beta, and gamma and are associated with brain processes in specific regions underlying attention, cognition, and emotion.

Frequency analyses are closely linked to physiological processes and brain structures. This is why it is often much easier to stick to the analysis of frequencies and frequency bands. Another benefit of frequency analysis is that much less data is required to arrive at conclusions. However, frequency-based analyses come with a cost: Unlike ERP designs that allow insights into millisecond changes of voltages, frequency-based EEG measures have much less time precision.

Frequency-based analyses are recommended whenever the testing time is limited. An analysis is not about the precise timing of stimulus-related activity but rather about the respondent's general mental, affective or cognitive state. Frequency analyses are instrumental in studying cognitive-affective states - when respondents' EEG is measured.

The Fast Fourier Transform (FFT)
The raw EEG signal is a time-course of voltages – a time-domain signal. Time is on the x-axis, and voltage is on the y-axis.

The Fast Fourier Transform (FFT) transforms the EEG signal into the frequency domain. Plot this data; frequency is on the x-axis, and voltage is on the y-axis. This is why frequency analysis neglects time and primarily focuses on the signal's frequencies.

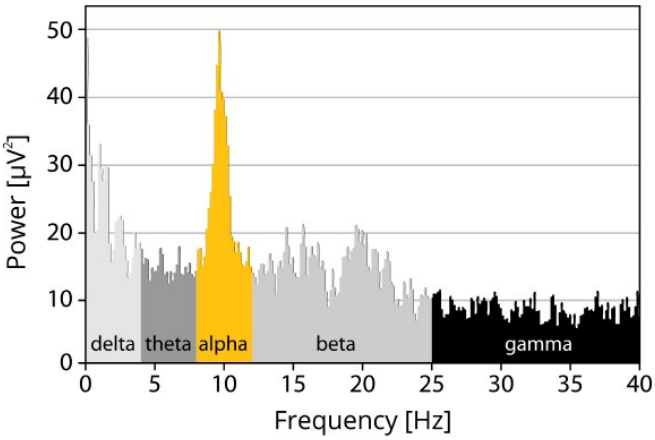
A detailed description of the math behind FFT is beyond the scope of this document. However, the basic procedure is as follows: FFT examines how similar the complex raw EEG is to sine waves consisting of specific pure frequencies. The more similar the signal to the sine wave, the larger the matching score. For example, the FFT compares raw EEG data with a 10 Hz sine wave. FFT would return a perfect matching score if the raw EEG data were completely identical to the sine wave.

For example,
FFT can analyze the entire frequency content in a signal ranging from 1 to 45 Hz (since this range contains all of the cognitive-affective frequency bands). The stronger a particular frequency, the higher the likelihood that the respondent is in a specific cognitive-affective state associated with that frequency. One example: If there is more overall theta in the EEG, the respondent might be in a general state of high mental workload. If there is a higher overall delta in the EEG, the respondent might be sleeping.

One of the most widely used terms in frequency analysis is power, which reflects the strength of a specific frequency in the signal. Higher power means that the EEG signal contains a specific frequency to a more significant extent. A specific frequency drives the EEG signal. To get started with frequency-based analysis, fin a respondent and run one of the oldest and most replicated EEG experiments:

Eyes open: Record EEG data for 5 minutes from respondents and simply instruct them to keep their eyes open (they are certainly allowed to blink).

Eyes closed: Record EEG data for another 5 minutes and instruct respondents to close their eyes and focus on their inner thoughts and mental images.



Analyze both conditions separately with an FFT and extract the frequencies underlying the spontaneous EEG data. Noticing that the condition eyes closed show much higher frequency power in the alpha band (8 – 12 Hz) in occipital channels than the condition eyes open. This effect of reduced alpha power when opening the eyes is called alpha-blocking and was initially described by Hans Berger in 1929.

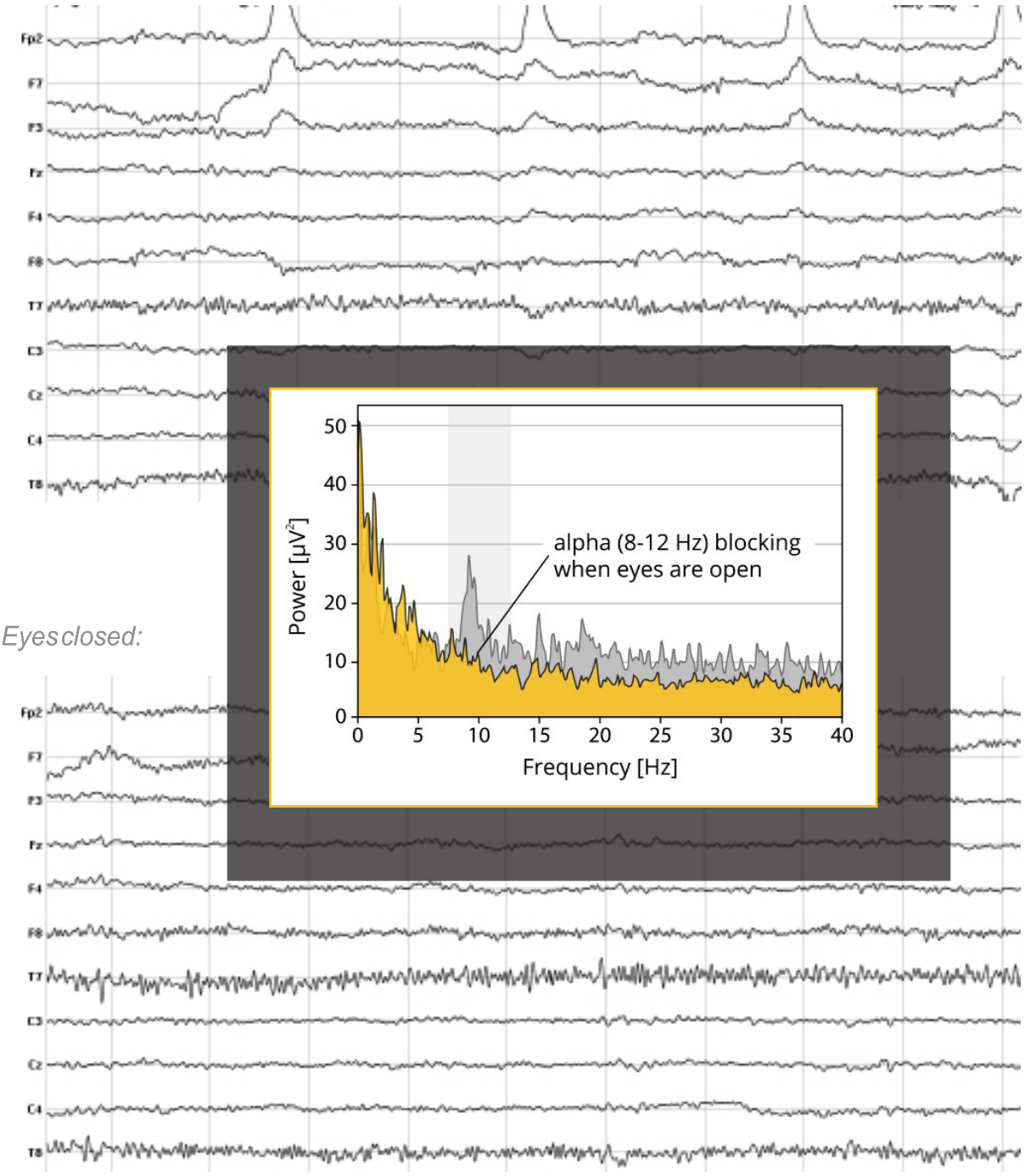
Peak Alpha Frequency

The alpha frequency band (8 – 12 Hz) is the most dominant EEG frequency found in the brain. The Peak Alpha Frequency (PAF), or posterior dominant rhythm, is primarily generated by the thalamus and reflects thalamocortical network activity; therefore, PAF can be conceptualized as the brain's pacemaker and is known to be a good measure of information processing capacity.

EEG studies have found that PAF rises from childhood to adolescence and decreases slowly around 11 years old. Regardless of age, individuals with strong working memory abilities have faster PAF than inferior memory performers. Conversely, abnormally low PAF (< 8 Hz) is found in cognitive disturbances and dementia patients. At the same time, a slowed PAF is correlated with the loss of hippocampal volume in many posterior regions of the brain in individuals suffering from MCI. Therefore, the PAF electrophysiology biomarker is used to help identify patients with preclinical dementia and monitor a patient's overall cognitive capacity over time.

Peak frequency is a statistic that tells us the frequency within a band with the highest amplitude. For example, in the alpha band (8-12 Hz), 10 Hz should be highest in most adults. Values rising above may result in problems experienced by the client, depending on where we see this, and peaks below ten can often result in cognitive difficulties and word-finding problems. The TQ shows peaks in alpha, beta, and overall peak. We are looking at the three together in the EEG and the assessment.

Eyes open versus Eyes closed:



Eyes closed:

What is a BrainView QEEG?

Quantitative Electroencephalography, abbreviated QEEG, is EEG data processed using various algorithms. The processed digital data is statistically analyzed, sometimes compared with normative database reference values. The processed EEG is commonly converted into color maps of brain function and is referred to as Brain maps. The EEG and the derived qEEG information are interpreted and used by experts as a clinical tool to evaluate brain function and track brain function changes due to various interventions such as Neurofeedback or medication. qEEG processing techniques and advanced software allow the brain to view dynamic changes during a cognitive process. This novel approach assists in determining which areas of the brain are engaged and processing efficiently.

What is QEEG Database?

QEEG stands for Quantitative Electroencephalography, commonly known as brain mapping. It can identify neuro markers or EEG phenotypes for various psychiatric disorders such as ADHD, Alzheimer's, Depression, dementia, schizophrenia, and PTSD. In addition, this information aids in forming personalizing treatments such as Neurofeedback or rTMS.

In addition to a wide range of diagnostic groups in a database, it is also necessary to have an excellent normative reference frame. Our normative database includes more than 20,000 healthy subjects and large patient groups with ADHD and Depression. The database also includes neurophysiological and neuropsychological data.

At the BrainView Research Institute, we have for the last decades been researching the optimal use of BrainView QEEG for optimizing psychiatric treatments. Furthermore, with our research, we are constantly pushing the envelope with the newest technologies and advances, such as source-localization, cross-frequency coupling, and deep learning to advance a future of stratified psychiatry or personalized psychiatry further.

What is a qEEG?

Electroencephalography (EEG) measures your brain's electrical patterns, specifically reflecting cortical activity, also called brain waves. Quantitative EEG (qEEG) is also called brain mapping. The qEEG provides further analysis of visual EEG interpretation, offering more insight into understanding brain function.

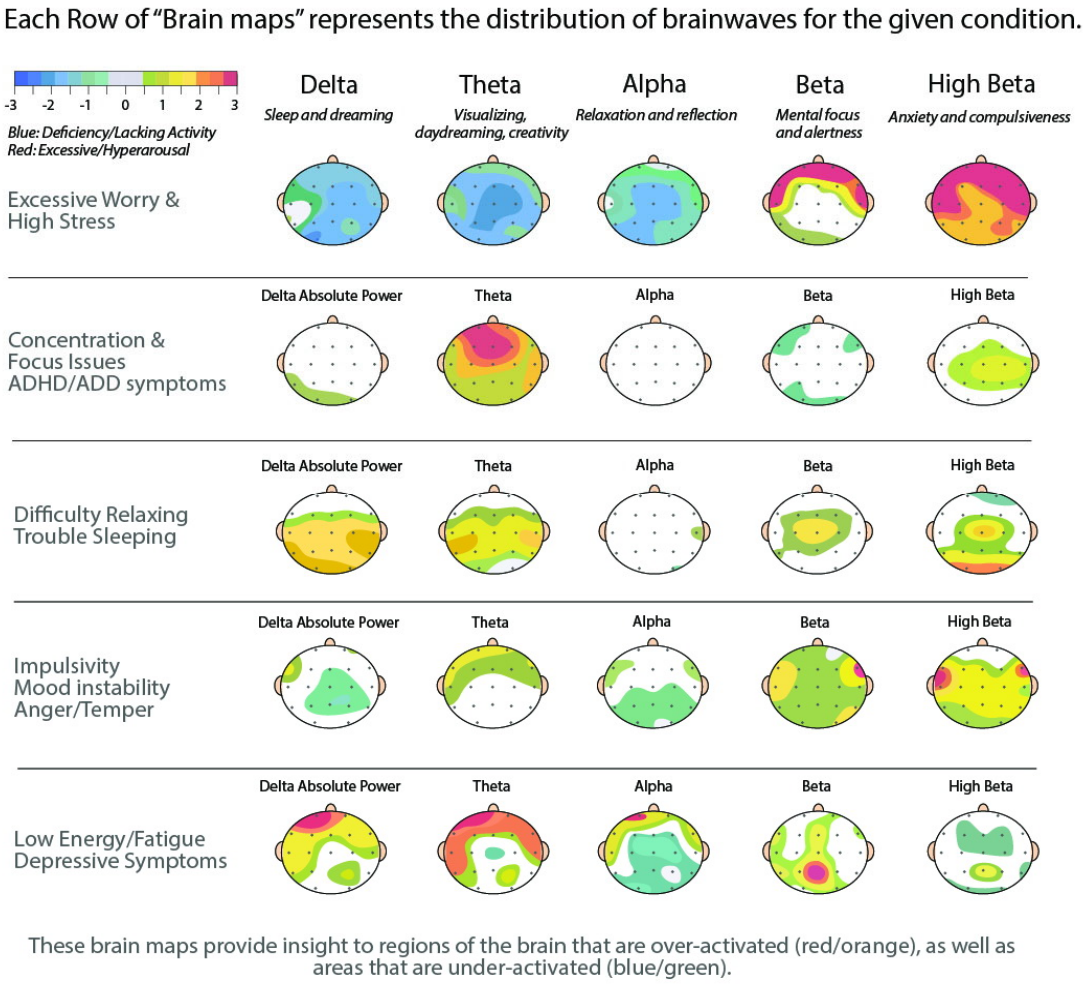
Quantitative Electroencephalography (qEEG) is a tool that processes the recorded EEG activity using a computer. Electrical activity is measured by analysis of brain wave patterns.
qEEG uses various algorithms, including wavelet analysis. The analyzed data is compared to a standard norm derived from a database.

The benefit is that this information is interpreted and used as a helpful tool to gain insight into cognitive function. In addition, it is used to monitor changes in brain function after introducing various interventions such as medications or neurofeedback therapy.

With advanced technology and techniques, we can now analyze the human brain has drastically improved. For example, advanced processing techniques and modern software offer the ability to use EEG data and QEEG data to view the various changes taking place in the brain during cognitive processing. This information is used to assist in identifying areas of the brain that are engaged and processing efficiently. Additional advances in neuroscience include Low-Resolution Electromagnetic Tomography (LORETA) and Independent Component Analysis (ICA).

How is qEEG Brain Mapping Used?

Using qEEG, we can visualize and understand how the various parts of the brain function under different conditions. Through this, we can identify areas working well and functioning abnormally. Once this information is obtained, a proper management plant can be created, which focuses on improving the areas functioning sub-optimally.



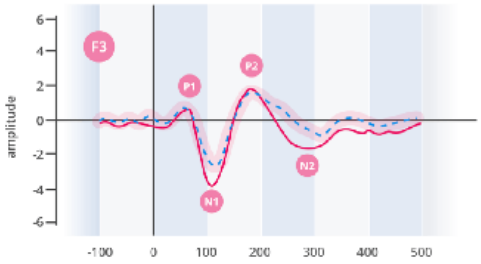
Event-related potentials (ERPs)

Event-related EEG paradigms aim to collect those brain processes triggered by external stimuli. For example, event-related EEG paradigms repeatedly present stimuli - 30 times or more. At the same time, stimuli are shown just very briefly for 200 to 1000 ms.

Take a look at the logic behind event-related EEG studies:

- There is ongoing solid EEG activity and random noise unrelated to the onset of a stimulus. Think of this as inner "default activity" (your ongoing thoughts and mental states).

- When a stimulus is presented (Visual or auditory), you trigger stimulus-related EEG activity. Here is one example: Showing the picture of a face (stimulus) triggers brain processes related to face perception. However, these processes are much smaller compared to the ongoing activity.



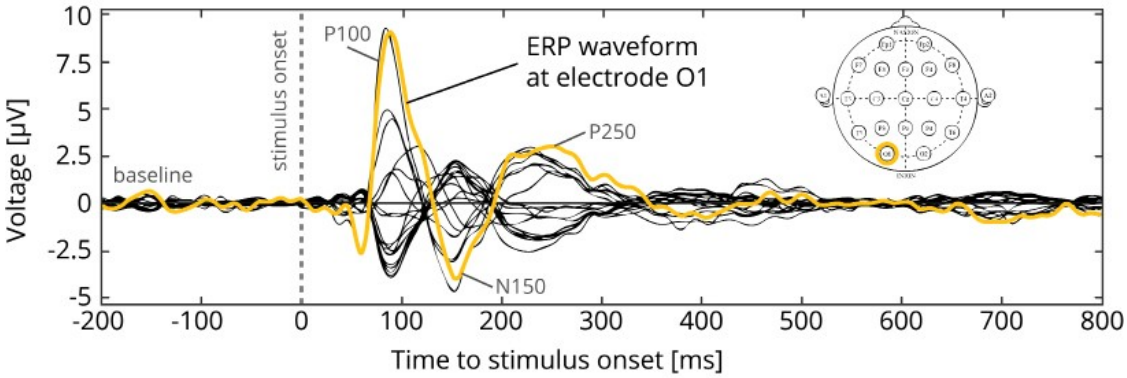
The stimulus-related EEG data is uncovered from the unrelated ongoing data by; the stimulus being shown - 30 times or more. At the end of the data collection, there will be 30 trials, data portions time-locked to stimulus-onset and typically range from about 200 ms prior to stimulus onset to 1000 ms after stimulus onset. Each trial is a time-course of data at each electrode. The selection of data portions from the continuous EEG recording is called epoching or segmentation (sometimes followed by a baseline correction of each trial where the average of the EEG data before each stimulus is subtracted from the data after the stimulus).

After excluding epochs containing artifacts (or the correction of data due to blinking, for example), the remaining epochs are averaged sample by sample, resulting in an average time-course of EEG data. Only the stimulus-related EEG activity survives by averaging the EEG time-courses of all trials. At the same time, the unrelated random background noise attenuates (the more repetitions you complete, the cleaner the event-related EEG data will be).

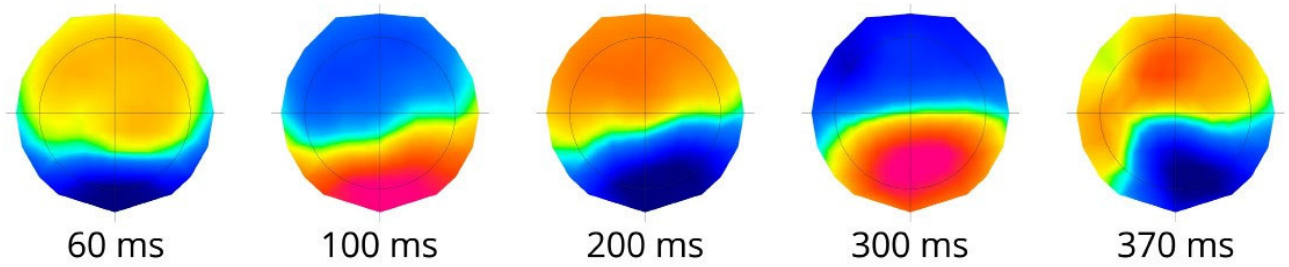
- The remaining average EEG waveform is the event-related potential, reflecting the average stimulus-related EEG activity triggered by a specific stimulus.

Research has identified ERPs for all sensory modalities - vision, touch and sound, olfaction, and haptic stimuli. All of these sensory stimuli trigger event-related EEG activity.

Several characteristics can describe ERPs: Appearance and shape, number, latency, amplitudes of the "wiggles," ERP components (positive and negative peaks), and topography (which is the voltage distribution at peak times across all electrodes). As a result, ERP components such as the N400, P300, or N170 represent some of the most broadly analyzed and well-understood ERP components in academic research.



They are plotting ERPs either as time-course or time-locked to stimulus onset. Alternatively, a sequence of voltage maps changes their distribution characteristics over time. It is dependent on stimulus properties or different internal states. Dependent on where the voltages are strongest (positive and negative poles), you can infer which brain regions are active at a given time.



Often, scientists compare ERPs of different experimental conditions - ERPs elicited by face stimuli compared to houses, for example. Alternatively, compare ERPs of different respondent groups - children who have Autism spectrum disorder vs. age-matched controls. In both situations, the analysis focuses on the differences in ERP latency, amplitude, or topographic distribution at specific time-points time-locked to stimulus onset between conditions.

ERP studies require two things:

- Stimulus repetitions. ERP cannot come from a single stimulus presentation (the EEG data will contain both stimulus-related and stimulus-unrelated aspects), repeating the presentation (think of 30 repetitions or more).

- Precise stimulus timing. Event-related paradigms assume that the EEG data of every single trial is precisely time-locked to stimulus onset. This requires that any stimulus onset markers must have been sent precisely at the moment of stimulus presentation. Unfortunately, whenever there is a randomly varying delay between the onset marker and the actual onset of a stimulus, the exact time-locking of the EEG data to stimulus onset cannot be guaranteed. As a result, the average ERP waveform might be washed out or vanish completely because the single trials are not perfectly aligned to the respective stimulus onsets. The only way to be sure about the actual stimulus onset on screen, for example, is to attach a photodiode on the stimulus presentation screen and store its brightness levels with the other data. The photodiode signal changes whenever a stimulus appears on the screen, properly aligning the data to the proper stimulus onset instead of a potentially incorrect onset marker.

ERP paradigms are used in the following application fields:

- General and experimental psychology use ERPs to uncover the brain dynamics related to sensory processing and how stimulus properties or combinations of different stimulus dimensions (shape and spatial location of letters, for example) modify brain network activity.

- Clinical psychology uses ERP studies to understand how cognitive brain processes are affected by neurological or psychological diseases. In this context, patient populations are compared to age-matched controls to compare defective and healthy processing of sensory stimuli. In addition, the differences in the ERP response between respondent groups allow insights into brain region activity affected by the disease.

- Biomedical engineering uses ERP designs in the context of Brain-Computer Interfaces.

Details on collecting and analyzing ERP paradigms are in Luck (2014).

Clinical use - Event-related potential (ERP)

An event-related potential (ERP) is the measured brain response directly from a specific sensory, cognitive, or motor event. More formally, it is any stereotyped electrophysiological response to a stimulus. The study of the brain in this way provides a noninvasive means of evaluating brain functioning.

An event-related potential (ERP) is any stereotyped electrophysiological response to an internal or external stimulus. In simple terms, any measured brain response directly results from a thought process or perception.

ERPs can be reliably measured using Electroencephalography (EEG). This method utilizes surface electrodes to measure the brain's electrical activity (specifically the cortex) through the skull and scalp. As the EEG reflects many thousands of simultaneously ongoing neuronal processes, the brain's response to a specific stimulus or event of interest is rarely visible in the ongoing EEG. In actual recording situations, even the most robust ERPs emerge only after many dozens of individual presentations of the stimulus of interest are averaged together. This technique cancels out noise and spontaneous EEG and enhances the voltage response to the stimulus, making it stand out clearly from the averaged-out background.

While evoked potentials may reflect the processing of the physical stimulus, they may also be modulated or even mediated by the "higher" processes involving memory, expectation, attention, or changes in mental state.

Evoked Potentials (EPs)

Event-related potentials (ERP) are also called evoked potentials (EP) and measure the brain's direct response to a specific sensory, cognitive, or motor event. EPRs can measure (to the millisecond) the brain's speed to process this information. This fast-paced processing allows us as humans to receive, filter, and process billions of pieces of information to make split-second decisions every second of every day. Due to the sensitivity of ERP testing, we can detect changes in this processing speed related to

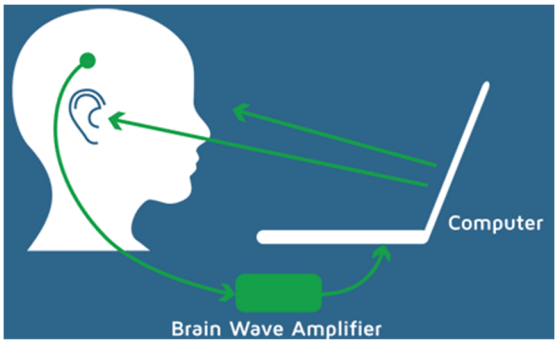
cognitive decline. Performing testing early on can show changes before becoming physically noticeable. As a result, the ERP can detect slowing in physical reaction times, decision-making skills, stress disorders, memory loss, and other neurological disorders.

Memory functions and cognitive processes within the brain can be measured using event-related potentials (ERPs). These waveforms represent time-locked neuronal responses generated in response to specific events or stimuli. The latency or time delay between the onset of the stimulus and a patient's physical response reflects brain processing speed. In contrast, waveform amplitude reflects neuronal recruitment and subsequent activation of the recruited neurons to process the information.

Fundamental memory elements include the degree of attention to a stimulus and the subsequent encoding of information for storage and retrieval. P300a and P300b are two ERP components useful in measuring these aspects of memory. The P300b component has been exceptionally well-studied regarding memory loss disorders, such as Mild Cognitive Impairment (MCI) and Alzheimer's disease (AD). When comparing AD to age-matched controls, AD patients had longer P300b latency measures and low amplitudes. P300b latency and amplitude can predict the progression of mild cognitive impairment. Additionally, P300b metrics demonstrate superior sensitivity over conventional assessments, such as the MMSE, detecting early preclinical memory loss.

Visual evoked potential (VEP)

A visual evoked potential is caused by a visual stimulus, such as an alternating checkerboard pattern on a computer screen. Responses are recorded from electrodes placed on the head and observed as a reading on an electroencephalogram (EEG). These responses usually originate from the occipital cortex, the area of the brain involved in receiving and interpreting visual signals.



When is the VEP used?

A doctor may recommend a VEP test when experiencing changes in vision due to problems along the pathways of specific nerves. Some of these symptoms may include:

- Loss of vision (this can be painful or non-painful)
- Double vision
- Blurred vision
- Flashing lights
- Alterations in color vision
- Weakness of the eyes, arms, or legs

These changes are often too subtle or not easily detected on clinical examination in the doctor's surgery. In general terms, the test helps detect optic nerve problems. This nerve helps transfer signals to see, so testing the nerve allows the doctor to see how the visual system responds to light. The test is also helpful because it can check vision in children and adults who cannot read eye charts.

What does the VEP detect?

The VEP measures the time it takes for a visual stimulus to travel from the eye to the occipital cortex. Therefore, it can give the doctor an idea of whether the nerve pathways are abnormal in any way. For example, the insulating layer around nerve cells in the brain and spinal cord (known as the myelin sheath) can be affected by multiple sclerosis. This means it takes longer for electrical signals to be conducted from the eyes, resulting in an abnormal VEP. On the other hand, a normal VEP can be fairly sensitive in excluding an optic nerve lesion along its pathways in the anterior part of the brain.

What the results may show

The VEP is beneficial in detecting past optic neuritis. Neuritis refers to inflammation of the optic nerve, associated with swelling and the progressive destruction of the sheath covering the nerve and sometimes the nerve cable. As the nerve sheath is damaged, it takes prolonged time for electrical signals to conduct to the eyes, resulting in an abnormal VEP. This may be seen in multiple sclerosis – one of the most common causes of optic neuritis (as above). Therefore, abnormal VEP's are seen in multiple sclerosis patients due to optic neuritis.

The following are less easily differentiated but may cause abnormal VEPs:

- Optic neuropathy can be due to damage of the optic nerve from several causes, including a blockage of the nerve's blood supply, nutritional deficiencies, or toxins. As the nerve is damaged, electrical signals do not conduct properly. Examples include diabetes in the advanced stages which can be associated with damage to the blood vessels and nerves supplying the eyes, or toxic amblyopia, which is a condition of the eyes associated with decreased vision due to a toxic reaction in part of the optic nerve.
- If the tumors or lesions compressing the optic nerve pathways for conduction are affected, an abnormal VEP appears.
- Glaucoma – patients who suffer from glaucoma have increased intraocular pressure (i.e., the pressure inside the eye). Pressure can damage the optic nerve, leading to prolonged VEPs.
- Ocular hypertension (high pressure) refers to any situation in which the pressure in the eye is higher than average. There are no signs of glaucoma, but patients may be at increased risk of developing glaucoma later in life.

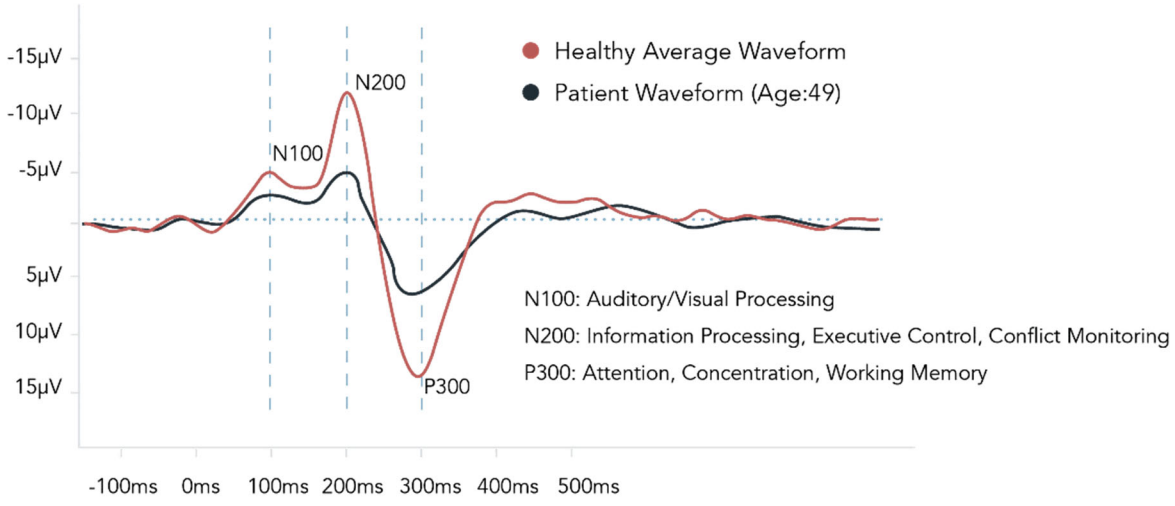
Clinical usefulness of the VEP

- The VEP is a standardized and reproducible test of optic nerve function
- It is more sensitive than magnetic resonance imaging (MRI) in detecting lesions affecting the visual pathway in front of the optic chiasm (area in the optic pathway where the optic nerve crosses sides)
- It is usually less costly compared to other investigations such as MRI
- If the results of the VEP are negative, this can be useful in excluding certain disorders.

What is an ERP Analysis?

An Event-Related Potential (ERP) is an electrical potential detected by Electroencephalography (EEG) used to understand how the brain processes visual and auditory information. It occurs after a sensory stimulus occurs. ERPs are measured while a patient is engaged in a task. It is an added tool used and often offers more detail than the standard detailed neurological examination.

ERP helps understand how the brain processes information and how long it takes to respond to sensory stimuli. Using ERP analysis, we better understand how the brain is processing while a patient is performing activities of daily living.



Data collected from the ERP test and subsequent analysis:

Results from the ERP test include amplitude, latency, and average amplitude for the ERP features extracted from the ERP wave. In addition, accuracy, false alarms, and reaction time for the target detection task associated with the test are also measured.
ERP peak "amplitude" is calculated as the difference between mean pre-stimulus baseline "0" and maximum peak amplitude. "Latency" is defined as the time point following stimulus presentation corresponding to the maximum amplitude (peak) for the specific feature. Finally, ERP "average amplitude" is defined as the averaged voltage over the time window specified for each feature. Average amplitude is highly correlated with amplitude for the same ERP features and likely shares the same functional interpretation. Thus, it can be used as a proxy measure to confirm amplitude data or in situations where an ERP peak might be challenging to identify.
For the target detection task, "accuracy" is calculated as the percent of correct responses to target tones, while "false alarms" indicate button presses to non-targets. "Reaction time" is calculated from stimulus onset to button press.

P50

The P50 is an early cortical potential elicited to standard and deviant stimuli. The amplitude increased in subjects at heightened risk of developing AD in response to standard stimuli. The increase in P50 amplitude is no longer significant in subjects with probable mild AD. However, these subjects still show an increase in the peak average amplitude. The P50 reflects neural activity in the temporal gyrus, an essential region for speech and language. Thus, an increase in P50 amplitude might reflect abnormal language function. Indeed, subjects with MCI have shown altered long-latency brain potentials associated with semantic processing.

N100

The N100 is a large, negative-going evoked potential that follows the P50. Its amplitude shows a significant decrease in subjects with mild AD. The N100 reflects bottom-up information such as stimulus characteristics. However, this ERP feature is modulated by attention and memory-related variables. Thus, the lower amplitude of the N100 in subjects with mild AD is consistent with attention and memory deficits in these subjects. Indeed, neuropathological studies show that sensory cortices are typically spared until the advanced stages of AD. A decrease in N100 amplitude could reflect changes in regulatory inputs from brain regions involved in higher cognitive processes and are more directly affected by the disease in its early stages. For example, the prefrontal cortex and the nucleus basalis have modulated auditory cortical responses to sound.

P200

The P200 is a positive deflection in the ERP wave that peaks at about 200ms after stimulus onset. Its functional interpretations include attention modulation of non-targets stimuli and stimulus classification [26]. It is suggested that individuals with reduced P200 amplitude have a weaker representation of auditory signals, which might contribute to slower reaction times to the stimuli and reduced accuracy in stimulus classification. Consistent with this hypothesis, subjects with mild AD have lower P200 amplitude than healthy individuals in response to the standard stimulus of the oddball paradigm and show lower accuracy and longer reaction time in the target detection task associated with the test.

N200

The N200 is a negative peak in the ERP wave for the target stimulus immediately preceding the P3b. This ERP feature is linked to the cognitive processes of stimulus identification and distinction, and its peak latency has been shown to correlate with measures of executive function and attention. In addition, published studies have reported delayed latency and smaller amplitude for the N200 in AD subjects. Indeed, N200 latency has proven helpful in separating AD subjects from subjects with mild cognitive impairment (MCI) and healthy controls (HC). In contrast, N200 amplitude has been combined with P300 latency to track longitudinal changes in overall cognitive function in MCI.

P3a

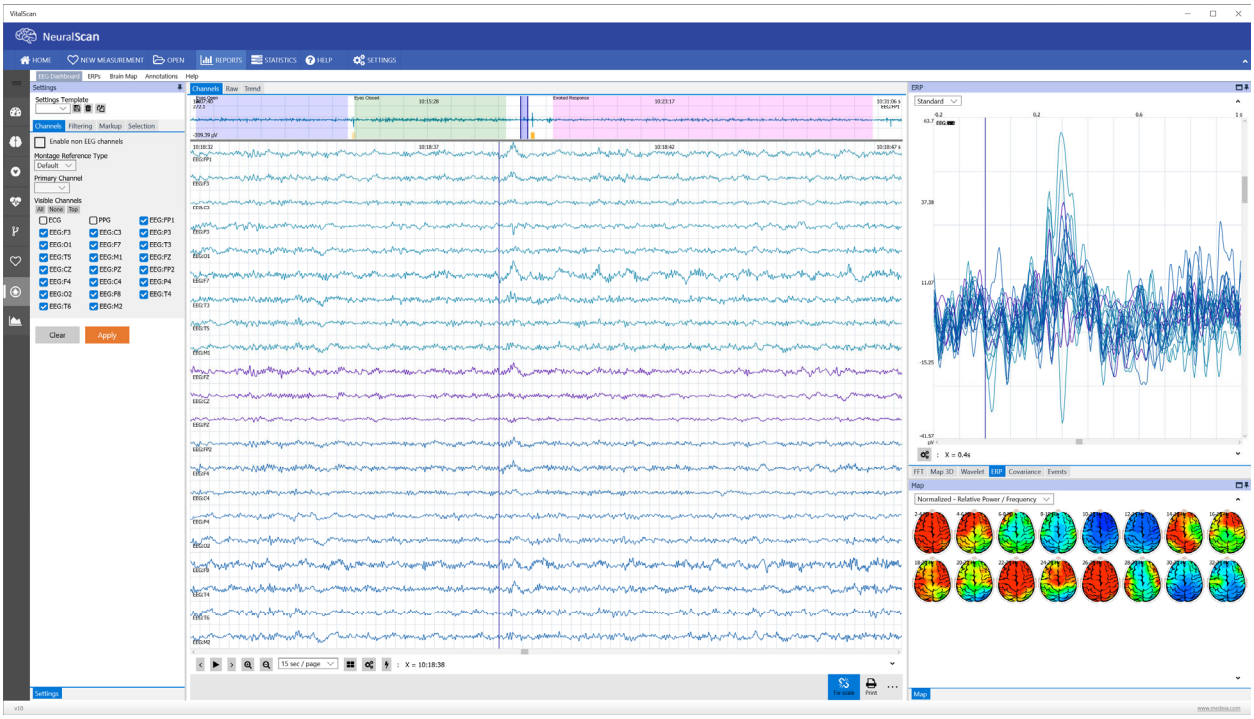
Inactive two-deviant oddball paradigms, the P3a is generated in response to the distractor stimulus. This ERP feature has been associated with the engagement of attention and processing of novel information [31]. The peak amplitude measures focal attention and has been positively correlated with executive function. The P3a latency reflects orientation to a non-target deviant stimulus [33]. Consistent with reports of decreased attention and executive function in neuropsychological testing in subjects with mild AD, P3a amplitude is significantly reduced in this population. Moreover, the significant group differences in P3a amplitude and reports of a decline in attention and some executive skills very early in the disease suggest that this ERP feature could be a valuable measure of the cognitive deficit since the preclinical stage of AD.

P3b

This ERP feature elicits a deviant stimulus associated with a task and reflects working memory updates. P3b amplitude is determined by the number of attentional resources allocated when updated working memory. P3b latency reflects stimulus evaluation and classification speed. Most studies examining differences in P3b between AD subjects and HC have found that P3b amplitude was typically more minor, and P3b latency was longer in subjects with AD. Moreover, when subjects were administered an oddball auditory paradigm similar to the one used for BrainView® testing, group differences were more prominent for P3b amplitude than latency.

Slow Wave

The Slow Wave is a negative deflection that follows the P3b. This ERP feature has frontal and central scalp distribution and reflects a final stage of stimulus evaluation. Slow Wave amplitude correlates with task demands. It is inversely correlated to stimulus detection accuracy, suggesting that an increase in peak amplitude might require further stimulus processing. Slow Wave latency is affected by task difficulty. The relative ease of categorizing events in an oddball test probably accounts for the slow wave's early onset and short duration in this ERP paradigm [40]. Slow Wave latency is recently delayed in subjects with mild AD. These data are consistent with a previous report of increased Slow Wave latency in MCI and suggest that AD subjects require more time for stimulus processing than HC.



Source Analysis – Brain 3D Mapping

We attempt to bridge the gap between surface EEG data and the respective neural source generators: EEG dynamics reflect the collective action (superposition) of many neuronal systems distributed across the brain with EEG source analysis. Source analysis disentangles the different neuronal sources and hints where and when it happened. Information pathways in the brain can be studied using either the reconstructed activation waveforms or time-frequency analysis. Source analysis can identify the brain regions involved in different tasks and depend on data quality and model quality, yield a precise localization of the generators in both space and time.

What is Loreta

Neuro-imagining techniques aim to represent the structure or functioning of the brain. They can be understood as an X-ray photograph of the brain that, in the case of functional imagining, will show the brain areas activated during a process or cognitive task, and techniques such as EEG or MEG are examples.

Pascual-Marqui, Michel, and Lehman published in 1994 a new method for localizing the electrical activity in the brain based on scalp potentials from multiple-channel EEG recording. This method solves the inverse problem: convert measurements into information about a physical object or system observed. This revolutionary technique was called LORETA, standing for low-resolution brain electromagnetic tomography, and can be understood as an EEG-based neuro-imagining technique. Loreta computes a three-dimensional distribution of 2394 voxels of 7x7x7 mm, generating electric neuronal activity in the grey matter. A significant advantage of this technique is that it is not restricted to a certain number of electrodes or electrode locations. Therefore, it self-adapts to almost every electrode set-up and EEG measuring device.

- **sLORETA**: standardized low-resolution brain electromagnetic tomography (Pascual-Marqui, 2002). It has no localization bias in the presence of measurement and biological noise.

- **eLORETA**: exact low-resolution brain electromagnetic tomography (Pacual-Marqui 2005). The first-ever 3D, discrete, distributed, a linear solution to the inverse problem of EEG/MEG with exact localization (zero localization error).

Scalp EEG activity shows oscillations at a variety of frequencies. This rhythmic activity divides into frequency bands, and the most commonly known bands are delta, theta, alpha, beta, and gamma. EEG frequency bands have been noted to have particular biological significance and are associated with different brain functioning states. There are still uncertainties about exactly where various frequencies are generated. However, on the contrary, there is substantial knowledge about the activated areas within the brain that generate specific spectral activity along the scalp. Loreta analysis of limited frequency bands can determine which brain regions are activated during different states or mental tasks, helping determine if the brain operates in an optimal electrical way.

Loreta voxels are located in fixed positions within the brain's grey matter. It is always interesting to analyze the activation on single voxels and entire regions associated with specific brain functionalities, and Brodmann areas can be an example. Broadman areas are regions of the cerebral cortex that were defined at the beginning of the 20th century based on their cell organization. Afterward, they were proven directly related to specific brain activities such as audition, vision, and motor functionalities.

Since the beginning of 2001, Loreta has also been used for Neurofeedback, expanding its use. So far, studies are replicating other findings in the areas of Neurofeedback with clinical populations, and they look to be more cost-effective than Neurofeedback for treating deep cortical structures. If interested in Loreta's use for Neurofeedback, Dr. Leslie H. Sherlin's dissertation is about Loreta and Neurofeedback here.

Loreta is now a well-extended EEG analysis technique used worldwide. Its versatility, and the fact that the number of EEG channels and channel location is not fixed, make it possible to use this technique with almost every EEG sensor and experimental set-up. Furthermore, the possibility of studying both simultaneously as the voltage measured at the scalp surface and the 3D distribution of the generating electric neuronal activity is a potent analysis tool worth taking into account.

BrainView has been developing and evolving Loreta.

Behavior Metrics

A natural process of aging includes the decline in neurophysical and cognitive abilities. Behavior performance can be measured as it relates to the daily stressors that everyone faces, including neuro-physical, emotional, and mental challenges. The observable changes can include changes in reaction time, errors in commission (how often you make mistakes), and omission errors (how often you miss information).

These performance measures can provide an accurate snapshot and an objective assessment of a patient's ability to effectively perform general or routine daily tasks and indicate the declining level.

Frontal asymmetry

Over the last decades, frequency-based analyses of EEG data have become much more sophisticated. One of the more advanced frequency-based metrics is frontal asymmetry or frontal lateralization.

This index of engagement and motivation typically uses beta (12 – 25 Hz) or gamma (> 25 Hz) band power, particularly in electrodes over frontal cortical regions (channels F3 and F4, for example). Researchers have consistently found that higher band power in the left vs. right frontal cortex indicates positive feelings, engagement and motivation (see Davidson, 2004; Schaffer et al., 1983). In addition, recent evidence suggests that frontal lateralization can be used to test respondents' engagement when confronted with media ads, physical products, and services (Astolfi et al., 2008; Vecchiato et al., 2012; Yilmaz et al., 2014).

Based on research on EEG biomarkers of stable personality traits for curiosity and excitement for novel stimuli, frontal lateralization reflects a person's momentary "approach-avoidance" tendencies to either engage or withdraw. Indirectly, this short engagement also reflects one's motivation (Harmon-Jones et al., 2010). Additionally, larger left-frontal band power may serve as an index of engagement-related emotions such as joy. In comparison, larger right-frontal band power might indicate negative emotional states (disgust, fear, or sadness, for example).

For example, EEG data from respondents watching TV advertisements would like to know which ads and which scenes drive the engagement levels of a target audience and which ones should be revised before market launch. In this case, frontal asymmetry can be computed relatively quickly from the continuous EEG data. The two electrodes needed are F3 and F4. Almost all EEG headsets comprise these standard locations. If the EEG system does not have electrodes F3 and F4, use electrodes near the original F3-F4 locations.

Cognitive-affective metrics

In addition to frequency-based brain signals associated with engagement and motivation, academic and commercial research investigates cortical processes underlying mental workload or drowsiness.

Continuous monitoring of respondents' fatigue levels, attention, task engagement, and mental workload in operational environments is beneficial in scenarios where wrong behavior could potentially result in hazardous situations. For example, drowsiness and task engagement in power plant controllers are helpful to analyze how the brain responds to generally very monotonous environments. (if everything goes well) and how cortical workload and engagement scores adapt to rare but occasional disasters or life-threatening situations. In addition, this information can be used to optimize devices, software interfaces, or entire work environments that increase engagement, motivation, and productivity.

Besides, the continuous extraction of psychophysiological markers of engagement and vigilance from ongoing brain activity allows the design of closed-loop systems, which provide feedback on cognitive, affective, and attentional states. In other words: Whenever brain-based workload or drowsiness levels exceed a specified threshold value (or engagement levels fall below a specific value), respondents can be notified to initiate counteraction. This strand of research will continue to grow in the next couple of years, designing entirely adaptive systems which respond fully automatically to brain-based user states.