muse™

the brain sensing headband

TECHNICAL SPECIFICATIONS, VALIDATION, AND RESEARCH USE

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INTRODUCTION TO MUSE

Muse: the brain sensing headband, is an electroencephalography (EEG) technology. EEG is a well-established, non-invasive, harmless method of recording the electrical activity of groups of brain cells. EEG provides robust real-time insight into the brain; and Muse is the most versatile and easy-to-use EEG system available.

MUSE FOR CONSUMERS

Muse is designed as a personal meditation assistant. It can pair with any tablet or smartphone and operate with the Muse application, which trains the user in meditation exercises and records EEG data.

Novice meditators usually struggle with two issues: knowing whether they are “doing it right,” and staying motivated. Muse addresses these issues by providing real-time “state of mind” feedback, and offering an engaging motivational framework.

Muse makes meditation easy.

MUSE FOR SCIENTISTS, CLINICIANS, AND RESEARCHERS

Muse is used in hospitals, clinics, and universities worldwide as a research tool. The research domains extend from cognitive neuroscience, to brain health, psychotherapy, music cognition, and more.

Institutions currently using Muse in research include Harvard, Stanford, MIT, Mayo Clinic, NYU, McMaster University, University of Toronto, University College London, and many others.

The Muse Professionals Program is a platform for clinicians and coaches to use Muse with their clients.
http://professionals.choosemuse.com

Muse is extremely accessible. It is wireless (Bluetooth), lightweight, flexible, adjustable, and easily worn with less than one minute of set-up.

Muse uses two channels on the left and two on the right, so it is ideal for exploring hemispheric asymmetries.

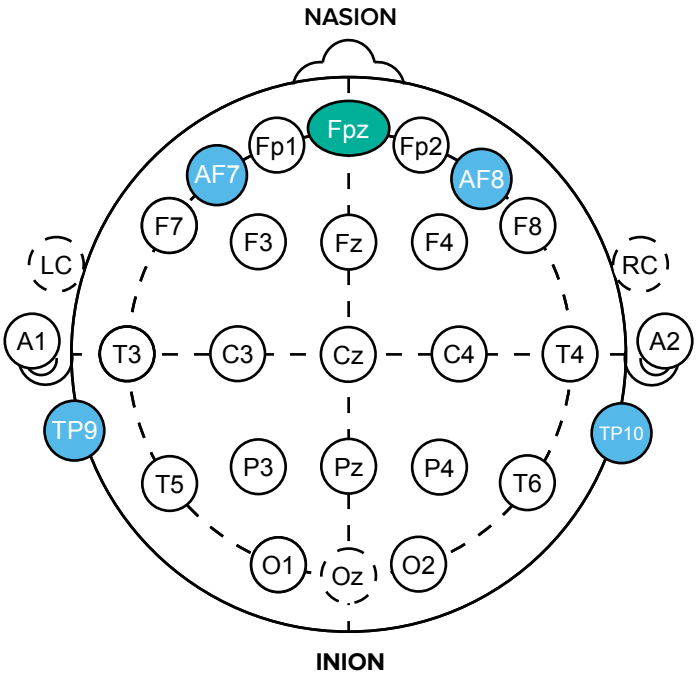
Muse has two micro-USB ports on the back of the ear pods where two auxiliary electrodes can be attached. These electrodes can be used to measure EMG, ECG, or EEG on other areas of the head or body.

MUSE ELECTRODE LOCATIONS

Muse electrode locations by 10-20 International Standards.

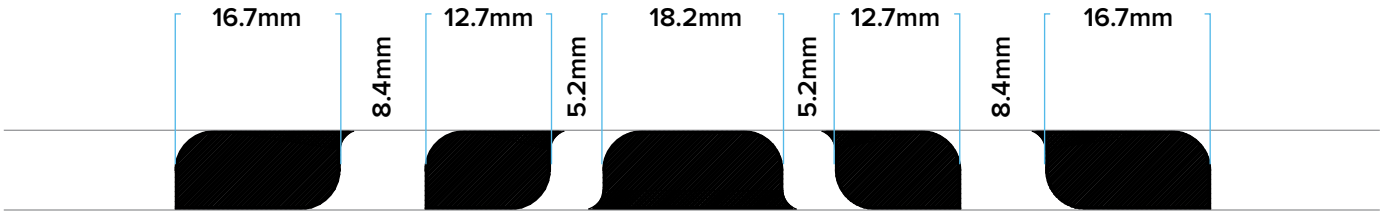
Reference

Channel



The channel electrode positions AF7 and AF8 are based on the size of an average adult head. While the earpieces of Muse are adjustable, the flex band is not. Using Muse on a smaller or larger head may change the positioning of the AF7 and AF8 channel electrodes. For example, on a smaller than average head, AF7 may become closer to F7 and AF8 may become closer to F8.

Below are the measurements between the channel electrodes on the flex band. Use these to determine if there is any change in electrode position based on head size.



TECHNICAL SPECIFICATIONS

Muse 2014

WIRELESS CONNECTION	Bluetooth 2.1 + EDR
EEG CHANNELS	4-6 Channels
	220Hz or 500Hz
	10 or 16 bits / sample
REFERENCE ELECTRODE POSITION	FPz (CMS/DRL)
CHANNEL ELECTRODES POSITIONS	TP9, AF7, AF8, TP10 (dry)
BATTERY LIFE	Maximum 5 hours (rechargeable Li-Ion)
CHARGING TIME	2.5 Hours
MATERIALS	Silver (frontal electrodes), Conductive silicone-rubber (temporal electrodes)
WEIGHT	61g
DIMENSIONS	Minimum head circumference 52cm
	Maximum head circumference 60cm
ACCELEROMETER	Three-axis @ 50Hz, 10 bit resolution, range +/- 2G
GYROSCOPE	None
INPUT RANGE	2mV p-p AC coupled signal
NOISE SUPPRESSION	DRL – REF feedback with 2µV (RMS) noise floor
	50 or 60Hz notch filter (regional)
MUSE APP COMPATIBILITY	iOS, Android
RESEARCH TOOLS	MuseIO, MuseLab and MusePlayer
RESEARCH TOOL COMPATIBILITY	Windows, Mac OS, Linux
LIBMUSE COMPATIBILITY	iOS, Android
MICRO-USB PORTS	2

TECHNICAL SPECIFICATIONS

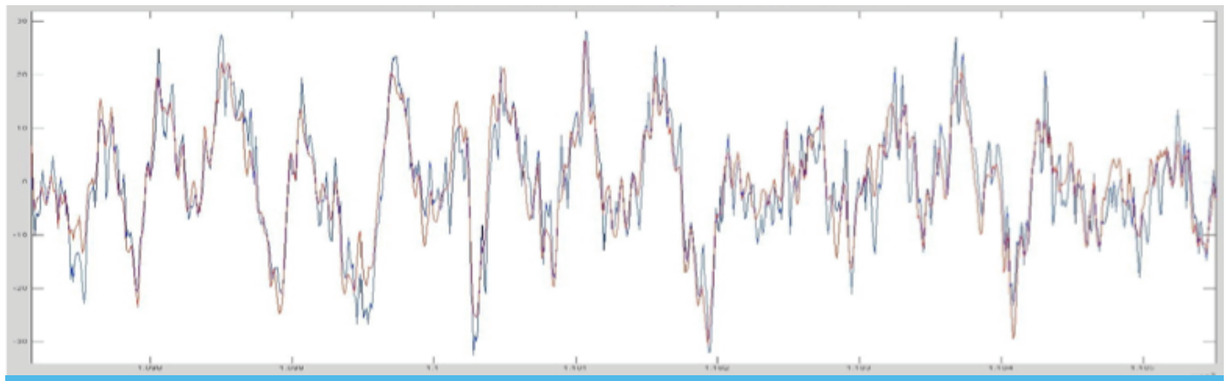
Muse 2016

WIRELESS CONNECTION	BT 4.0 BTLE
EEG CHANNELS	4-5 Channels
	256Hz
	12 bits / sample
REFERENCE ELECTRODE POSITION	FPz (CMS/DRL)
CHANNEL ELECTRODES POSITIONS	TP9, AF7, AF8, TP10 (dry)
BATTERY LIFE	Maximum 10 hours (rechargeable Li-Ion)
CHARGING TIME	2.5 hrs on slow charge, 1.5 hrs on fast charge
MATERIALS	Silver (frontal electrodes), Conductive silicone-rubber (temporal electrodes)
WEIGHT	60g
DIMENSIONS	Minimum head circumference 52cm
	Maximum head circumference 60cm
ACCELEROMETER	Three-axis @ 52Hz, 16 bit resolution, range +/ - 4G
GYROSCOPE	+/- 1000 degrees per second
INPUT RANGE	2mV p-p AC coupled signal
NOISE SUPPRESSION	DRL – REF feedback with 2µV (RMS) noise floor
	No notch filter onboard
MUSE APP COMPATIBILITY	iOS, Android
RESEARCH TOOLS	MuseLab and MusePlayer
RESEARCH TOOL COMPATIBILITY	Windows, Mac OS, Linux
LIBMUSE COMPATIBILITY	iOS, Android
MICRO-USB PORTS	1

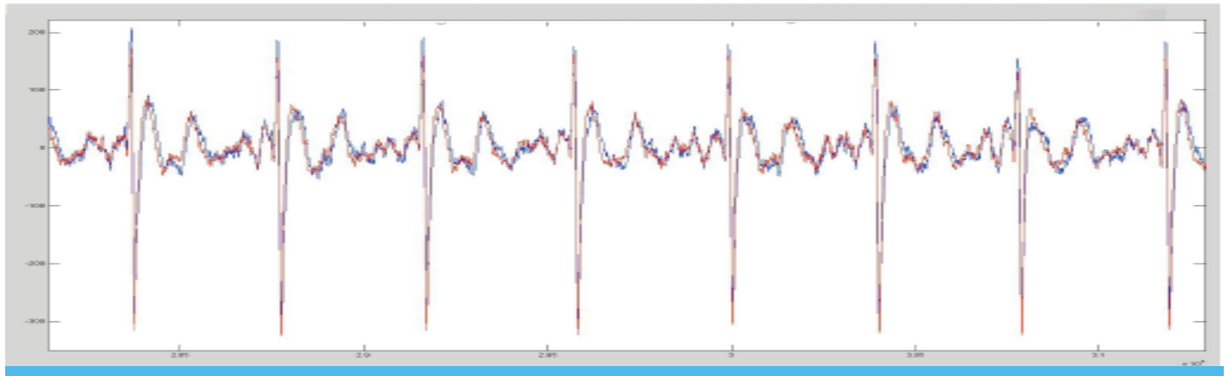
RESEARCH VALIDATION

Muse has been tested against industry standard EEG systems including the Brain Vision actiCHamp system and the g.Tec g.USBamp system. Muse achieves comparable performance in voltage trace comparisons and in patterns of total and hemispheric power.

Voltage Trace Comparison (Muse in red, actiCHamp in blue):



Right ear (TP10) voltage comparison.

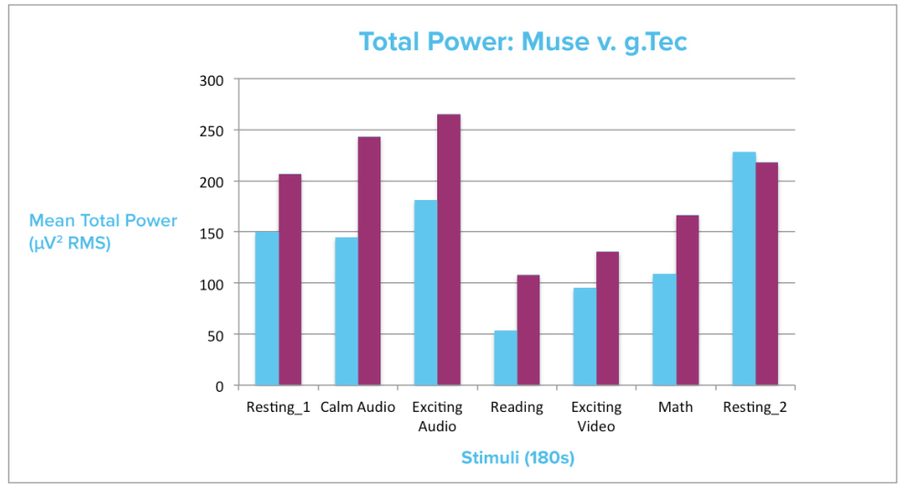


ECG voltage comparison on the left collar bone.

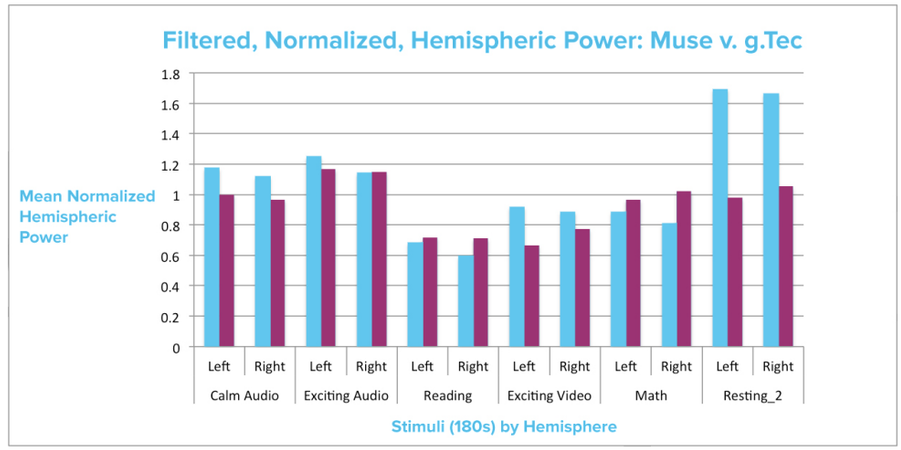
g.Tec Comparison:

McMaster University's LIVELab compared Muse with g.Tec's research-grade gel-electrode EEG system. Both Muse and g.Tec distinguished patterns of brain activation in a standard battery of cognitive tasks.

Muse was sampled at 220Hz across four channels while g.Tec was sampled at 256Hz across eight channels (FPz, Fz, Cz, Oz, F5, P7, F6, P8), with bandwidth filtered from 1-60Hz. Below are two figures which display the comparison of EEG measures. As shown, the pattern of activation is similar between the technologies.



Total power, calculated as the median variance across 180 1s epochs, across stimuli, averaged across electrode channels, averaged across participants (n=11).



Hemispheric power, pre-filtered to 1-40Hz, normalized to the preliminary resting phase, with g.Tec re-referenced to FPz, calculated as the median variance across 180 1s epochs, averaged between hemisphere electrodes (Muse channels 1,2 (left) and 3,4 (right), g.Tec channels 5,6 (left) and 7,8 (right)), across stimuli, across participants (n=11).

VISUALIZING AND RECORDING EEG

Muse is an open platform: anyone can record raw data with Muse and anyone can build their own Muse application. EEG data can be recorded with MuseLab, MusePlayer, or via the third-party mobile application MuseMonitor (for Android and iOS).

The following tools for researchers and developers are provided in the free SDK (Download the SDK at **http://choosemuse.com/developers**) :

RESEARCH TOOLS

SOFTWARE TOOLS TO RECORD AND ANALYZE MUSE DATA.

MuseIO:
- A desktop driver to stream Muse data over OSC or LSL.

MuseLab:
- Visualize, record, and filter Muse data.

MusePlayer:
- Reroute, replay, and convert Muse data to a variety of formats including MATLAB, .muse, and .csv.

LIBMUSE

A LIBRARY FOR BUILDING NATIVE MUSE APPLICATIONS.

Data includes:
- Absolute and relative power for delta, theta, alpha, beta, and gamma, for each channel.
- FFTs for each channel.
- Proper fit indicator for each channel.
- Blink event.
- Jaw clench event.

Muse's free desktop visualization and recording suite provides rich, raw EEG data, raw accelerometer data, raw spectra (delta (1-4Hz), theta (4-8Hz), alpha (8-13Hz), beta (13-30Hz), gamma (30-44Hz)), total power, artifact detection (eye blink, jaw clench), Fast Fourier Transform (FFT) coefficients, experimental brain-state classifiers, and more.

MuseLab screenshot featuring raw EEG, raw ECG, and raw accelerometer.

For any inquiries into the technical specifications, validation, or applications of Muse, please visit: **http://developer.choosemuse.com**, or contact **community@choosemuse.com**.