Introductory Guide
to EEG & BCI for Entertainment

NeuroSky®

Body and Mind. Quantified.

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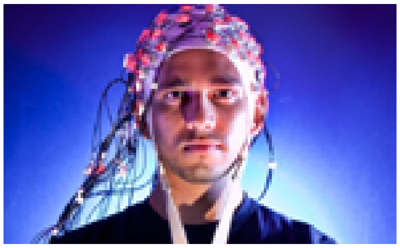
EEG (electroencephalogram) and BCI (Brain-Computer Interface) technology are on the cutting edge of some of the most impressive entertainment experiences available today (and yet to come!). So you can begin imagining the possibilities. This introductory guide will provide important information on what exactly EEG and BCI technologies are and how they work. Along the way, you'll be introduced to a few key terms to keep in mind when you begin to explore the technology more deeply. There's a lot to understand, so we'll try to keep this light, yet informative!

EEG Decoded: Begin With the Basics



To have a better understanding of EEG technology, you first have to know what an EEG is. As defined by the Mayo Clinic, an EEG is "A test that detects electrical activity in your brain using small, flat metal discs (electrodes) attached to your scalp." Your brain cells, which are commonly referred to as neurons, communicate via electrical impulses and are constantly active and managing how you think, react, and interact with the world, even when you're asleep! Essentially, what we call "thought" is an ever-changing concert of electrical impulses. The average human brain has about 100 billion neurons, and an EEG test can track changes in neuron activity that may be useful in diagnosing brain disorders.

An EEG setup can be quite a sight depending on the number of electrode attachments it includes. Once these electrodes are positioned on the head, an EEG test can take upwards of 60 minutes. While that may seem long, it's important to note that an EEG test is perfectly safe for both children and adults. This is because it is a passive (listening) device that captures brainwave signals without emitting any harmful electrical signals of its own.

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Capturing Raw EEG Data

When an electrode captures neuron activity, it also captures all of the electrical activity that is taking place in its proximity. This combined activity is what is known as raw EEG data. Raw EEG data is a complex wave form of not simply brainwave activity, but the electrical activity of nearby muscles, electrode motion interference and what is called "ambient noise" (caused by electrical supplies and appliances in the room). These noise sources are called artifacts.

Understanding Raw EEG Wave Forms

In order to have a better overall understanding of raw EEG wave forms, consider the following analogy:

Suppose I drop a pebble (neuron) into the middle of a still pond (brain surface). That action creates a pure wave (brainwave). Meanwhile, as my official wave collector, you are eagerly waiting for that wave to arrive to you on the shore so you can measure it (electrode). On its way, your wave encounters a few disturbances such as a floating log, swimming fish and a motor boat (artifacts). These encounters disrupt and transform the wave such that, by the time it arrives, it's no longer in its original shape.

Because raw EEG wave forms can be dramatically changed by artifacts, they need to be filtered. The result of this process is a filtered EEG—an EEG with all artifacts and extraneous information removed.

Artifact removal is one of the greatest challenges for EEG. Think about how difficult it would be for you to somehow restore the original wave form in the previous pebble example!

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EEG Band Frequencies

An EEG has different "bands", defined by the frequency of the waves; delta (slow) waves are less than 4 Hz; theta bands are 4-8 Hz, alpha bands range from 8 to 12 Hz, beta bands from about 14-30 Hz, and gamma bands from 30-80 Hz. A Fast Fourier Transform (FFT) is used to separate a wave into its bands. EEG bands are associated with different states of mental activity.

Back to our pebble example, assume that instead of one pebble, many different-sized pebbles (multiple neurons) are dropped at random times into the pond, creating a multitude of overlapping waves. Thus, the wave you see at the shore (electrode) is made up of a composition of many other waves having different heights (amplitudes) and speeds (frequencies), all sort of running into each other. Your job, as the wave collector, is to separate out and classify these individual waves (band frequencies).

EEG bands provide insight into our mental and emotional states of mind at any given time. But, how does one go from a squiggly waveform to a meaningful interpretation? The answer is algorithms. EEG algorithms, also known as interpretive models, help to identify and quantify categories of mental or emotional states.

On an important side note, today's EEG algorithms are not sophisticated enough to interpret a person's actual thoughts. Therefore, many privacy concerns sometimes expressed by the general public pertaining to EEG's somehow "knowing what I'm thinking" are quite fallacious.

BCI Decoded: What is BCI?

NeuroSky's mission is the proliferation of consumer EEG technology into mainstream use cases by enabling our partners to design and manufacture wearable BCI devices.

Brain-computer interface (BCI) is a technology that captures the brainwave signals of a user, and transmits that information to an external device (e.g. computer) with processing capability in order to execute some action on that data. For example, using EEG biosensors, a BCI headset from NeuroSky would capture and transmit a user's brain data to a tablet. Running on the tablet is an application, such as a video game, that uses the brain data to manipulate the action within the game. Think of a BCI headset in the same way that you might think about using a mouse or a video game controller, except the input is not from button clicks or joy stick motion—it is from your own brainwave information.

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Headset Design Considerations

BCI headsets can be designed using two different approaches:

- Stand-alone – the singular function of the headset is to deliver BCI-related output. An example of a stand-alone headset is NeuroSky's MindWave Mobile that has one single purpose: to deliver the BCI information to a platform (laptop, tablet, smartphone, console, toy, etc.).
- Multi-purpose – the primary function of the headset is to support some non-BCI purpose while the secondary function is the BCI-related output. An example of a multi-purpose headset is a standard gaming headset with headphones and microphone along with a BCI component. The primary function of the headset is to support communication between gamers along with a more refined audio experience. The BCI element offers a secondary value-add. Another emerging multi-purpose device is the virtual reality HMD (head-mount display) whose form factor is compatible with some BCI solutions. An HMD's primary role is to configure an AR or VR experience. The secondary function is delivered by the BCI data that acts as a supplement to the overall experience.

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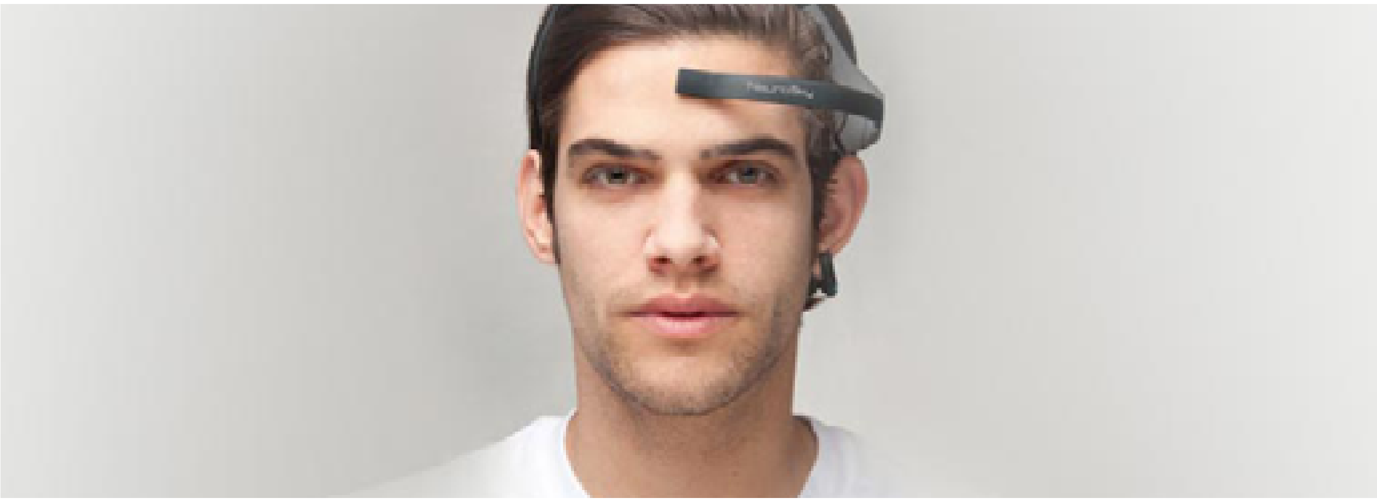
The chief advantage of the multi-purpose headset over the stand-alone is that the gaming community already uses (and is comfortable using) traditional, non-BCI gaming headsets on a massive scale. Adding a low-cost BCI component to next-generation devices augments their value by enabling its users to play either BCI-enabled or non-BCI-enabled games. Thus, the BCI add-on could essentially be turned off or the data ignored when the games played do not require BCI, but turned on when they do. Thus, it's a 2-for-1 deal for the consumer and, more importantly, a more gradual introduction of BCI technology into the gaming world through the traditional peripheral integration path. This logic can be applied equally to all genres of entertainment headset peripherals outside of gaming. On the other hand, stand-alone headsets require users to play only BCI-enabled games. This might be a less expensive approach, but it is more disruptive to the existing gaming ecosystem and a more challenging beach head to establish.

Which headset approach you take is an important consideration when an OEM is evaluating a possible BCI headset project.

The Top 10 Things OEMs Should Look for in BCI for Entertainment

NeuroSky and its product solutions offer many important advantages to the OEM / ODM Entertainment partner, including:

- Single-channel EEG sensor modules - reduce head contact points for fast, reliable headset placement and more aesthetic designs options
- Dry electrodes – no messy gels or solutions
- Low Cost - sensors meet sensitive consumer market price points for end-products
- Turn-key – one-stop shop for sensors & algorithms
- Flexible – sensor hardware adapts to various form factors (with or without headphones, multi-sensory, HMD, etc.) and I/O options
- Ease-of-integration – small footprint and minimal wiring requirements
- Robust developer tools – application development has never been easier
- Support – layers of technical support and design services at your disposal
- Brand – the most recognized brand in the consumer BCI business
- Track record – proven supplier to recognized brands in the entertainment industry



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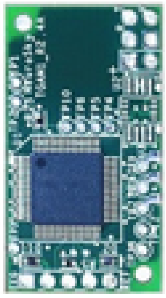
Special Note: Embedded Design Considerations for Algorithms

From a hardware perspective, the TGAM1 sensor module is an embedded solution, meaning that the processing for NeuroSky's first two algorithm releases, Attention (concentration) and Meditation (relaxation), is completed on the module ("on-chip"). All other algorithms require "off-chip" processing as indicated in the table.



Algorithm	Where Processed?	Off-Chip Options	
Attention	On-Chip (TGAM1)	N/A	
Meditation			
Blink	Off-Chip	MCU Board (on headset) ARM M4 equivalent or higher	Platform Processor Smartphone, tablet, laptop
Mental Effort			
Familiarity			
Appreciation			

Where any off-chip algorithm is processed is an important design consideration that depends on the OEM's particular end-product requirements.

- On-Chip – least costly, fastest time-to-market approach; limited to only Attention and Meditation releases; utilized when processor on remote platform (e.g. toy) is restricted and product cost reduction is essential
- Off-Chip / Platform – average cost (certain SDK license fees may apply), fast time-to-market approach; supports all algorithms; utilized when processor on remote platform (e.g. laptop, tablet, smartphone) has no sharing restrictions.
- Off-Chip / MCU Board – most costly, longer time-to-market approach; supports all algorithms; utilized when processor on remote platform (e.g. a more expensive hand-held device) is restricted, but non-embedded algorithms are essential to the overall product solution; Note: the MCU board is not supplied by NeuroSky

For data specification information on TGAM1, please click here.

NeuroSky: Trailblazers in Consumer BCI Technology

NeuroSky's mission is the proliferation of consumer EEG technology into mainstream use cases by enabling our partners to design and manufacture wearable BCI devices. Some NeuroSky highlights include:

- Consumer Brain-Computer Interface (BCI) technology pioneer
- First EEG biosensor chip launched in 2007
- EEG biosensors, algorithms & wearable BCI peripheral manufacturer
- Core technology (B2B) enabler ("Intel Inside" Model)
- Largest consumer BCI developer / OEM partner community in the world
- Broad vertical market (entertainment, health/wellness, education) applicability

Are you interested in partnering with NeuroSky for your breakthrough BCI device? If the answer is yes, then schedule a discovery call with us today and find out how we can help you take your project to the next level.

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