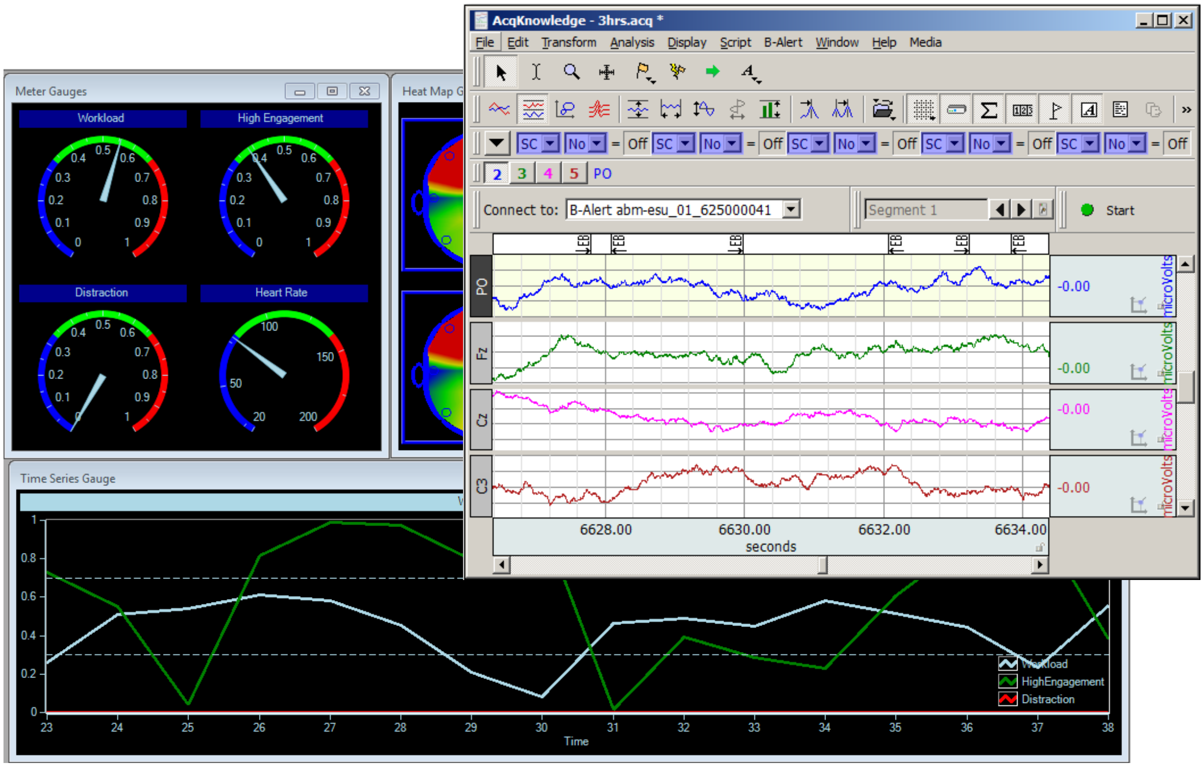
B-Alert with Acq*Knowledge* Quick Guide

Benchmark Acquisition and Cognitive States Analysis



42 Aero Camino, Goleta, CA 93117
Tel (805) 685-0066 | Fax (805) 685-0067
info@biopac.com | **www.biopac.com**

Distributed by BIOPAC Systems, Inc. Manufactured by Advanced Brain Monitoring, Inc.

Table of Contents

Introduction

Welcome to the B-Alert® with Acq*Knowledge* Quick Guide. The purpose of this manual is to familiarize Acq*Knowledge* users with the optionally licensed B-Alert® wireless EEG Cognitive States Analysis software, as well as the various screens and file formats generated during an EEG study subject's Benchmark Definition file session.

What is B-Alert?

B-Alert is a is a Bluetooth wireless system and sensor headset integrated with Acq*Knowledge* software to record up to 9 channels of monopolar EEG, plus one optional channel of ECG data. B-Alert Cognitive States Analysis software can be additionally used to create a "Benchmark" file of a subject's EEG profile by administering a series of simple onscreen tests, and storing the resulting session data as a permanent reference for future EEG recordings. The B-Alert Brain State Gauges can be used to display a real-time view of B-Alert headset data as it is being acquired. The EEG data itself is recorded in Acq*Knowledge* via the wireless B-Alert hardware.

Although the B-Alert Cognitive States Analysis software covered in this manual is a stand-alone application manufactured by Advance Brain Monitoring Inc®, the following B-Alert features are fully accessible via the Acq*Knowledge* application's hardware* menu:

- B-Alert Headset Check Impedance
- B-Alert Headset Benchmark Session
- B-Alert Generate Definition File
- B-Alert ESU Configuration
- B-Alert Show Brain State Gauges

The software controls for these features (as well as EEG analog and calculation channel setups) are initially explained in Chapter 25 of the Biopac Acq*Knowledge* Software Guide, and this Quick Guide is intended as an adjunct to assist the user in greater detail. Using B-Alert with Acq*Knowledge* should be intuitive for users already familiar with Acq*Knowledge*. For specific information on using B-Alert Live software independently of Acq*Knowledge*, see the **B-Alert Software Manual**.

**In B-Alert hardware mode, the B-Alert menu replaces the MP hardware menu.*

For a full explanation of the B-Alert wireless EEG hardware and hardware setup, please refer to the **B-Alert®** X10 User Manual.

Minimum System Requirements

- Personal computer (PC) with minimum Pentium™ 2.4 GHz processor
- Minimum of 2 GB of installed RAM memory and 4 MB virtual memory
- Windows 7 or higher operating system
- .NET framework version 3.5 installed
- Minimum of 50 MB hard disk space per 5-hour session
- One CD-ROM drive
- VGA or higher resolution video adapter
- One available USB port
- Monitor size between 15" and 21" required for Metric Benchmarking Sessions

NOTE: The older-style (silver) B-Alert X10 headsets are not supported in Acq*Knowledge* versions 5.0.5 and higher.

Configuration

A. Items Required for Use

B-Alert Headset x10

B-Alert USB Receiver
B-Alert Dongle or ESU

B. Connect Hardware

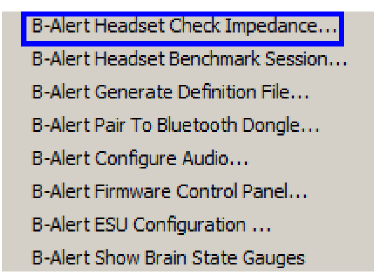
Before starting Check Impedance, connect the B-alert USB Receiver to the computer and turn the headset to ON. Wait for the solid green LED pattern on both headset and B-Alert USB Receiver to confirm the Receiver and Headset have connected. (Refer to the **B-Alert X10 User Manual** for full details on attaching the Headset to the subject).

For pairing communication troubleshooting, see page 21.

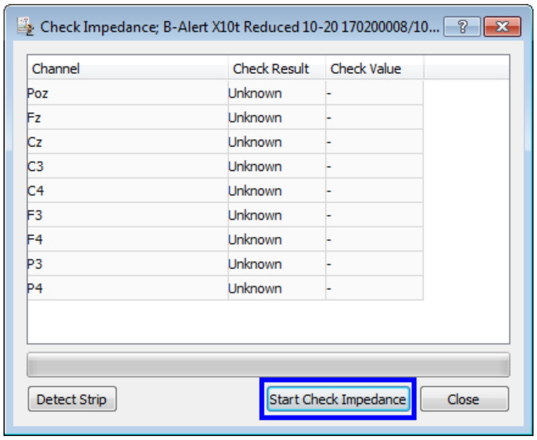
C. Check Impedance

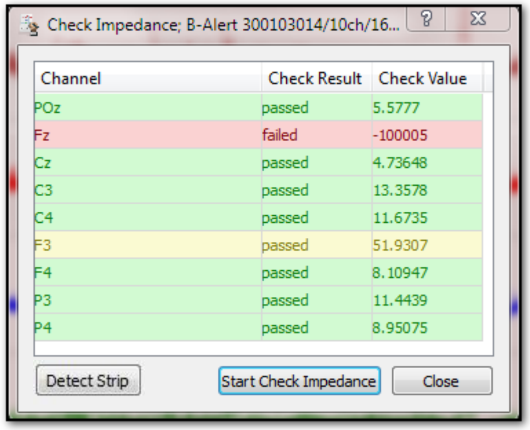
The Check Impedance function allows the technician to test the impedance levels at each electrode site. Impedances measure resistance between the scalp and electrode in kΩ, where lower values reflect lower resistance and better conductivity between scalp and electrodes. **In order to optimize data quality, the manufacturer strongly recommends conducting an impedance check before starting any data collection. In Acq*Knowledge* software** access Check Impedance via:

1. **B-Alert menu > B-Alert Headset Check Impedance**.



2. Click **"Start Check Impedance"** to perform the test.





- Impedance values lower than 40 kΩ will be highlighted in green.
- Impedance values between 40 kΩ and 80 kΩ will be highlighted in yellow.
- Impedance values higher than 80 kΩ will be highlighted in red, indicating that the sensor is outside of the acceptable range. Note that it is possible for a red impedance value to indicate a Check Result of "passed," but the resulting EEG data would contain unacceptable levels of noise. Never accept any impedance value in the red range, regardless of the Check Result.

Impedances generally will decrease for the first 30-45 minutes following application to a participant. For additional tips on lowering impedance values, refer to troubleshooting (pg.10)**. The manufacturer recommends getting all electrode sensors below 40 kΩ for optimal data quality.** Users are recommended to set a standard impedance threshold for data collections to maintain data quality across subjects. Having impedances higher than 40 kΩ (yellow) will still collect good quality EEG and may not be reason to exclude a participant from continuing to collect, however, the manufacturer recommends getting impedances lower than 40 kΩ for all EEG sites and the Ref (mastoid sensors) sites before starting an acquisition. If high impedances are seen across ALL EEG channels, try replacing the mastoid sensors before troubleshooting each EEG site – high Reference impedance will impact ALL EEG impedance measurements.

The following output files are generated during an impedance test, thee files are useful for technical support not for data analysis:

- *xxxxxxxxx.xxxxx.xxxxx.Impedance.Results.csv:* This CSV file will contain the impedance values from each impedance test performed. If repeated impedance tests are performed for the subject, a unique CSV file will be saved each time, organized by system time.
- *xxxxxxxxx.xxxxx.xxxxx.Impedance.ebs:* An impedance EBS file is saved in the subject folder for each impedance test performed. The system time is included in the file name to allow simple file tracking.

It is important to note: All impedance values should have passing results before the Benchmark Task is started. Refer to the hardware manual or strip labeling for the electrode site naming convention.

Acquiring Metric Benchmarks for B-Alert Classifications

A. Benchmark Acquisition with Alertness and Memory Profiler (AMP)

The acquisition of Benchmark data is used to create the individualized EEG profiles required for the B-Alert Cognitive State and Workload Metrics to be valid and accurate across individuals. Each complete Benchmarking Session includes three distinct tasks:

- 3-choice Vigilance Task (3CVT)
- Visual Psychomotor Vigilance Task (VPVT)
- Auditory Psychomotor Vigilance Task (APVT)

Three durations are supported that vary in increasing order of classification accuracy:

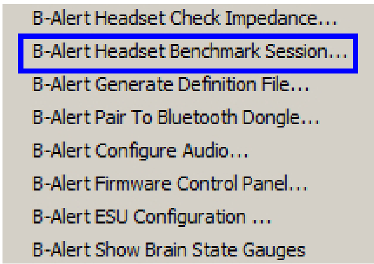
- Short_Benchmark: Approximately **9-10** minutes to complete
- Medium_Benchmark: Approximately **15** minutes to complete
- Long_Benchmark: Approximately **30** minutes to complete

Typically benchmark data only needs to be obtained one time for each individual, if performed on a healthy, rested subject. However, additional session iterations are recommended when pre- and post-conditional changes are made.

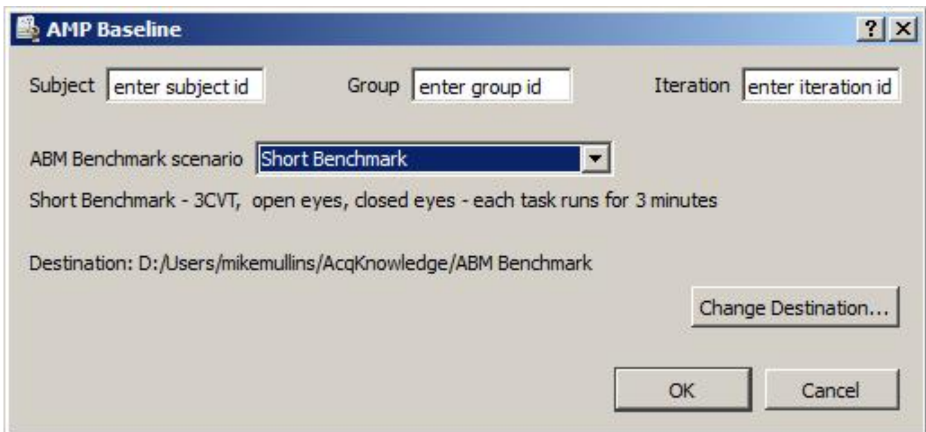
> **NOTE:** Standard lengths of the session may be appended with additional time if the subject fails to respond consistently (suggesting subject was fatigued or fell asleep, thereby distorting Benchmark measures).

In Acq*Knowledge* software access the Benchmark Session setup via:

1. **B-Alert menu > B-Alert Headset Benchmark Session.**



2. Enter the **Subject id** (four digits), **Group id** (one digit) and **Iteration** number (one digit).



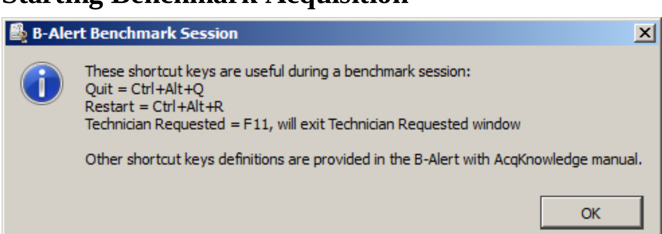
3. Select the desired recording length (**ABM Benchmark scenario).**

4. Click **OK**.

The B-Alert Benchmark Session shortcut key prompt will appear, followed by the blue startup screen (shown below, Fig. 1). Refer to the following Sections (B and C) for details about performing AMP Benchmark tasks.

B. Steps for Benchmark Acquisition

Starting Benchmark Acquisition



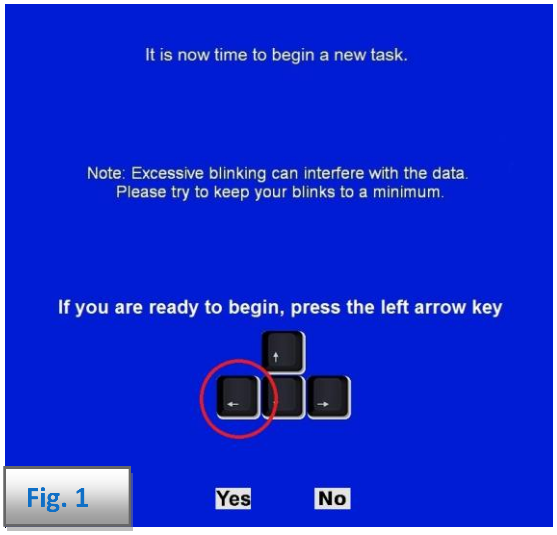


Fig. 1

C. Completing the Benchmarking Tasks

The subject will be prompted to complete at least three neurocognitive tasks. The standard session length for these tasks may be appended with additional time extended if the user fails to respond consistently (suggesting they fell asleep, thereby distorting the Benchmark measures).

1. Three-Choice Vigilance Task (3CVT)

After the instructions are presented (Figures 2 and 3), the 3CVT session begins with a Practice Session. During the practice session, the session instructions will alert the subject when an incorrect response is made (Figure 4) to insure that he/she understands the task. As soon as the user demonstrates that they understand each of the responses, the practice session will terminate (Fig 5) and the testing session will begin.

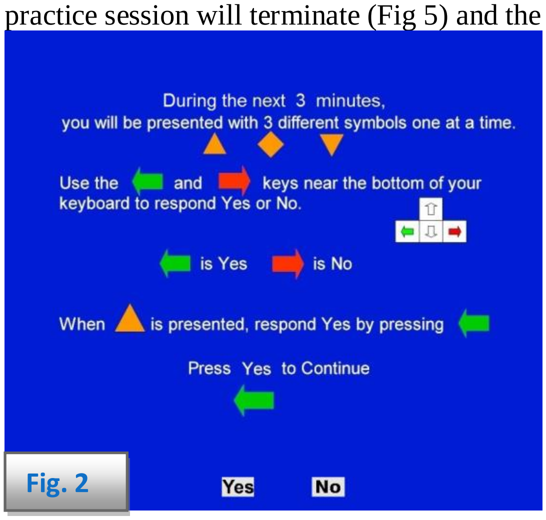


Fig. 2

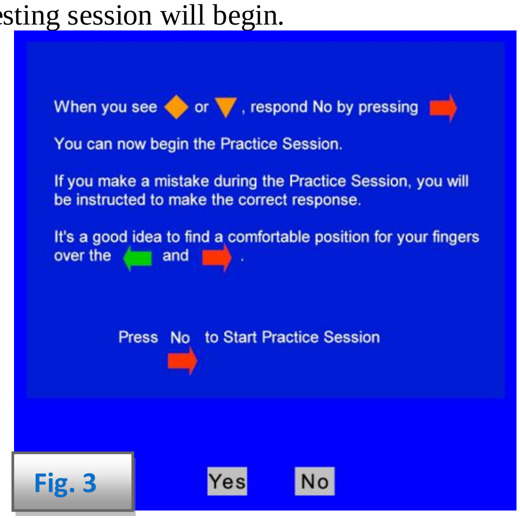
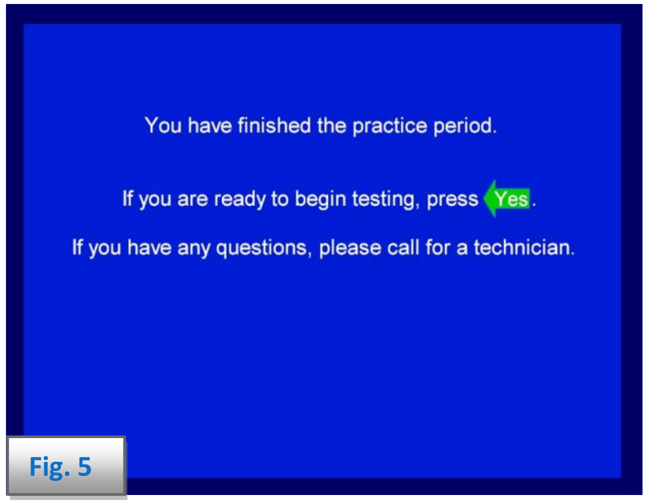


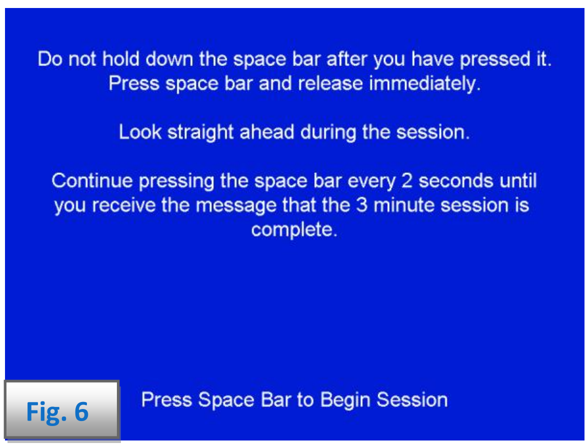
Fig. 3



The length of the 3CVT (after the practice period) will depend on the Benchmark type selected. During the first 3-minute period, stimuli appear frequently and require a high state of alertness. The inter-stimulus intervals are extended in the remaining minutes of the 3CVT in order to better identify individuals who are unable to remain engaged (i.e., excessive daytime drowsiness or other sleep related disorders). Subjects who are unable to sustain performance within a normal range across the 3CVT will be flagged as having an invalid Benchmark session.

2. Visual Psychomotor Vigilance Task (VPVT)

Figs. 6 and 7 are screenshots of the **VPVT** instructions:



3. Auditory Psychomotor Vigilance Task (APVT)

Figs. 8 and 9 are screenshots of the **APVT** instructions.

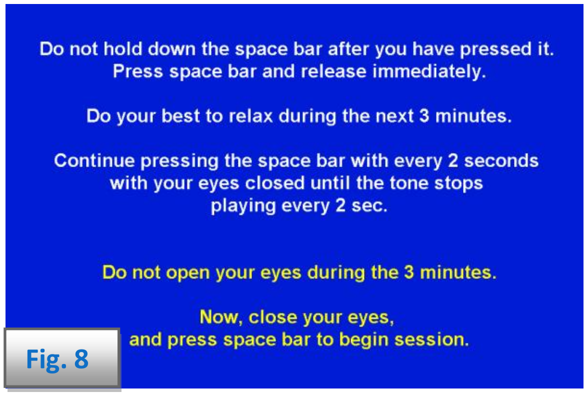


Fig. 8

Fig. 9

After completing the third and final Benchmarking Task, a completion dialogue will appear (**Fig. 10**) informing the subject to wait for the technician. The technician must press the F11 key at this time to complete the testbed and initiate the final quality check. Once acquired, the Benchmarking session files are stored in the subject's folder. The definition file needed for B-Alert classifications will also be automatically generated and placed in the subject's folder. The *.def file is required for generating EEG classification metrics in Real-Time during acquisition or during offline data analysis.

Fig. 10

B-Alert Benchmark Issues

Shortcut Keystrokes

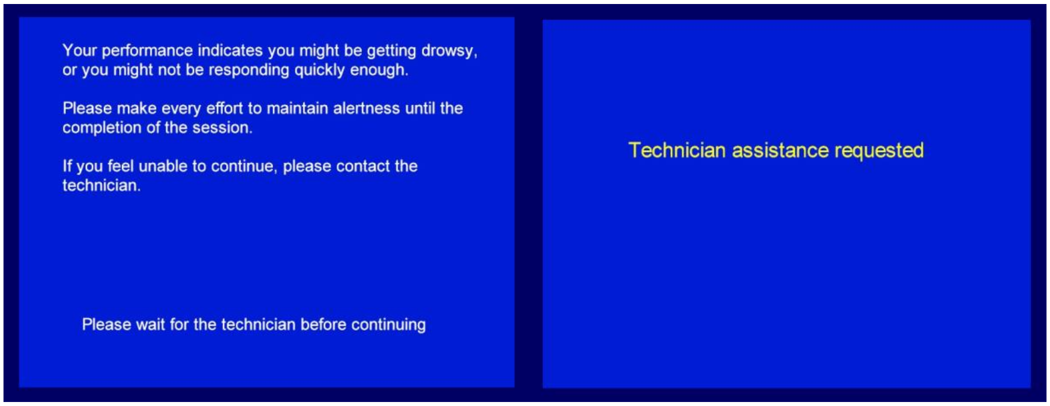
During any of the three tasks in the Benchmarking sessions, the following shortcut keystrokes are supported:

- Ctrl+Alt+Q (Quit): Quit the session. For use by the technician.
- Ctrl+Alt+R (Restart): Restart the current task. For use by the technician.
- Ctrl+Alt+P (Pause): Pause the current task. It is not recommended to pause the task.
- Ctrl+Alt+C (Continue): Resume after Pause.
- Ctrl+Alt+J (Jump): Skip the current task.
- Ctrl+Alt+V (Review): Review previous instructions before the commencement of the task.

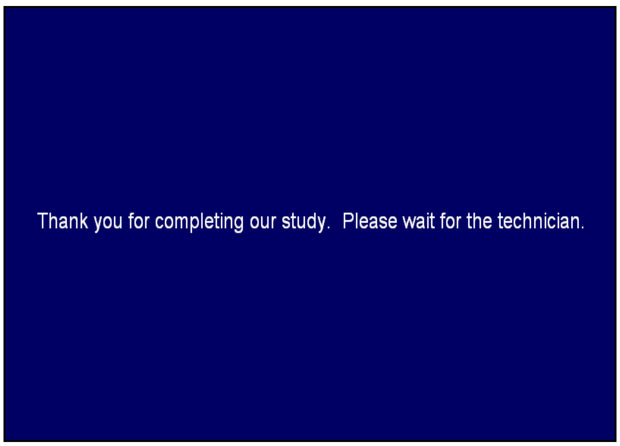
NOTE: If the session is prematurely terminated before completion of all tasks, use the Ctrl+Alt+Q keystroke to quit the session in order to save all outputs to the files. Failure to do so will result in loss of all output data.

Exiting Benchmarking Session

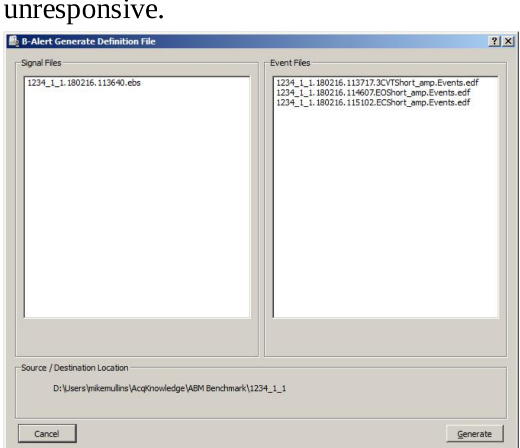
Function Key F11 - is used to get out of a "Technician Requested" window, when subject is kicked out of a task due to a lack of response, or to exit out of the last screen of the Benchmark.
The following are examples of when to use this button:

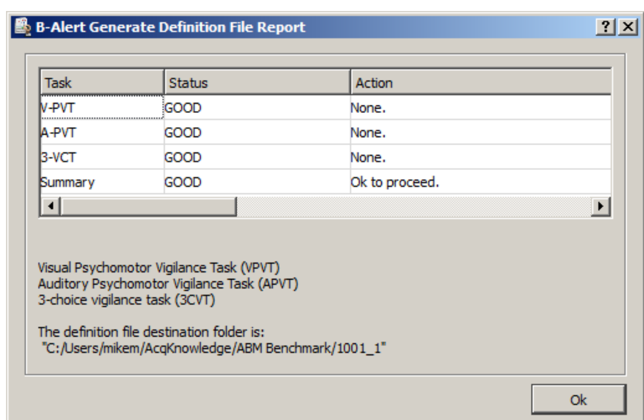


Upon completing the final task, the following screen will appear:



Once the technician exits this screen using F11, the system will automatically run a data quality and performance check. Following these checks, a "Generate Definition File" dialog will appear. Click "**Generate**" to create the file. Creation of the Benchmark file may take several minutes, during which time the software will appear unresponsive.





When processing is complete, a "Definition File Report" dialog will appear (see above right figure).

The definition file will be labeled as follows:

xxxx_by_MMDDYY_HHMMSS.def

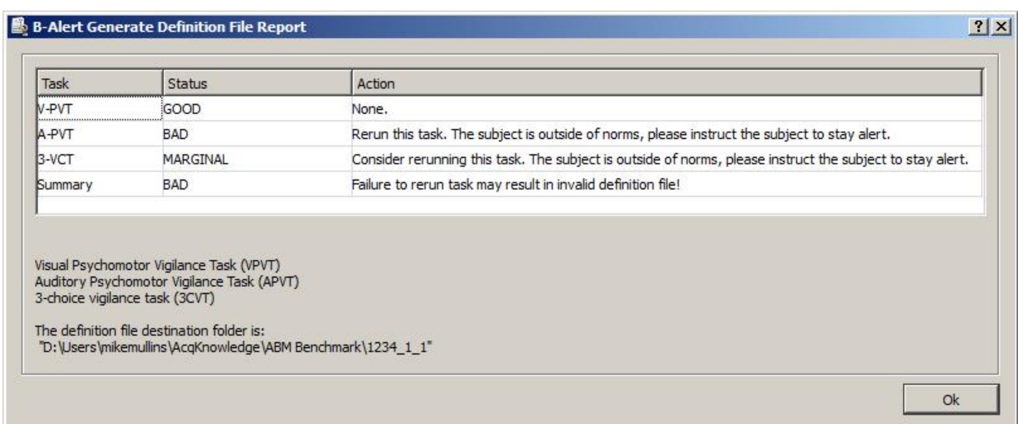
Where,

- xxxx = subject number
- b9, b15, b30 for short, medium, long session
- MMDDYY = date
- HHMMSS = time

A summary report called "BenchmarkReport.csv" will be created for each session and will provide additional information regarding the quality of the definition file that was created. The sections included in the report are as follows:

- Session Quality
  - Based on Artifacts
  - Based on subjects performance
  - Based on Cognitive State classifications
- Cognitive State Metric classifications for the session
  - Thresholds for three tasks
  - Quality based on the thresholds
- Individual/Population Metrics for each task
  - Quality
  - % classifications (based on epochs)
  - Valid/Total epochs used
  - % artifacts
  - Average of classifications for the entire task
  - Performance parameters (Correct responses, Reaction time, lapses)

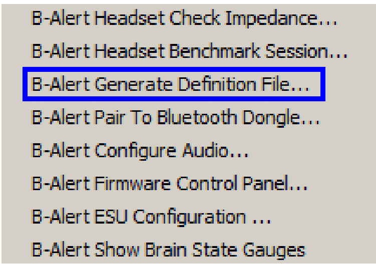
A report status summary will appear following completion of the Benchmark session. If the summary indicates any problems that occurred during the Benchmark session (such as those indicated in the report example below), rerun the session.

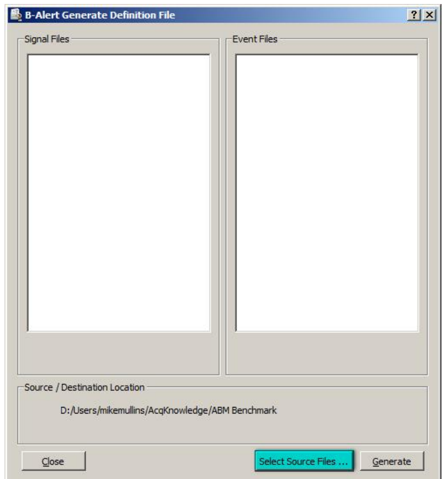


B-Alert Generate Definition File

Use this feature to extract a definition file and report from a previously completed Headset Benchmark session. This enables an existing Benchmark session's parameters to be reused across sessions (for Cognitive State and/or Workload Metric classifications) for a given individual.

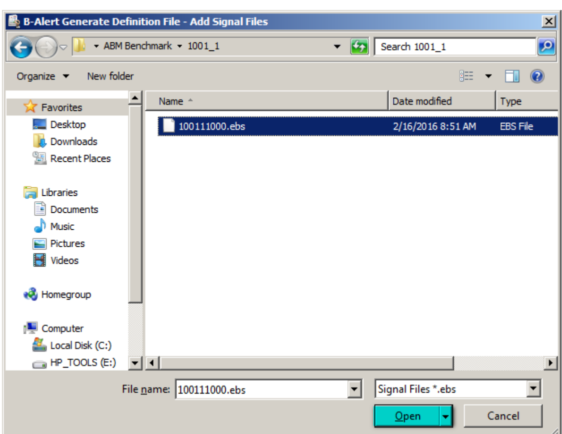
In Acq*Knowledge* software access B-Alert Generate Definition File via:



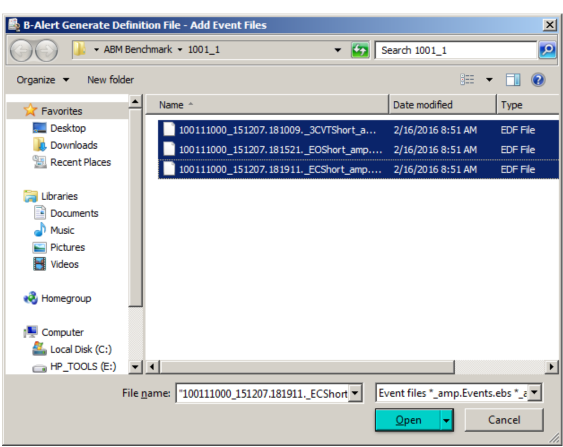


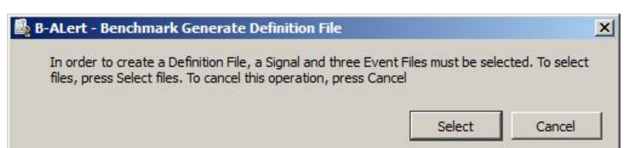
Note that the Generate Definition File setup dialog shown above has two panes. The left pane is for the selected Benchmark session's Signal file (*ebs) and the right pane is for the selected session's Event files (*.edf).

1. Click "Select Source Files…" and navigate to the desired Benchmark session folder.
2. Open the Benchmark folder, select the desired Signal (*ebs) file and click "Open" (see below).

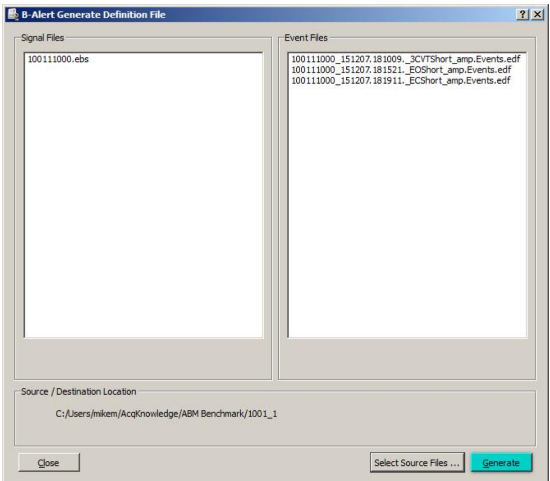


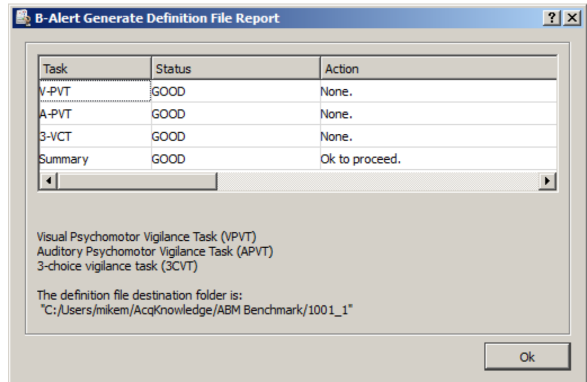
3. Then select the associated Event (*.edf) files and click "Open." There must be a minimum of three Event files selected in order to create the new definition file. If not, the prompt shown on lower right will be displayed.





4. Click "Generate" to create the new definition file (*.def) and Benchmark report (*csv). The new definition and report files will be copied to the Benchmark session source folder.

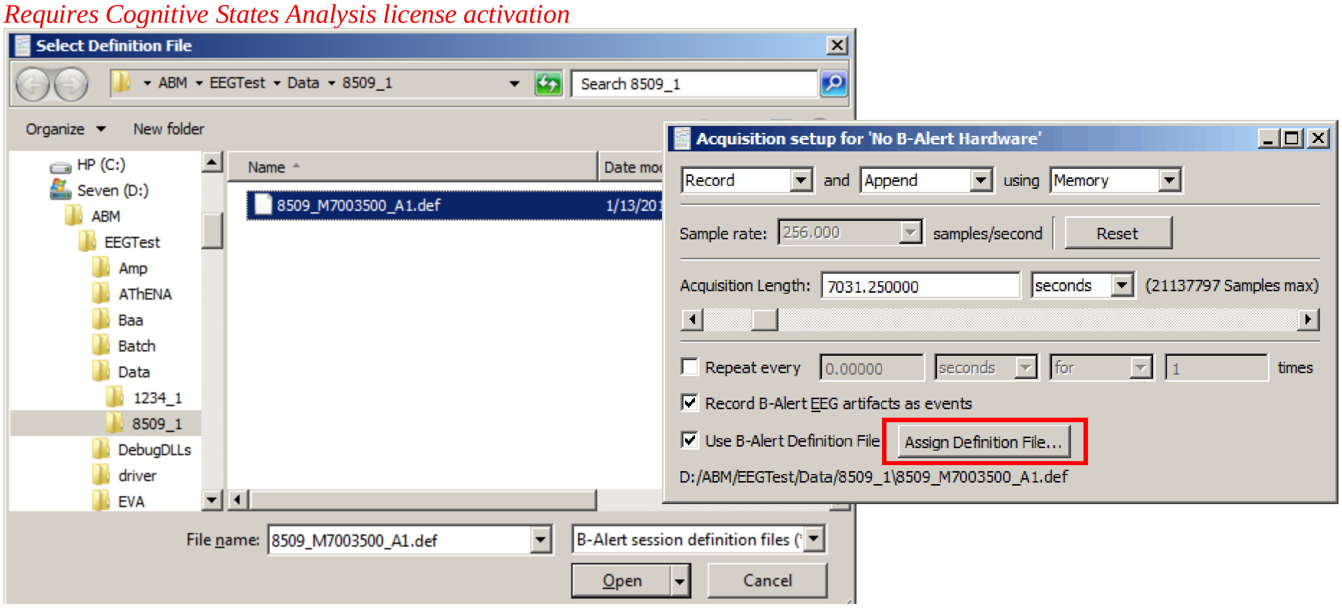




5. Assign the new definition file as described below.

Assigning the Definition File in Acq*Knowledge* Software

Requires Cognitive States Analysis license activation



Once the Definition File is created following the initial Benchmark EEG recording or after using the "Generate Definition File" option, that file is saved to the directory containing the subject's B-Alert profile folder. The subject's Definition File can then be referenced for subsequent recordings and analysis in Acq*Knowledge*.

In order to apply a subject's Definition File for a recording, it must first be selected and assigned in the Acq*Knowledge* Data Acquisition Setup. Use the following steps to assign the Definition File:

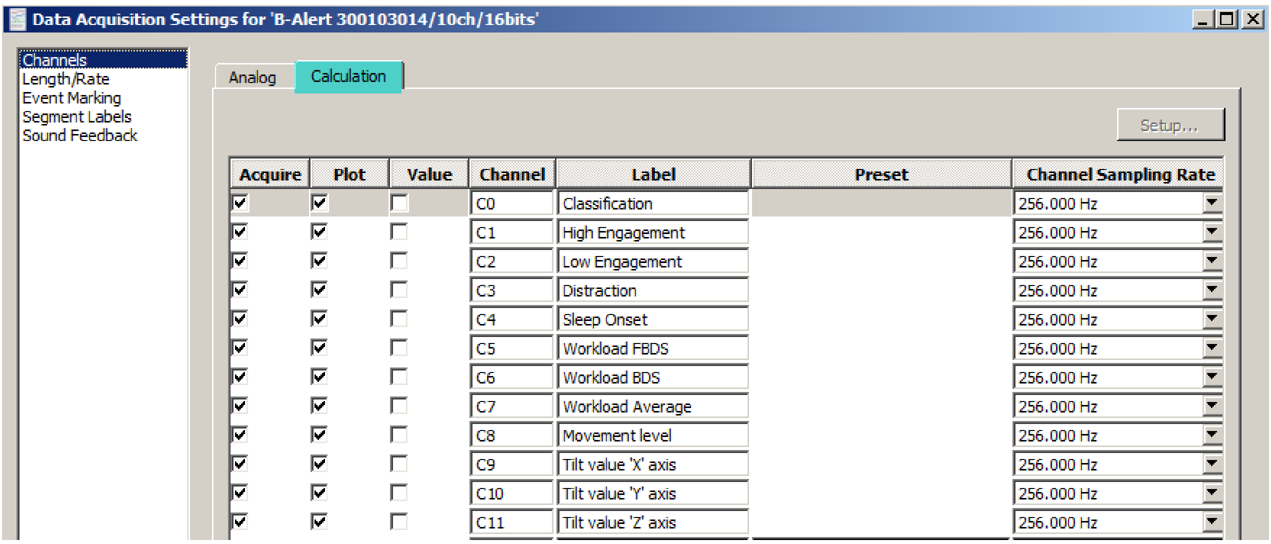
1. Choose **Set Up Data Acquisition** > **Length Rate**.
2. Enable the "Use B-Alert Definition File" checkbox.
3. Click the "Assign Definition File" button and browse to the location of the subject's Definition File (*.def).
4. Click "Open" to select the file for the subject about to undergo the recording.

Cognitive States Analysis Calculation Channels

Once a subject's B-Alert Definition File has been assigned, additional Acq*Knowledge* calculation channels become available. These additional channels extract cognitive workload, high/low engagement, distraction, drowsiness, movement and tilt angle data from the subject's Definition File during the recording and display these classifications in real time in the Acq*Knowledge* graph.

To use the available calculation channels:

1. Choose **Set Up Data Acquisition > Channels**.
2. Click on the "Calculation" tab.



3. Select or deselect the channels as desired. Selected channels will appear in the Acq*Knowledge* graph during the recording.

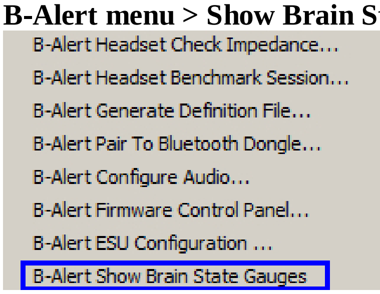
NOTE: The Cognitive States Analysis calculation channel setups and presets are not editable. They can be turned on or off, but not modified.

B-Alert Gauges GUI

The B-Alert Brain State Gauges visualize raw and processed physiological signals in a range of formats to provide a comprehensive visualization of physiology in real time and offline.

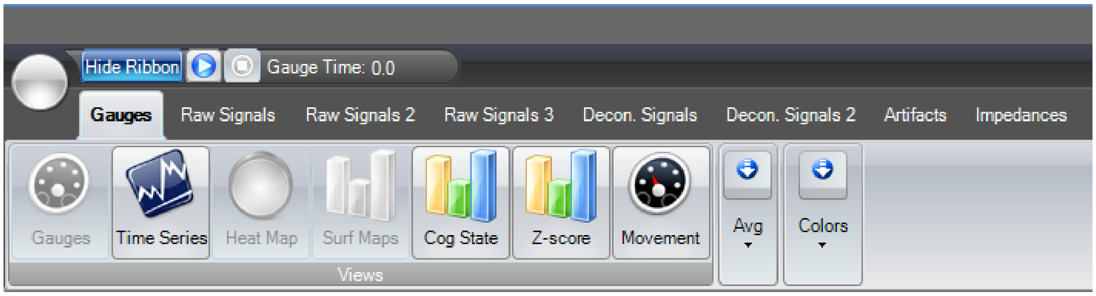
In Acq*Knowledge* software access the B-Alert Brain State Gauges via:

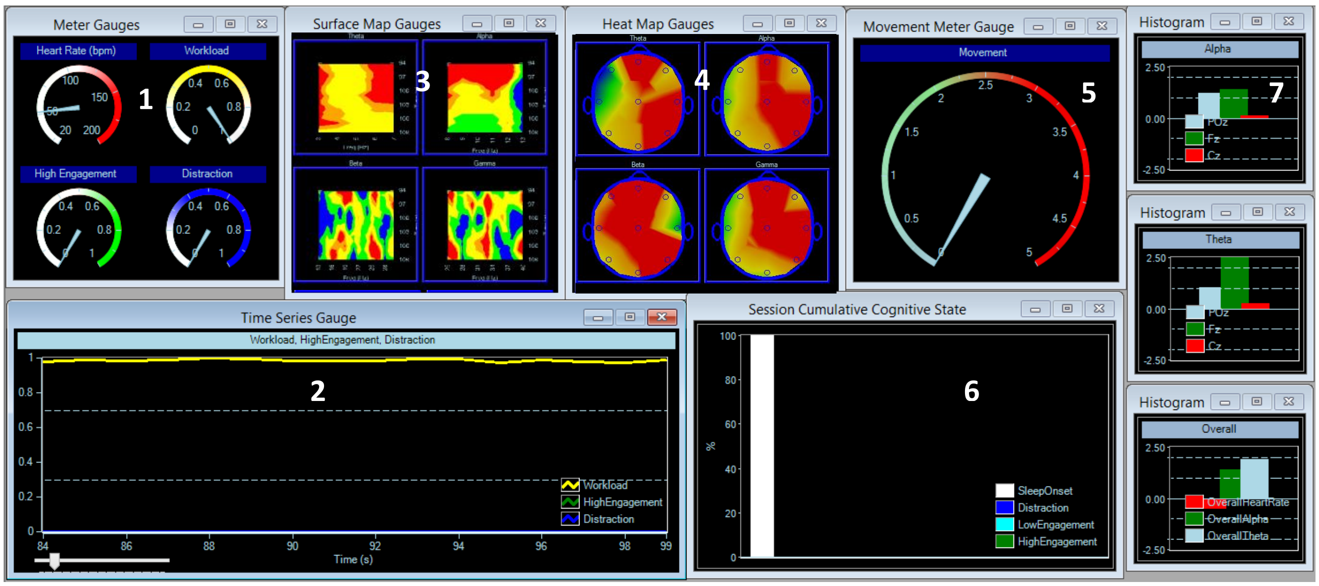
B-Alert menu > Show Brain State Gauges



Gauges Window

The gauges are fully customizable to optimize information display to fit the requirements of the user. The easy-to-read gauge and time series windows present second by second B-Alert classification metrics: Engagement, Workload, Drowsiness, and Heart Rate. Heat maps display EEG power spectral densities (PSD) in both spatial and temporal maps for the traditional Hz bands (Beta, Alpha, Theta, Gamma).





1. **Meter Gauges:** These include the High Engagement and Distraction classifications from the Cognitive State Metrics, as well as the Workload Metric, and Heart Rate (when acquired). For the Metrics, the default presentation setting is second-by-second changes averaged on a trailing 3-second window. For users with longer duration testbeds, it may be helpful to reduce the sensitivity of the Metrics with the "Avg" button. Here, users can display more meaningful outputs by varying the sensitivity from two to thirty seconds.
2. **Time Series:** Shows z-scored values (updated every second) in a 15-second window. Three views are selectable: (1) Workload, High Engagement, and Distraction (default); (2) Drowsy, Low Engagement, and High Engagement; and (3) Overall Heart Rate, Overall Alpha, and Overall Theta.
3. **Surface Map:** Shows z-scored time history (5-sec) of the PSDs of individual bins calculated across all the channels.
4. **Heat Map:** Shows 4-second averaged distribution of PSDs for the specified EEG band across the scalp. The PSDs are computed from decontaminated data (if available), smoothed using Kaiser-window, and averaged across 3-epoch overlays. Default bands are: Theta (3-7 Hz), Alpha (8-13 Hz), Beta (13-29 Hz), and Gamma (25-40 Hz).
5. **Movement***:* Shows movement scale computed from the change in the dominant angles of the 3-axis accelerometer.
6. **Cog State:** Shows the relative percentage of each Cognitive State Metric for the cumulative session. Please note the inverse relationship between each of the classifications.

7. **Z-Score:** Shows z-scored second-by-second values of EEG Bands for specified electrodes in histogram format. Three default views are available: (1) POz, Fz, Cz for Theta band; (2) POz, Fz, Cz for Alpha band; and (3) Overall Alpha and Theta across all channels and HR.

NOTE: The availability of the gauges depends on the type of the device and brain state processing selected. For example:

- If no brain state classifications are selected in Acquisition Settings, the corresponding gauges will not be available.
- If Artifact decontamination is not selected in Acquisition Settings, PSDs will be computed from raw data.

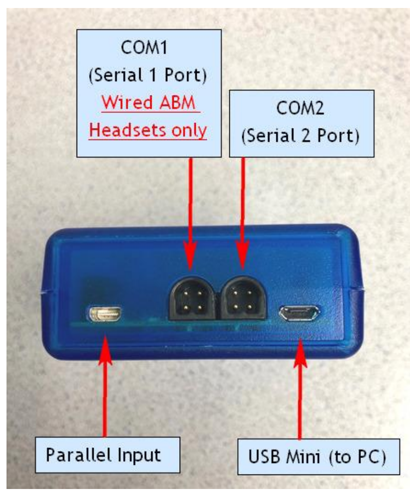
Connecting the ESU Unit

The External Syncing Unit (ESU) can be used to timestamp data from both ABM devices and events from third party applications at millisecond level precision through a dedicated robust hardware timer. For full details and block diagram of the ESU, see the **B-Alert Software Manual**.

Before configuring the ESU settings, the ESU must be paired with the B-Alert unit via a Bluetooth connection. The pairing procedure for ESU is the same as for the B-Alert Bluetooth dongle.

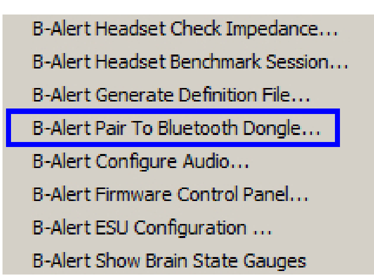
To Pair the ESU in Acq*Knowledge*

1. In Acq*Knowledge*, verify that B-Alert is the selected hardware in the “Connect to” menu. If another hardware is selected, go to “Preferences > Hardware > Data Acquisition Hardware Priority” and move B-Alert to the top of the list.



NOTE: When the ESU device is being used with the B-Alert headset, make sure the B-Alert Bluetooth dongle is not connected. Multiple Bluetooth connections are not supported.

2. Connect the B-Alert X10 headset to USB and power on if necessary.
3. In Acq*Knowledge*, choose “**B-Alert > Pair to Bluetooth Dongle**” and follow the prompts.

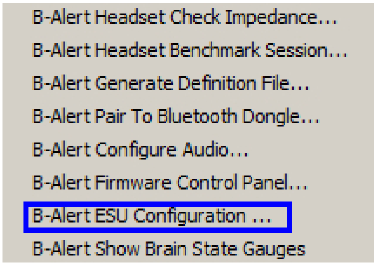


4. Plug the ESU unit into a computer USB port. **IMPORTANT:** Make sure the B-Alert Bluetooth dongle is disconnected.

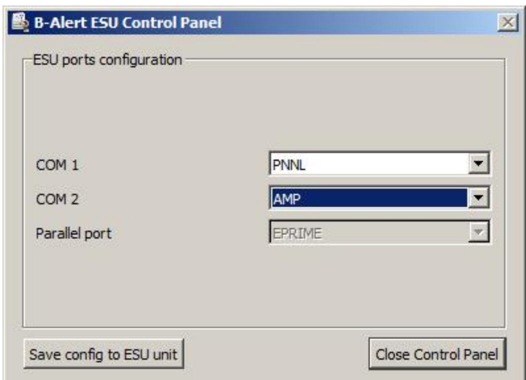
5. Once pairing is complete, disconnect the B-Alert headset from USB and restart it. The LEDs on the paired devices will be stop blinking and become solid when connected.

To Configure the ESU in Acq*Knowledge*

1. In Acq*Knowledge* choose **B-Alert > B-Alert ESU Configuration**.



2. In the ESU setup, use the pop-up menus to configure ESU third-party data (two serial ports and one parallel port) as desired (see below).



3. Click "Save config to ESU unit" to save the settings.
4. Wait until the "saved configuration" confirmation dialog appears. Restart the ESU by unplugging it and then re-plugging into the computer's USB port.

Third Party Protocols and Packet Structure

The ESU supports multiple protocols for acquiring third party data. The specifications of the protocols are listed below:

Serial communication protocols				
Type	**Baud Rate (kb/s)**	**Data bits**	**Stop bit**	**Parity**
PNNL (recommended)	57600	8	1	None
SMI	9600	8	1	None
ASL	19200	8	1	None
AMP	Reserved	8	1	None

Parallel communication protocols		
Type	**STROBE (YES/NO)**	**Packet Structure (YES/NO)**
PNNL	Yes	Yes
ANITA	Yes	Yes
DAIMLER	No	No*
E-PRIME (recommended)	No	No*

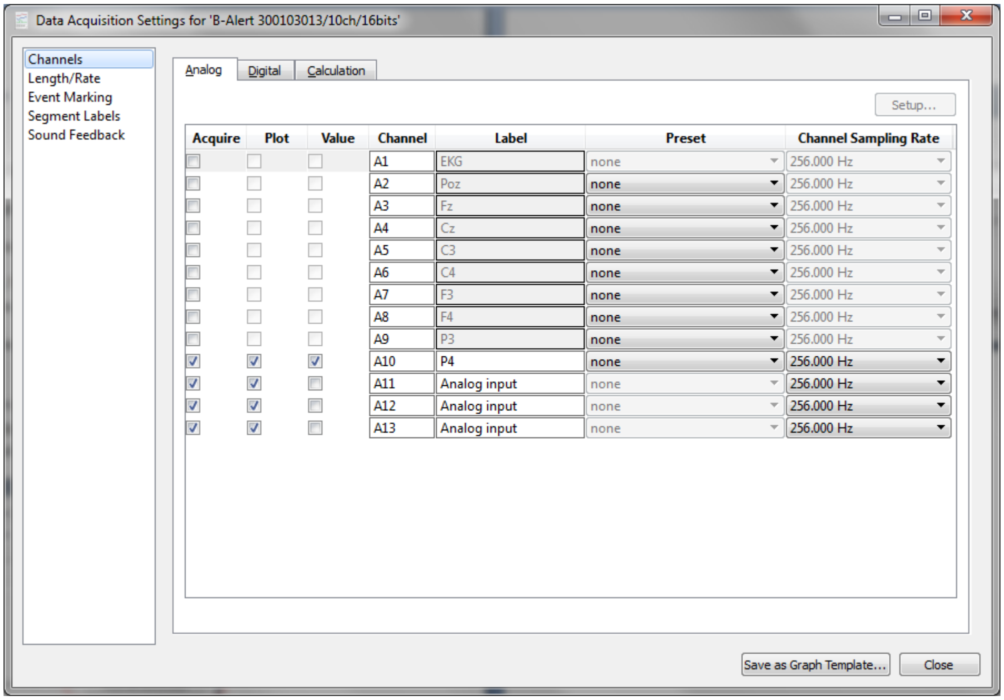
*For protocols without a packet structure, the changes in the 8-bit parallel lines are time-stamped. Idle values (0) must be used in between valid data and the values must be held for at-least 100 uses for registration.

For detailed information about ESU data and packet structure, see the ESU section of the B-Alert Live Software Manual.

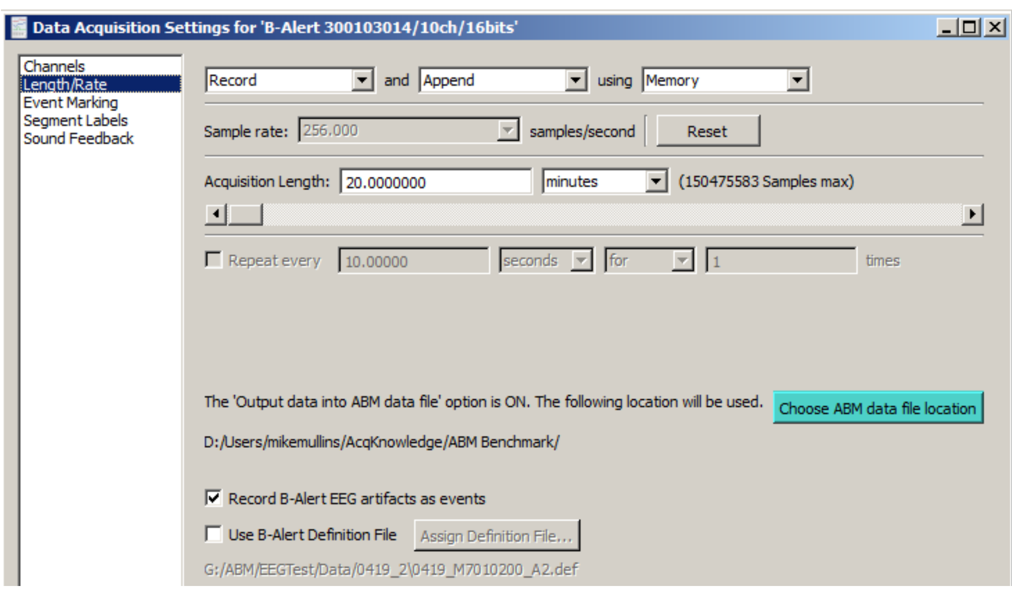
Enabling ESU Channels in Acq*Knowledge*

1. Select B-Alert > Set Up Data Acquisition > Channels and enable the required channels. The COM port channels are displayed on analog channels 11 - 13 and the Parallel port channels are digital channels D0-D7.

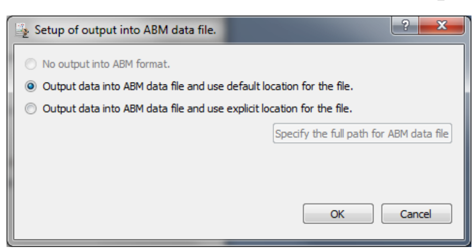
NOTE: One channel of EEG must be selected for the system to work even when testing the ESU marker system.



2. Select "B-Alert > Set Up Data Acquisition > Length/Rate" and open the ABM data file location option. Select "**Output data into ABM data file at**" and choose a directory.

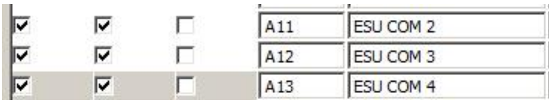


3. Select the Output data into ABM data file and choose "default" or "explicit" (user defined) file location.

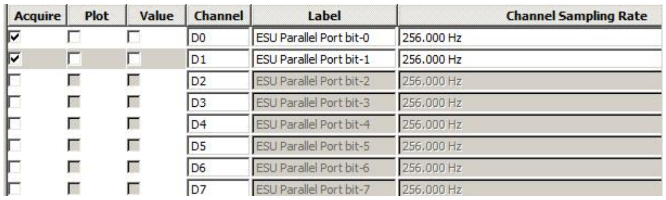


4. Click the Acq*Knowledge* "Start" button and the system will record and display the EEG data and the event marker information from the ESU.

To acquire ESU COM port data in graph channels with Acq*Knowledge*, choose "B-Alert > Set Up Data Acquisition > Channels > Analog" and select the desired channels. (COM2 = CH11, COM3 = CH12, COM4 = CH13.)



To acquire digital channels associated with an ESU parallel port connection, choose "B-Alert > Set Up Data Acquisition > Channels > Digital" and select the desired channels (D0-D7).

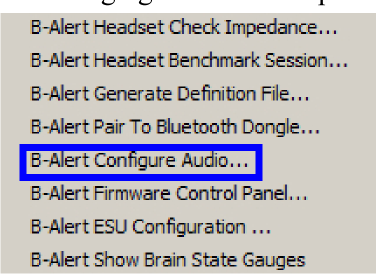


Acquire	Plot	Value	Channel	Label	Channel Sampling Rate
☑	☐	☐	D0	ESU Parallel Port bit-0	256.000 Hz
☑	☐	☐	D1	ESU Parallel Port bit-1	256.000 Hz
☐	☐	☐	D2	ESU Parallel Port bit-2	256.000 Hz
☐	☐	☐	D3	ESU Parallel Port bit-3	256.000 Hz
☐	☐	☐	D4	ESU Parallel Port bit-4	256.000 Hz
☐	☐	☐	D5	ESU Parallel Port bit-5	256.000 Hz
☐	☐	☐	D6	ESU Parallel Port bit-6	256.000 Hz
☐	☐	☐	D7	ESU Parallel Port bit-7	256.000 Hz

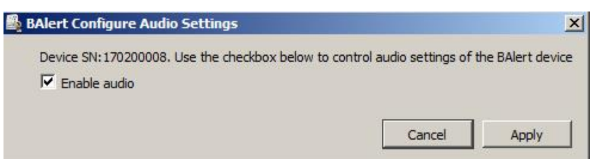
Other B-Alert Menu Options

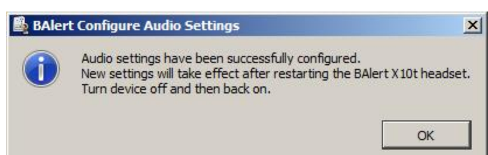
Configure Audio

Voice prompts are available in the B-Alert X10 headset, offering information such as power-on/power-off, pairing, and charging status. These prompts can be enabled or disabled via the "**B-Alert Configure Audio**" menu item.



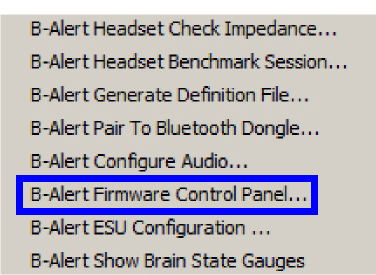
To enable or disable audio, select this item and check or uncheck "Enable audio" and click "Apply." Modified settings will be applied the next time the B-Alert X10 headset is power-cycled.





Firmware Control Panel

This feature offers options for updating the firmware for the B-Alert X10 headset, Bluetooth dongle, or ESU. To obtain the latest firmware files, contact support@biopac.com. After downloading files to a known directory, select B-Alert Firmware Control Panel, select the appropriate B-Alert device and follow the prompts. (Your B-Alert device must be connected in order to complete the firmware update.)



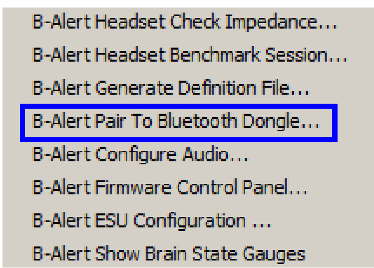
Communication Troubleshooting

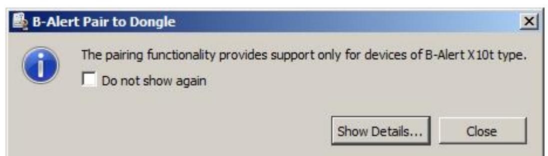
PROBLEM: Pairing between headset and B-Alert Dongle/ESU is lost and cannot be reestablished.

B-Alert headsets are shipped paired to either a B-Alert Dongle or an ESU. If the pairing is lost, the devices must be re-synced using the Acq*Knowledge* software's "**B-Alert > Pair to Bluetooth Dongle**" feature.

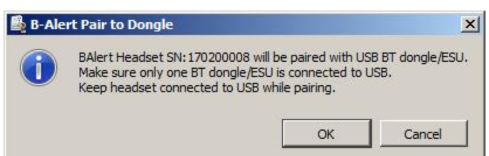
1. Plug the Bluetooth receiver (i.e., dongle or ESU) into your PC. *Note*: Ensure that all nearby B-Alert products, including headsets and other dongles/ESUs, are turned off and unplugged.
1. Connect the B-Alert headset to USB and power on. The LED will flash green.

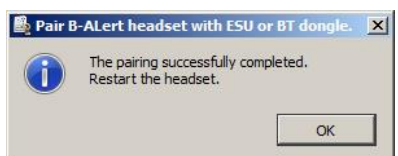
2. In Acq*Knowledge*, choose "**B-Alert > Pair to Bluetooth Dongle**" and follow the prompts.





2. Connect the B-Alert Dongle or ESU to a USB port. ***IMPORTANT:*** Ensure that all other nearby B-Alert dongles/ESUs, are turned off and unplugged.





3. Once pairing is complete, disconnect the B-Alert headset from USB and restart it.
3. LEDs on the paired devices will be solid when connected.

Acquisition Troubleshooting

Problem: Brain State Gauge Surface and Heat Maps are unresponsive during acquisition; colors remain a uniform green (Surface Map) and yellow (Heat Map).

This is most likely because the "No output into ABM format" option is selected in the B-Alert Data Acquisition Settings. In order for Surface and Heat Map output to be recorded, a valid ABM data file location must be defined.

Use the following steps to ensure proper Surface and Heat Map operation:

1. Choose B-Alert menu > Set Up Data Acquisition > Length/Rate.
2. Click the "Choose ABM data file location" button.
3. Select the "Output data into ABM data file at:" option, assign a valid file path, and click OK.
4. Rerun the B-Alert acquisition. The Surface and Heat Map gauges should display the expected color output.

Note that this issue is common only to Acq*Knowledge* versions 4.4.1 and earlier. In Acq*Knowledge* 4.4.2 and higher, Heat and Surface Map output will function properly even with the "No output" option selected.

Appendix: Data Outputs Guide

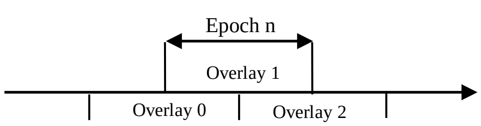
Overview

The B-Alert Live Software (BLS) allows users to utilize patented and peer-review validated EEG-based Metrics, Automatic Decontamination, PSD, and ECG algorithms if desired. These data outputs are either created in real time (See Real-Time Data Outputs Overview Table below) or offline. Below is an overview of some of the methods and techniques used by BLS to compute its various measures.

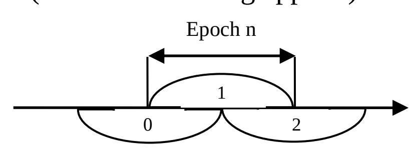
1. **Computing Power Spectral Densities:** Power spectral density (PSD) is computed by performing Fast Fourier Transform (FFT) on a segment of data that is of interest, and calculating the amplitudes of the sinusoidal components for designated frequency bins. Input variables to this transformation are an EEG segment for which PSD is to be computed, and its length; output variables include PSD amplitudes. Frequency domain variables are based on the power spectral density derived after application of a 50% overlapping window, and a FFT with ('_raw') and without ('_class') application of a Kaiser window. The B-Alert software provides two sets of PSD values (Ref_Raw and Ref_Class) from 1 to 40 Hz for each EEG channel that are logged to obtain a Gaussian distribution. Selected 1-Hz bins are averaged, then logged to create conventional EEG bands (e.g., theta = 3 – 7 Hz, alpha = 8 – 13 Hz, etc.). 'Diff_' files contain data for Differential EEG channels used for the Cognitive State Metric classifications (FzPOz, CzPO, FzC3, C3C4, and F3Cz). 'Ref_' files contain PSD values for 9 referential EEG channels (POz, Fz, Cz, C3, C4, F3, F4, P3, and P4).

   Both sets of PSD output files apply a 50% overlapping window which averages the PSD across three x one-second overlays to smooth the data. The illustration below shows that overlays 0, 1, and 2 are averaged (each overlay containing 256 data points with 128 data points being shared for each overlay) to provide the PSD values for epoch n:

   50% Overlap – Ref_Raw, Diff_Raw

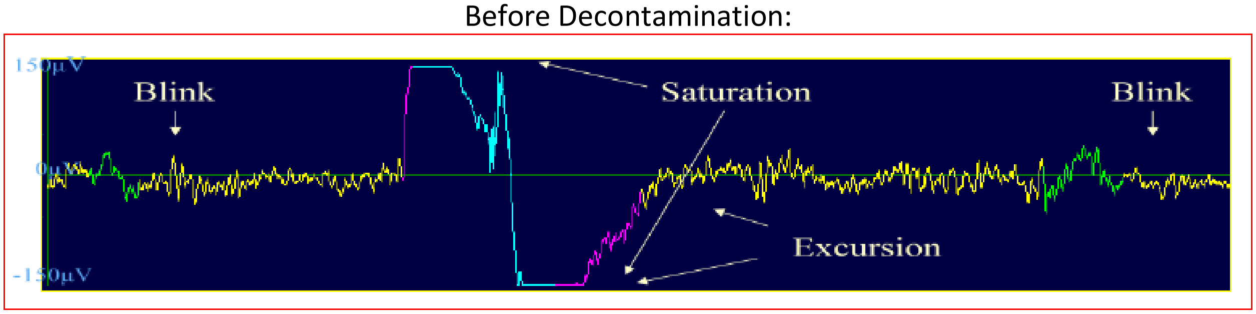
   50% Overlap – Ref_Class, Diff_Class
   (Kaiser windowing applied)

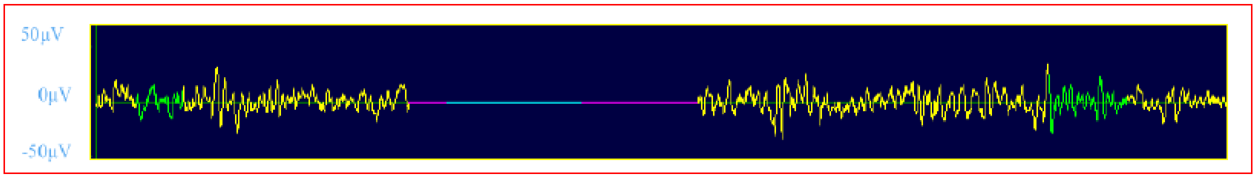
   For the 'Ref_Class.csv' and 'Diff_Class.csv' PSD calculation, a Kaiser window is applied to each overlay in order to accentuate the contribution of power from the signal in the middle third of the overlay, and minimize the impact of signal near each edge of the overlay. Windowing reduces the likelihood of extreme PSD values resulting from edge-effects when an EEG wave shape does not begin or end at the exact edge of an overlay. No Kaiser windowing is used for Ref_Raw and Diff_Raw analysis. ABM recommends using the _Raw data for users wishing to use PSD-based computations using this PSD overlaying procedure.

2. **Decontaminating Signals**: Prior to computing the 1-Hz PSD bins, the raw signals are processed to eliminate known artifacts. Spikes, excursions and amplifier saturations, which occur when ambulatory EEG is acquired, can impact both low and high frequencies. EMG will contaminate the beta and gamma frequency ranges. Eye blinks (EOG) occur in the same frequency range as theta activity.

Before Decontamination:



After Decontamination:



- Excursions and amplifier saturation – contaminated periods are replaced with zero values, starting and ending at zero crossing before and after each event.

- Spikes caused by artifact are identified and signal value is interpolated.

- Invalid Epochs – If more than 128 zero values are inserted for an overlay, the overlay is excluded from the epoch average; if 2 of the 3 overlays are rejected, the epoch is classified 'invalid' (-99999 inserted for PSD value) and should be excluded from analysis.

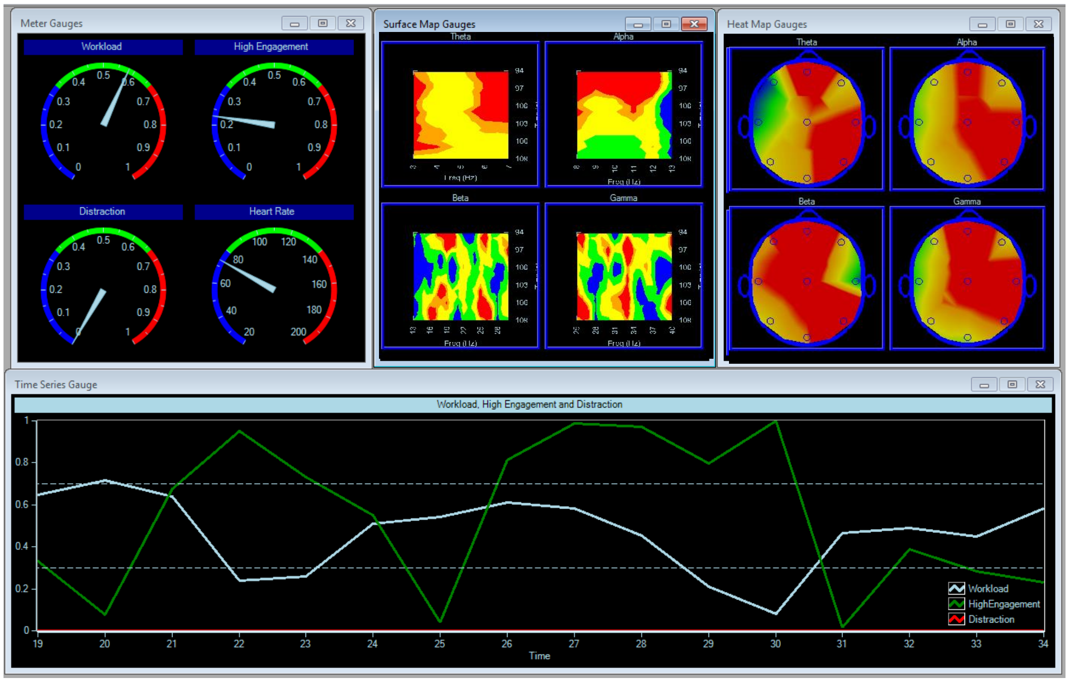
- EMG – a combination of High Frequency EMG (based off 70 - 128 Hz bins for each overlay) and Low Frequency EMG (based off 35 - 40 Hz) is used to identify periods with excessive EMG. If only one overlay has EMG, the PSD for the epoch is based on the average of the remaining two overlays. If excessive EMG is detected in two overlays, the second is classified as 'EMG' and should be excluded from analysis.

- Eye Blinks (EOG) – wavelet transforms deconstruct the signal and a regression equation is used to identify the EEG regions contaminated with eye blinks. Representative EEG preceding the eye blink is inserted in the contaminated region.

The artifacts are colored as follows:

Artifact Type	Color
EMG	Orange
Eye-blinks	Blue
Saturation	Light Blue
Excursion	Dark Green
Spike	Dark Brown

3. **Classifying the Cognitive State And Workload Models:**



The EEG-based Metrics are normalized to an individual subject using 5-7 min of Benchmark data from three distinct tasks (3CVT, VPVT, and APVT), with the sleep onset classification predicted from the Benchmark PSD values, for a total of 15-17 min of data across tasks. Based on this identification data, a probability-of-fit is then generated for each of the four classes for each epoch with the sum of the probabilities across the four classes equaling 1.0 (e.g., 0.45 high engagement, 0.30 low engagement, 0.20 distraction and 0.05 sleep onset). Cognitive State for a given second represents the class with the greatest probability using numeric labels (.1 = sleep onset, .3 = distraction, .6 = low engagement, and .9 = high engagement). The Cognitive State Metrics are derived for each one-second epoch using 1 Hz PSDs (from the bins from differential sites FzPOz, CzPO, FzC3, C3C4, F3Cz) in a four-class quadratic discriminant function analysis (DFA) that is fitted to the individual's unique EEG patterns. The table below identifies and briefly describes each Benchmark task, and associates the task with the B-Alert classification.

Benchmark Task	Action	B-Alert Class probabilities
3CVT	Discriminate between primary vs. secondary or tertiary stimulus every 1.5 to 3 seconds	High Engagement
VPVT	Respond to visual probe every 2 seconds	Low Engagement
APVT	Respond to audio tone every 2 seconds	Distraction
None	Derived by regression from other 3 tasks	Sleep Onset

Important Note: ***Failure to collect these 3 specific Benchmark tasks will result in an inability to utilize the B-Alert Cognitive State Classifications.***

The Cognitive State Metric probabilities for each individual should be interpreted in a relative, rather than absolute, manner. Three standardized benchmarking tasks normalize the metrics to each individual. High population variability for EEG activity requires individualized model fitting, which is done for each 1Hz bin (from 1-40Hz), and is not fit to classic summed bandwidths/rhythms (i.e., theta, alpha, beta, etc.) to optimize classification measures.

Two individuals will generate somewhat different probabilities for the same task due to a) their innate capability, and b) their state during the benchmarking tasksIf a participant is mentally balancing their checkbook during the APVT task, for example, they will not generate as much alpha activity as they would in a relaxed state. This may increase the occurrence of Distraction probabilities when applied to a different task in which they do mentally relax. Participants are more aroused the first time they complete a benchmarking session due to the novelty, so it is preferable to reuse the individual's DFA to classify new data/sessions rather than re-run the identification tasks repeatedly. Participants should avoid consuming excessive caffeine or nicotine immediately prior to conducting their Benchmarking Tasks data; and the session should occur in the morning (8am-10am) after a full night of sleep to collect an optimal session.

The Cognitive Workload Metric is a generalized model (i.e., it is not individually fit), thus it should also be interpreted in a relative manner. For the linear 2-class workload DFA, probabilities closer to 1 reflect higher workload. EEG workload is correlated with increased working memory load and difficulty level in mental arithmetic and other complex problem solving tasks. ABM has 2 workload models -- one model was built on a Forward digit span (FBDS) task (recommended to use, as it fits for ~85% of population) and the other built on a backward digit span (BDS) task (fits ~15% of population). ABM's data outputs also contain the mean probability between the FBDS and BDS model.

Z-scoring is a useful transformation to convert the relative Cognitive State Metrics into values that can be compared across participants, or for a repeated-measures within-subject experimental design.

4. **Output files**: EEG and other raw data are stored in both EBS and EDF files. The EDF file is compatible with most of the third-party EDF viewers. The csv output files generated with the B-Alert Live software share common formatting features. For example, all file names begin with the nine digit subject/session number (XXXXXXXXX), followed by a 6 digit date (YYYYYY), followed by a 6 digit timestamp(ZZZZZZ), followed by the label which describes the data. For generated files, one row of data is provided per second of recording time. The first column lists the subject/session number, the second column the elapsed time (since the start of recording) in hour:minute:second:millisecond (HH:MM:SS:MS), and the third column the system clock time associated with the start of the primary (middle) overlay for the epoch. Output files use a comma separated value (CSV) format for easy import into statistical/analytical software applications.

Real-Time Data Outputs Overview Table

Real-Time Output file name	Description
Data file	
Xxxxxxxxx.yyyyyy.zzzzzz.ebs	Proprietary Extensible bio-signal file format. Stores raw data with identical sampling such as EEG and EKG.
Xxxxxxxxx.yyyyyy.zzzzzz.Signals.Raw.edf	European data format containing raw data with variable sampling such as EEG, EKG, Accelerometer data, Marker etc. The EDF file is compatible with most third party viewers. Some channels in EDF file are selectable.
Xxxxxxxxx.yyyyyy.zzzzzz.Decon.edf	Decontaminated data from Signas.Raw.edf
Xxxxxxxxx.yyyyyy.zzzzzz_Events.edf	Events generated by the ESU stored in EDF+ annotation format.
Xxxxxxxxx.yyyyyy.zzzzzz.Impedance.Results.csv	Lists the values obtained for each channel each time impedance was measured.
Automatically Generated during Acquisition – for all EEG Channels	
Xxxxxxxxx.yyyyyy.zzzzzz.Ref_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (no edge-effect window)

Xxxxxxxxx.yyyyyy.zzzzzzRef_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (with Kaiser window)
Automatically Generated during Acquisition – Derived Signals	
Xxxxxxxxx.yyyyyy.zzzzzz.HR_beat.csv	Presentation of heart rate based on beat-to-beat interval
Xxxxxxxxx.yyyyyy.zzzzzz.HR_epoch.csv	Beat-to-beat heart rate interpolated to sec-by-sec value
Optionally Generated with Cognitive State Metrics	
Xxxxxxxxx.yyyyyy.zzzzzz.Classification.csv	Probabilities for sleep, distraction, low and high engagement, cognitive state from DFA with greatest probability, probability of high workload based on forward and backward digit span (FBDS), backward digit span (BDS), and average of FBDS and BDS.
Xxxxxxxxx.yyyyyy.zzzzzz.Diff_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for differential channels: FzPO,CzPO,FzC3,C3C4, and F3Cz (no edge-effect window).
Xxxxxxxxx.yyyyyy.zzzzzz.Diff_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for 5 differential channels FzPOz, CzPO, FzC3, C3C4, F3Cz (with Kaiser window).
Xxxxxxxxx.yyyyyy.zzzzzz.Zscore.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for both the Cognitive State (sleep onset, distraction, low and high engagement) and Workload Metrics (three workload measures).
Xxxxxxxxx.yyyyyy.zzzzzz.Zscore_psd.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for PSD for all channels requested in initialization process.
Other files	
Xxxxxxxxx.yyyyyy.zzzzzz.Actigraphy.csv	Contains raw tilt values from accelerometer and derived movement vales/scales.
Xxxxxxxxx.yyyyyy.zzzzzz.Artifact.csv	Contains detected artifacts and their start/end markers.
Xxxxxxxxx.yyyyyy.zzzzzz.ArtifactInfo.csv	Contains epoch-by-epoch details of artifacts detected in each channel such as number of datapoints affected, number of datapoints with inserted zero values, etc.
Xxxxxxxxx.yyyyyy.zzzzzz.thirdparty.bin	Stores third-party packets sent to the ESU (only for ESU).
Xxxxxxxxx.yyyyyy.zzzzzz.optical.bin	Stores IRED data from the headset (only for X4).
Xxxxxxxxx.yyyyyy.zzzzzz.accelerometer.csv	Stores raw accelerometer data in bin format.

Note:
The files created during acquisition depend on the selection in “Configure Data Storage” setting (see the **Advanced Settings and Operations Chapter** of the B-Alert Software Guide). It also depends on the type of processing selected (Artifact Decontamination), EEG-based Metrics (Cognitive State and Workload classifications), and type of the device used (X4, X10, X24).

A.2 EEG-based Metrics including Cognitive State & Workload Outputs

1. **_Classification.csv**

Classification.csv shows the second by second (epoch by epoch) data outputs for ABM's two EEG models: (1) 4-Class Cognitive State Metric model of drowsiness: (Sleep Onset, Distraction, Low Engagement, High Engagement); and 2-Class model of Workload (High Workload, Low Workload). These outputs will *only* be generated if the user has checked either of the 'Brain State' check boxes (Cognitive State Metrics and/or Workload Classification), and selected the appropriate .def file prior to initializing a data Acquisition.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time(hh:mm:ss:ms)
D	ProbSleepOnset	Sleep Onset classification probability (0-1)
E	ProbDistraction	Distraction classification Probability (0-1)
F	ProbLowEng	Low Engagement classification probability (0-1)
G	ProbHighEng	High Engagement classification probability (0-1)
H	CogState	The highest Probability in columns D, E, F, G will determine what the epoch is classified. Classifications are: 0.1: Sleep onset, 0.3: Distraction, 0.6: Low Engagement, 0.9: High Engagement. Seconds with excessive artifact where classification data could not be computed are identified with 0.05, 1, and/or 2.
I	ProbFBDSWorkload	Raw Workload probability (FBDS model), where higher probability reflects higher WL (FBDS is the best model for 85% of population).
J	ProbBDSWorkload	Alternate WL model (BDS model): Not recommended for use, higher probability reflects higher WL (Best WL model for other 15% of population).
K	ProbAveWorkload	Average Workload between 2 models (in Columns I and J).

A.3 Power Spectral Densities Outputs

_Diff_Class.csv
_Diff_Raw.csv
_Ref_Class.csv
_Ref_Raw.csv

Power spectral density (PSD) is computed by performing Fast Fourier Transform (FFT) on a segment of data that is of interest, and calculating the amplitudes of the sinusoidal components for designated frequency bins. Input variables to this transformation are an EEG segment for which PSD is to be computed, and its length; output variables include PSD amplitudes. Frequency domain variables are based on the power spectral density derived after application of a 50% overlapping window, and a FFT with (_raw) and without (_class) application of a Kaiser window. Refer to Outputs Overview above for additional information regarding the PSD analysis procedures.

1. **Diff_Class.csv**

PSDs (1-40Hz) for the differential channels (FzPOz, CzPO, FzC3, C3C4, F3Cz) are computed for generating ABM's classifications for each second of a given .ebs file. PSDs in this file are computed for each second of a given session with the Kaiser Windowing procedure described above. Relative power values are derived by subtracting the logged power of the individual Hz bin from the summed logged power for the EEG band (1-40 Hz for that channel.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	fzpoz_1	PSD power at channel FzPoz (with Kaiser windowing) for the 1 Hz bin
E	fzpoz_2	PSD power at channel FzPoz (with Kaiser windowing) for the 2 Hz bin
F - AQ	fzpoz_3-40	PSD power at channel FzPoz (with Kaiser windowing) for the 3-40 Hz bins
AR	fzpoz_rel1	*Relative* PSD power at channel FzPoz (with Kaiser windowing) for 1 Hz Bin
AS - CE	fzpoz_rel2-rel40	*Relative* PSD power at channel FzPoz (with Kaiser windowing) for 2-40 Hz Bin
CF	fzpoz_Delta_1_2	PSD for Delta Bandwidth at channel FzPoz (not relative PSD) summed from Hz bins 1-2
CG	fzpoz_ThetaSlow_3_5	PSD for Theta-Slow Bandwidth (not relative PSD) summed from Hz bins 3-5
CH	fzpoz_ThetaFast_5_7	PSD for Theta-Fast Bandwidth (not relative PSD) summed from Hz bins 5-7
CI	fzpoz_ThetaTotal_3_7	PSD for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7
CJ	fzpoz_AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth (not relative PSD) summed from Hz bins 8-10
CK	fzpoz_AlphaFast_10_13	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 10-13
CL	fzpoz_AlphaTotal_8_13	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 8-13
CM	fzpoz_Gamma_25_40	PSD for Gamma Bandwidth (not relative PSD) summed from Hz bins 25-40
CN	fzpoz_Beta_13_29	PSD for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29
CO	czpoz_1	PSD power at channel CzPOz (with Kaiser windowing) for the 1 Hz bin
CP - QF		PSD/Relative PSD information for all differential channels (CzPOz, FzC3, C3C4, F3Cz uses the same naming convention as FzPOz, described above)
QG	ThetaOverall_3_7	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7
QH	AlphaOverall_8_13	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-13
QI	BetaOverall_13_29	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29
QJ	GammaOverall_25_40	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Beta Bandwidth (not relative PSD) summed from Hz bins 30-40

2. Diff_Raw.csv

PSDs (1-40Hz) for the *differential channels (*FzPOz, CzPO, FzC3, C3C4, F3Cz) are computed for generating ABM's classifications for each second of a given .ebs file. PSDs in this file are computed for each second of a given session *without* the Kaiser Windowing procedure. *Relative* power values are derived by subtracting the logged power of the individual Hz bin from the summed logged power for the EEG band (1-40Hz) for that channel.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	fzpoz_1	PSD power at channel FzPoz (without Kaiser windowing) for the 1 Hz bin
E	fzpoz_2	PSD power at channel FzPoz (without Kaiser windowing) for the 2 Hz bin
F - AQ	fzpoz_3-40	PSD power at channel FzPoz (without Kaiser windowing) for the 3-40 Hz bins
AR	fzpoz_rel1	*Relative* PSD power at channel FzPoz (without Kaiser windowing) for 1 Hz Bin
AS - CE	fzpoz_rel2-rel40	*Relative* PSD power at channel FzPoz (without Kaiser windowing) for 2-40 Hz Bin
CF	fzpoz_Delta_1_2	PSD for Delta Bandwidth at channel FzPoz (not relative PSD) summed from Hz bins 1-2 (without Kaiser windowing)
CG	fzpoz_ThetaSlow_3_5	PSD for Theta-Slow Bandwidth (not relative PSD) summed from Hz bins 3-5 (without Kaiser windowing)
CH	fzpoz_ThetaFast_5_7	PSD for Theta-Fast Bandwidth (not relative PSD) summed from Hz bins 5-7 (without Kaiser windowing)
CI	fzpoz_ThetaTotal_3_7	PSD for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7(without Kaiser windowing)
CJ	fzpoz_AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth (not relative PSD) summed from Hz bins 8-10 (without Kaiser windowing)
CK	fzpoz_AlphaFast_10_13	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 10-13 (without Kaiser windowing)
CL	fzpoz_AlphaTotal_8_13	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 8-13 (without Kaiser windowing)
CM	fzpoz_Gamma_25_40	PSD for Gamma Bandwidth (not relative PSD) summed from Hz bins 25-40 (without Kaiser windowing)
CN	fzpoz_Beta_13_29	PSD for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)
CO	czpoz_1	PSD power at channel CzPOz (with Kaiser windowing) for the 1 Hz bin (without Kaiser windowing)
CP - QF		PSD/Relative PSD information for all differential channels (CzPOz, FzC3, C3C4, F3Cz uses the same naming convention as FzPOz (described above)
QG	ThetaOverall_3_7	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7 (without Kaiser windowing)
QH	AlphaOverall_8_13	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-13 (without Kaiser windowing)

QI	GammaOverall_25_40	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Beta Bandwidth (not relative PSD) summed from Hz bins 25-40 (without Kaiser windowing)
QJ	BetaOverall_13_29	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)

3. Ref_Class.csv

PSDs (1-40Hz) for the *referential channels* are computed for generating ABM's classifications for each second of a given .ebs file. PSDs in this file are computed for each second of a given session *with* the Kaiser Windowing procedure described above. *Relative* power values (_rel) are derived by subtracting the logged power of the individual Hz bin from the summed logged power for the EEG band (1-40Hz) for that channel.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	POz_1	PSD power at channel POz (with Kaiser windowing) for the 1 Hz bin
E	POz_2	PSD power at channel POz (with Kaiser windowing) for the 2 Hz bin
F - AQ	POz_3-40	PSD power at channel POz (with Kaiser windowing) for the 3-40 Hz bins
AR	POz_rel1	*Relative* PSD power at channel POz (with Kaiser windowing) for 1 Hz Bin
AS - CE	POz_rel2-rel40	*Relative* PSD power at channel POz (with Kaiser windowing) for 2-40 Hz Bin
CF	POz_Delta_1_2	PSD for Delta Bandwidth at channel POz (not relative PSD) summed from Hz bins 1-2 (with Kaiser windowing)
CG	POz _ThetaSlow_3_5	PSD for Theta-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-5 (with Kaiser windowing)
CH	POz _ThetaFast_5_7	PSD for Theta-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 5-7 (with Kaiser windowing)
CI	POz _ThetaTotal_3_7	PSD for Theta-Total Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-7 (with Kaiser windowing)
CJ	POz _AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-10 (with Kaiser windowing)
CK	POz _AlphaFast_10_13	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 10-13 (with Kaiser windowing)
CL	POz _AlphaTotal_8_13	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-13 (with Kaiser windowing)
CM	POz _Gamma_25_40	PSD for Gamma Bandwidth at channel POz (not relative PSD) summed from Hz bins 25-40 (with Kaiser windowing)
CN	POz _Beta_13_29	PSD for Beta Bandwidth at channel POz (not relative PSD) summed from Hz bins 13-29 (with Kaiser windowing)
CO	Fz_1	PSD power at channel Fz (with Kaiser windowing) for the 1 Hz bin (with Kaiser windowing)
CP - ADX		PSD information for all referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4); uses the same naming convention and analysis as Fz (described above-- all with Kaiser windowing)

ADY	ThetaOverall_3_7	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7 (with Kaiser windowing)
ADZ	AlphaOverall_8_13	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-13 (with Kaiser windowing)
AEA	GammaOverall_25_40	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Gamma Bandwidth (not relative PSD) summed from Hz bins 25-40 (with Kaiser windowing)
AEB	BetaOverall_13_29	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29 (with Kaiser windowing)

4. Ref_Raw.csv

PSDs (1-40Hz) for the *referential channels* are computed for generating ABM's classifications for each second of a given .ebs file. PSDs in this file are computed for each second of a given session *without* the Kaiser windowing procedure. *Relative* power values (_rel) are derived by subtracting the logged power of the individual Hz bin from the summed logged power for the EEG band (1-40 Hz) for that channel.

Column	**Column Name**	**Description**
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	POz_1	PSD power at channel POz (without Kaiser windowing) for the 1 Hz bin
E	POz_2	PSD power at channel POz (without Kaiser windowing) for the 2 Hz bin
F - AQ	POz_3-40	PSD power at channel POz (without Kaiser windowing) for the 3-40 Hz bins
AR	POz_rel1	*Relative* PSD power at channel POz (without Kaiser windowing) for 1 Hz Bin
AS - CE	POz_rel2-rel40	*Relative* PSD power at channel POz (with Kaiser windowing) for 2-40 Hz Bin
CF	POz_Delta_1_2	PSD for Delta Bandwidth at channel POz (not relative PSD) summed from Hz bins 1-2 (without Kaiser windowing)
CG	POz _ThetaSlow_3_5	PSD for Theta-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-5 (without Kaiser windowing)
CH	POz _ThetaFast_5_7	PSD for Theta-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 5-7 (without Kaiser windowing)
CI	POz _ThetaTotal_3_7	PSD for Theta-Total Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-7(without Kaiser windowing)
CJ	POz _AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-10 (without Kaiser windowing)
CK	POz _AlphaFast_10_13	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 10-13 (without Kaiser windowing)
CL	POz _AlphaTotal_8_13	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-13 (without Kaiser windowing)
CM	POz _Gamma_25_40	PSD for Gamma Bandwidth at channel POz (not relative PSD) summed from Hz bins 25-40 (without Kaiser windowing)
CN	POz _Beta_13_29	PSD for Beta Bandwidth at channel POz (not relative PSD)

		summed from Hz bins 13-29 (without Kaiser windowing)
CO	Fz_1	PSD power at channel Fz (without Kaiser windowing) for the 1 Hz bin
CP - ADX		PSD/Relative PSD information for all referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) uses same naming convention and analysis as Fz (described above -- all without Kaiser windowing)
ADY	ThetaOverall_3_7	Mean PSD across ALL referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7 (without Kaiser windowing)
ADZ	AlphaOverall_8_13	Mean PSD across ALL referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-13 (without Kaiser windowing)
AEA	GammaOverall_25_40	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Gamma Bandwidth (not relative PSD) summed from Hz bins 25-40 (without Kaiser windowing)
AEB	BetaOverall_13_29	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)

Note:
Ref_xxx.csv files will not be generated for B-Alert X4, as it does not have referential channels.

A.4 Heart Rate Outputs

_HR_beat.csv
_HR_epoch.csv

Signal processing performs 5 operations on the raw ECG signal, the output being a signal with QRS complexes enhanced, and other components attenuated. The r to r interval is calculated to determine each heart rate. Heart rate variability will be determined based on detected heart rate values. ABM's Heart Rate (HR) algorithm computes beat to beat (_HR_beat.csv) and second by second (_HR_Epoch.csv).

1. **_HR_beat.csv**

   This file contains the beat to beat heart rate data based on B-Alert Live's Heart Rate algorithm.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	Beat Quality	1 or 0 value: 0 = beat quality good, 1 = beat quality poor based on artifact in ECG channel.
E	Inter-Beat Interval	Inter-beat Interval.
F	Heart Rate	Beat to Beat Heart Rate (beats per minute).

2. _HR_epoch.csv

This file contains the second by second (epoch by epoch) heart rate based on B-Alert Live's Heart Rate algorithm.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	Beat Quality	1 or 0 value: 0 = beat quality good, 1 = beat quality poor based on artifact in ECG channel.
E	Inter-Beat Interval	Inter-beat Interval: Interpreted to the second
F	Heart Rate	Second to Second Heart Rate (beats per minute)

A.5 Z-Score Outputs

To remove individual variability from the various metrics, a z-score output is also provided. The Z-score for this purpose is calculated on the mean and standard deviation (SD) for at least the first 5 seconds, with additional epochs (seconds) added. The initial period to begin calculation is defaulted to 5 sec, but can be set by the user. A new mean and SD are computed if the raw data differs more than 2.5 SD from the mean. Epochs that are invalid will not be included in Z-score calculation. Instead the mean, SD, and z-score from a previous valid second are used.

After acquiring the configured period of valid seconds to determine the mean and SD, the ZScore algorithms begins computing the z-score for each epoch for input signal by:

ZScore = (Epoch value - mean)/ standard deviation

1. ZScore.csv

The ZScore.csv output file contains classification, workload, and heart rate information.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	class_higheng	Z-Score of High Engagement Probability (-99999 if it falls within Z-score computation window)
E	class_loweng	Z-Score of Low Engagement Probability (-99999 if it falls within Z-score computation window)
F	class_distraction	Z-Score of Class Engagement Probability (-99999 if it falls within Z-score computation window)
G	class_drowsy	Z-Score of Class Drowsy Probability (-99999 if it falls within Z-score computation window)
H	wl_fbds	Z-Score of Workload probability (FBDS model), where higher probability reflects higher WL (FBDS is best model for 85% of population) (-99999 if it falls within Z-score computation window)
I	wl_bds	Z-Score of Alternate Workload probability (BDS model): Not recommended for use, higher probability reflects higher WL (BDS Best WL model for other 15% of model) (-99999 if it falls within Z-score computation window)

J	wl_ave	Z-score of mean workload probability (mean of BDS and FBDS models), higher probability reflects higher workload (-99999 if it falls within Z-score computation window)
K	HeartRate	Z-Score of the second by second Heart Rate (-99999 if during Z score computation window)

2. **_ZScore_PSD.csv**

Z-scored info (same Z-scoring procedure as used for _ZScore output) for Heart Rate, and PSD info for 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) and 5 differential channels (FzPOz, CzPOz, FzC3, C3C4, F3Cz). The 5 differential channels available are fixed, based on the channels required for ABM's classification models.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	HeartRate	Z-Score of Heart Rate (-99999 if it falls within Z-score computation window) Interpreted to the second
E	OvRawRef_0	Z-score PSD (No Kaiser Window) for Theta Total (3-7Hz bins)
F	OvRawRef_1	Z-score PSD of (No Kaiser Window) for Alpha Total (8-13Hz bins)
G	poz_3	Z-scored PSD (No Kaiser Window) for Theta Total (3-7 Hz bin) at Channel POz
H	poz_6	Z-scored PSD (No Kaiser Window) for Alpha Total (8-13 Hz bin) at Channel POz
I	poz_7	Z-scored PSD (No Kaiser Window) for Gamma (25-40 Hz bin at Channel POz
J	poz_8	Z-scored PSD (No Kaiser Window) for Beta (13-30 Hz bin) at Channel POz
K-BJ		Z-Scored PSD for all 9 Referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) and 5 Differential channels using same naming conventions described above (FzPOz, CzPOz, FzC3, C3C4, F3Cz)

A.6 Actigraphy Outputs

1. **Actigraphy.csv**

The Actigraphy.csv output file contains both raw tilt data as well as the derived/processed data from the accelerometer.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	X_Raw	Raw x-axis tilt value
E	X_Angle	X-axis Angle derived from tilt value
F	Y_Raw	Raw Y-axis tilt value
G	Y_Angle	Y-axis Angle derived from tilt value
H	Z_Raw	Raw Z-axis tilt value
I	Z_Angle	Z-axis Angle derived from tilt value

J	Movement_value	Sum of change in two dominant angles
K	Movement_Scale	Value between 0-5 derived from the change in two dominant angle using proprietary algorithm

A.7 Signal Quality Outputs

1. **Artifact.csv**

Artifacts (i.e., EMG, Eye blinks, Saturation, Spike, Excursion) detected in the signal.

Column	Column Name	Description
A	StartEpoch	Start Epoch of the detected artifact
B	StartDP	Start Datapoint of the detected artifact
C	EndEpoch	End Epoch of the detected artifact
D	End DP	End Datapoint of the detected artifact
E	Artifact Type	Artifact type (0 - Spike, 1 - Excursion, 2 - Saturation, 3 - EMG, 5 - Eye blink)
F	Channel	Channel in which the artifact was detected (Eye blinks are reported in all channels, hence channel field is empty)
G	Rule	Artifact rule (reserved for internal debugging)

2. **_missed_blocks.csv**

This output file can be used to determine whether BT packets (or blocks) were dropped or missed during a data collection.

Column	Column Name	Description
A	sessionID	.ebs file Name
B	Blocks	Blocks: this increments for each blocks of lost packets, for example if packets 5,6,7 were missed and then 25,26,27,28 were missed, There will be two row entries in the csv file. Blocks will be 1 for former and 2 for late
C	Start Counter	Count when missed block started (6-bit counter in the headset (debugging)
D	End Counter	Count when missed block stopped (6-bit counter in the headset (debugging)
E	Epoch Start	Starting second (Epoch) of missed block
F	Offset Start	Starting Sample (datapoint or Offest) of missed block (in 1/256sec)
G	Epoch End	Ending second (Epoch) of missed block
H	OffsetEnd	Ending Sample (datapoint or Offest) of missed block (in 1/256sec)
I	Hour	Time of storing to file (or time of first packet AFTER missed blocks)
J	Minute	
K	Second	
L	Millisecond	

Create .def File Output Files

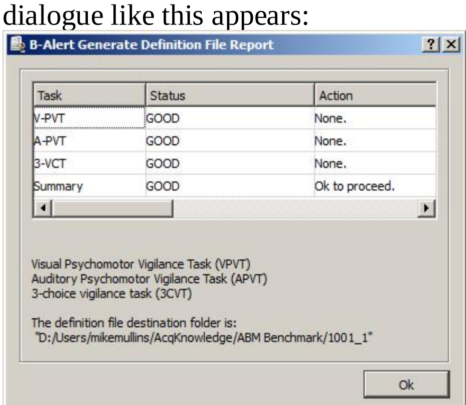
Running the Create .def file function from the B-alert Software will create 2 output files, a .def file and a BenchmarkReport.csv file.

Definition File (xxxx_ M7003500_A1.def)

The Definition file is used to individualize the Engagement and Workload classification models. When a series of tasks conclude that include the three Benchmark tasks (or when the 'Create Definition File' function is invoked), then a Definition file (xxxx_M7003500_A1.def) will be generated. ***The Definition file should not be used directly for analysis***. It is solely used by the software to individualize the data for cognitive classification. Once a valid Definition file is created, it can then be used to classify Engagement and/or Workload for any EEG session for that participant.

BenchmarkReport.csv

This file summarizes performance, classification data, and PSDs (along with heart rate if available) across the three Benchmark tasks: Eyes open (xxxxxx111.ebs), Eyes closed (xxxxxx121.ebs) and the 3 choice vigilance task (3CVT; xxxxxx231.ebs). Included are healthy, fully rested population norms (n=160) for all three aspects for comparison purposes. When a series of tasks conclude that include the three Benchmark tasks, then a definition file (used to individualize the classification models) and this Benchmark report automatically generate, and when completed a dialogue like this appears:



If any of the data is determined to be 'bad', the reasons for classifying the definition file as such and suggested action will be presented in this box.

If the definition file and Benchmark report generation are not automatically triggered, or fail for some reason, you can get them offline, by selecting the "create definition file" button and following the instructions in the manual. The dialogue summary will also appear when invoking the action offline.

(xxxxx_BenchmarkReport.csv) where xxxxx- indicates subj ID and session ID

The Benchmark report contains the following information:

Cell/Cell range	Description	Notes
A1-B1	Data Quality based on performance	Subject's performance must fall within a given performance range (percent correct) for the definition file model to be valid
A2-B2	Data Quality based on EEG data quality	This summarizes the quality in terms of artifacts (EMG, eyeblinks, spikes, excursions, etc.), and tells if enough good data was collected to determine a valid definition file model
A5-E9	Performance Data- subject	Gives the number of responses (EO/EC) or percent of correct responses (3CVT), and lapses (single: missed, and mulitple:slow) for EO/EC, and Reaction time for 3CVT
H5-K9	Population performance	The population norm performances
A12-F15	Percentage of epochs (1s periods) classified as one of the 4 brain state classifications by task	EO should primarily be low engagement, EC should be primarily distraction, and 3CVT should primarily be high engagement; you can calculate these using the # of epochs classified as a given classification : total valid epochs in the session
G12-H15	Percentage of epochs that were not classified due to excessive EMG or INV (INV included all other artifacts, such as spikes, excursions, etc.)	
I12-L15	Average probability of being classified as a given brain state	Based on our B-ALERT algorithm that uses the PSD values to classify each epoch; it also determines the probability
M12-P15	Number of epochs classified as each brain state	
Q12-R15	Number of epochs not classified due to INV or EMG	
S12-T15	Number of Valid epochs and total epochs	
Rows 17-22	Population Classification percentages, probabilities and # of epochs	
Rows 24-47	Average log10 PSD values for FzPO and CzPO from Hz bin 1- 40	
Row 49-74	Population Average log10 PSD values for FzPO and CzPO from Hz bin 1-40	

06.20.2019