MABR Toolbox - v19A

Matlab Auditory Brainstem Response Toolbox

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1. Introduction

The Matlab Auditory Brainstem Response (***MABR***) Toolbox was designed for the specific purpose of acquiring and organizing auditory stimulus-locked brain responses using a standard personal computer running on the Windows operating system and high quality sound cards. The highest frequency of your auditory stimulus is determined by your sound card's maximum sampling rate. Using a high quality sound card (see recommendations below) provide up to 192 kHz sampling rate which can produce frequencies up to 96 kHz (theoretically, but in practice).

? Clicking this icon will give you information on what you see.

__**Important Note**__: When running the ***MABR*** Control Panel or Calibration utility a background instance of Matlab will be opened. This background instance of Matlab handles the sound delivery and data acquisition for precise timing. This background instance will be opened and closed automatically, but should not be closed by the user unless a significant error with the ***MABR*** software has occurred. If you do need to manually close the background instance of Matlab using the Windows task manager, just restart Matlab and run ***MABR*** again.

2. Getting Started

2.1. Requirements

2.1.1. Hardware

- Personal computer with quad-core processor or better and at least 8 GB memory (more processors and ram is always better).
- High-quality sound card with at least 2 input and 2 output channels. The sound card should come with (or at least support) ASIO drivers. If your sound card does not provide its own ASIO drivers, then you can try the ASIO4All drivers (http://www.asio4all.org).
  - *Recommended*: RME Fireface UCX (http://www.rme-audio.de/en/products/fireface_ucx.php)
- Differential Bioamplifier and headstage; Recommended:
  - *Recommended*: A-M Systems Model 3000 AC/DC Differential Amplifier (https://www.a-msystems.com/p-254-model-3000-acdc-differential-amplifier.aspx)
  - *Recommended*: A-M Systems Model 3000 Headstage (https://www.a-msystems.com/p-271-model-3000-headstage.aspx)
- Appropriate electrodes for your application and connections to your headstage.

2.1.2. Software

- Windows 10 operating system
- Matlab 2018b (v9.5) or newer including the following toolboxes and versions (or newer):
  - Signal Processing Toolbox, v8.1
  - Audio System Toolbox, v1.5
  - DSP System Toolbox, v9.7

2.2. Software Setup

- *First time installation only*
  - Install Matlab and required toolboxes (see section Software).
  - Copy the ***MABR*** folder to a known location on your computer. It is recommended to copy the folder to `C:\MABR` for the sake of simplicity.
  - Start Matlab.
  - In Matlab's command window, type `addpath('C:\MABR')` replacing `C:\MABR` with the directory where you copied the software, and hit Enter on your keyboard.

- To run the ***MABR*** Control Panel, type `MABR` in Matlab's command window and hit Enter on your keyboard. You should see a message in Matlab's command window and the Control Panel should appear momentarily.

2.3. Hardware Setup

- Connect the sound card output channel 1 to an audio amplifier and speaker.
- Connect bioamplifier output to input channel 1 on your sound card.
- Create a *loop-back* connection by connecting the sound card's output channel 2 to input channel 2. The *loop-back* connection ensures precise stimulus/acquisition timing.
- Note that this channel configuration can be customized in the ***MABR*** Control Panel by selecting "Define Audio Channels" under the "Options" menu.

3. ***MABR*** Terminology

3.1. Sweep - Refers to a recorded data in response to a single stimulus presentation. The duration of a sweep is typically 10 ms for ABRs.

3.2. Block - Refers to a group of sweeps in response to the same stimulus parameters.

3.3. Schedule - A table that permits the selection of which stimuli will be presented during an ABR session. Each activated row of the table will generate its on block. A schedule is created using the Schedule Design utility and modified using the Block Schedule utility.

3.4. Trace - Refers to a waveform created by averaging a block and is displayed in the Trace Organizer utility.

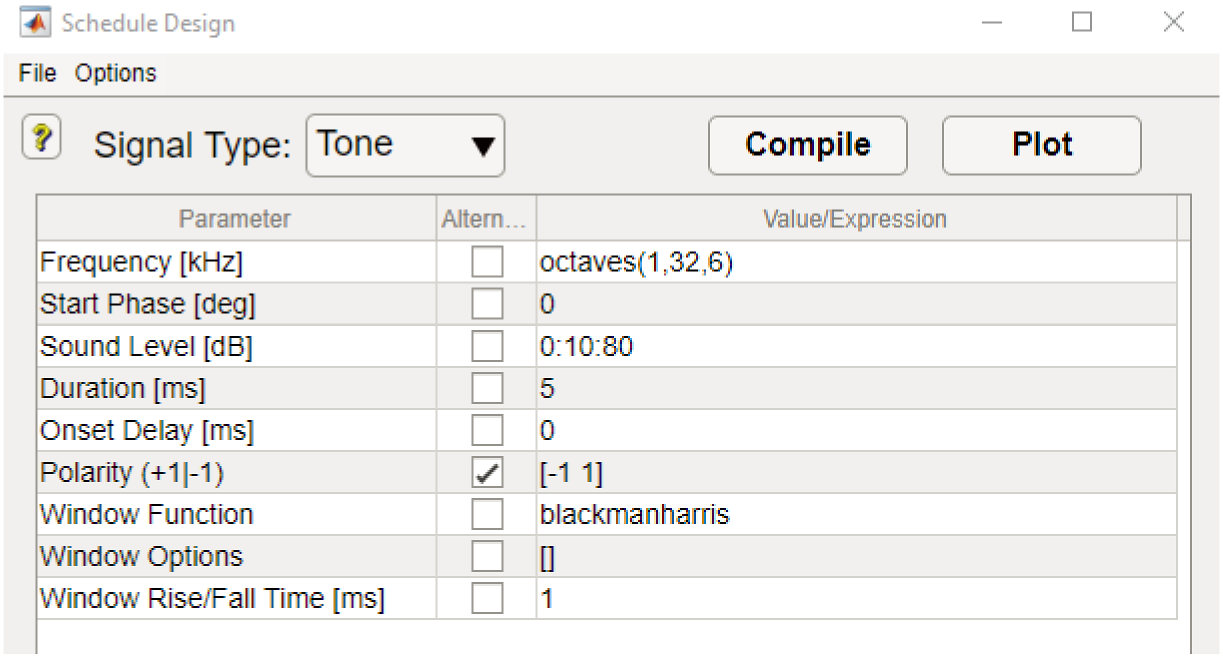
4. The Parametric Stimulus Schedule

The ABR is used to determine how the auditory brainstem responds to sounds varying across one or multiple stimulus dimensions, typically sound level and frequency. The ***MABR*** toolbox includes a "Schedule Design" utility which will help you to setup a stimulus that varys its parameters along one or more dimensions. The result of this process is a "Schedule" that will be used to select the stimulus parameters during an ABR acquisition.

4.1. Creating parametric sound stimuli

The Schedule Design utility can be accessed in two ways:

1. In Matlab's command window, type: `abr.ScheduleDesign`
2. Click the "Schedule Design" button on the Utilities tab located on the ***MABR*** Control Panel.



Signal Type: Tone

Parameter	Altern...	Value/Expression
Frequency [kHz]	□	octaves(1,32,6)
Start Phase [deg]	□	0
Sound Level [dB]	□	0:10:80
Duration [ms]	□	5
Onset Delay [ms]	□	0
Polarity (+1|-1)	☑	[-1 1]
Window Function	□	blackmanharris
Window Options	□	[]
Window Rise/Fall Time [ms]	□	1

Setting the Sampling Rate

The first step when creating a new schedule is to set the sampling rate. Select "Stimulus Sampling Rate" under the "Options" menu. Select the sampling rate you would like to use to generate the stimulus. Typically, this is the highest sampling rate supported by your hardware. Note that the ***MABR*** software does not know what sampling rates your sound card supports. Please select a sampling rate your sound card supports.

Signal Type

You will then need to select what kind of sound stimulus you would like to generate. Select from "Tone", "Noise", "Click", "File" in the dropdown box next to "Signal Type". Selecting a new signal type will update the property table with signal-specific values.

Modifying Signal Properties

The table on the Schedule Design utility contains signal parameters in the leftmost column. The idea is to define one or more values for each property. You can enter a scalar value for a parameter if it is constant for all stimuli. For example, the `Duration [ms]` is given a value of `5`. Note that the units for parameters are indicated in brackets. Entered values must use these units.

Parameters that vary, such as frequency and sound level in the figure above, can be given multiple explicit values. For example, the `Frequency [kHz]` parameter can be given values `[1, 3, 5, 7, 9, 11, 13, 16, 17, 19, 21]`. Alternatively, any Matlab expression that yields a vector can be entered. For example, the `Frequency [kHz]` parameter can be given the equivalent expression `1:2:21` or `linspace(1,21,11)`.

More examples:

Parameter	Expression	Result
`Frequency [kHz]`	`[1 2 4 8 16 32]`	`[1 2 4 8 16 32]`
`Frequency [kHz]`	`2.^[0:5]`	`[1 2 4 8 16 32]`
`Frequency [kHz]`	`octaves(1,32,6)`	`[1 2 4 8 16 32]`

The “Alternate” column contains only a checkbox. Currently, this is only enabled for the `Polarity (+1|-1)` parameter. This will enable/disable a flag to alternate the polarity of the signal on each stimulus sweep.

Compile

Once you have all parameters defined for your needs, click the Compile button. This will launch a new Schedule utility window containing the generated schedule. Make sure to save the generated schedule in the Schedule utility as this is what will be used by the ***MABR*** Control Panel during an ABR session. For more details, see the section on modifying the parameter schedule.

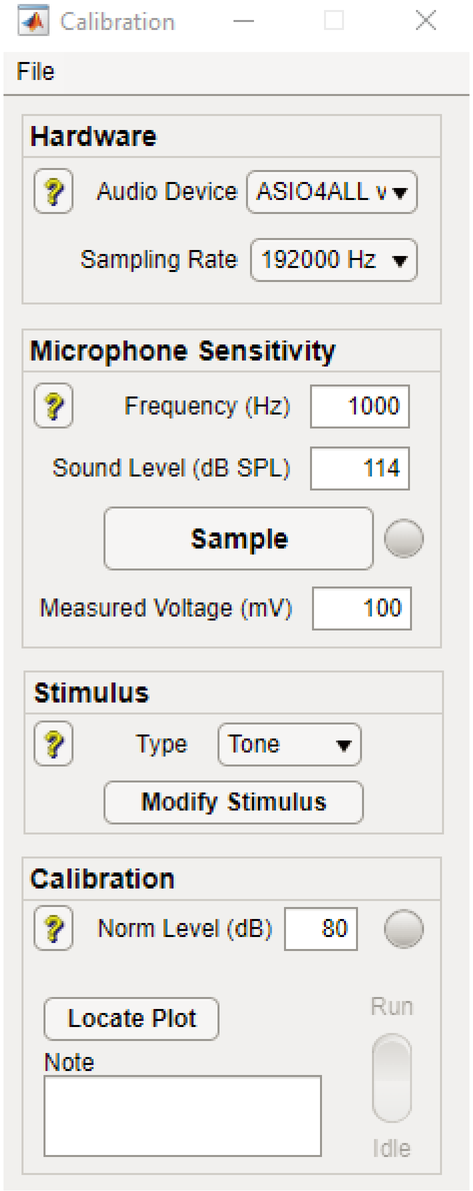
Save/Load

You can save or load a Schedule Design file using the “File” menu.

4.2. Calibrating parametric sounds

The Calibration utility can be accessed in two ways:

1. In Matlab's command window, type: `abr.CalibrationUtility`
2. Click the "Sound Calibration" button on the Utilities tab located on the ***MABR*** Control Panel.



Audio Device: ASIO4ALL v

Sampling Rate: 192000 Hz

Frequency (Hz): 1000

Sound Level (dB SPL): 114

Measured Voltage (mV): 100

Type: Tone

Norm Level (dB): 80

* Note that startup may take a few moments while a second instance of Matlab is loaded in the background.

The Calibration utility can be used to calibrate sound stimuli. You will need to hook up a microphone and preamplifier to the acquisition channel of your sound card (typically the input from your bioamplifier).

<u>Hardware</u>

Select your audio device and sampling rate. The audio device and sampling rate will be the same used to run the ABR. The sound card will typically be some version of ASIO. You will most likely set the sampling rate to its maximum value, unless this results in program crashes or other instability.

<u>Microphone Sensitivity</u>

In order to properly calibrate the sound level of a speaker, we need to determine the sensitivity of a microphone and amplification system. You can do this using one of two methods:

1. ***Recommended*** Use a piston phone or electronic speaker with a known sound level to measure the sensitivity of your microphone and amplifier. Enter the frequency of the sound source and it's sound level (dB SPL) and click the Sample button. Inspect the resulting time- and frequency-domain plots for a clean sinusoid at the specified frequency.
2. Enter the sensitivity from the data that came with the microphone which is typically some number of mV at 1 Pascal. Since 1 Pascal is equal to 94 dB SPL, enter 94 in the sound level field and the mV in the measured voltage field (ignore the frequency field). Note that you will need to adjust the measured voltage value based on any additional amplification in the microphone system; eg. multiply by 10 for 20 dB amplification.

Stimulus Selection

Select the stimulus type from the dropdown list and click Modify to adjust the stimulus parameters to your needs.

You can load a previously generated stimulus using the Schedule Design utility.

Tone stimuli are calibrated using interpolation of frequency so you will need to set the frequency parameter to characterize your speaker's transfer function. Typically, you will set the parameter to cover the range from the lowest frequency you want to present to just below the Nyquist rate = Sampling Rate/2. Other stimulus types are calibrated using a look-up table, so you will need to enter the parameters of stimuli you will be using.

Calibration

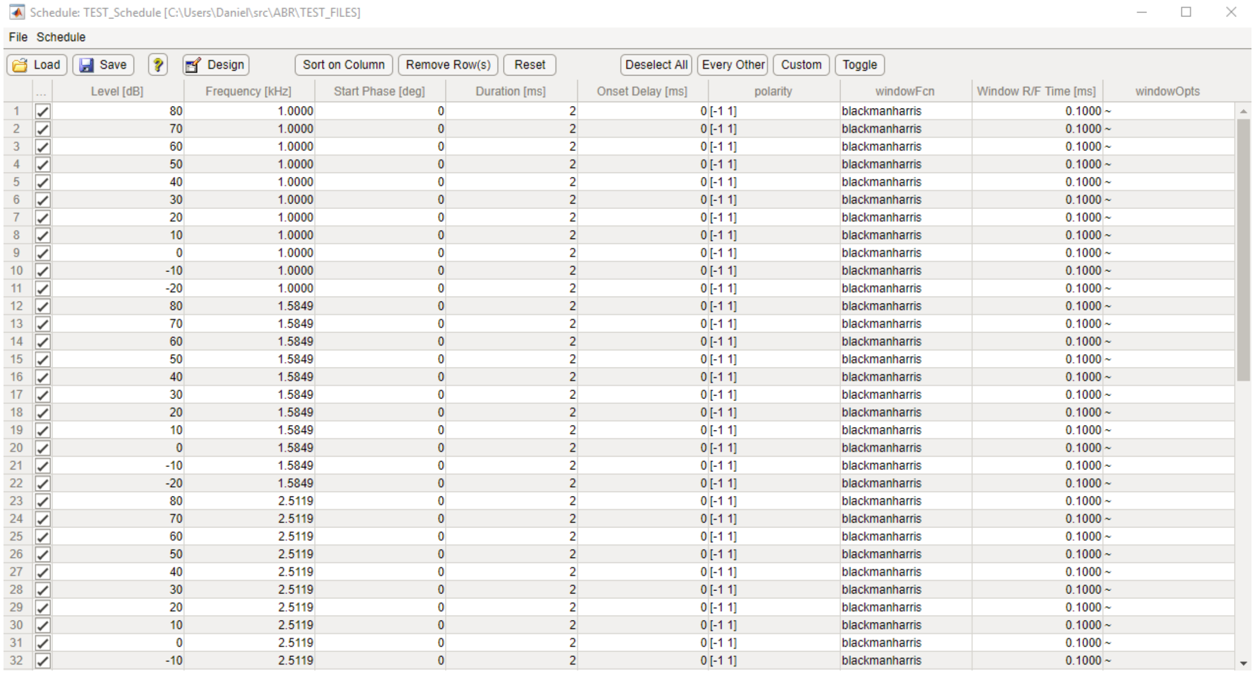
First, specify a sound level, the **Norm Level**, as a target for the calibrated stimulus. This is often the maximum sound level you intend to present. It is possible that the voltage required to produce this sound level will be too high for your sound card to produce (>1 V). If this is the case, then you will need to provide additional amplification and recalibrate. Click Run to begin. The stimuli will be played through entirely and once finished the results will be plotted. The stimuli will then be played through a second time at the calibrated voltage. The results will be plotted again and should be flat on the Norm Level line. You will be prompted to save the calibration file once the calibration procedure has been completed.

4.3. Modifying the Stimulus Block Schedule

The Schedule utility can be accessed in two ways:

1. In Matlab's command window, type: `abr.Schedule`
2. Click the "Schedule" button on the Utilities tab located on the ***MABR*** Control Panel.

The Schedule utility displays a fully parameterized version of a stimulus type created using the Schedule Design utility (see the section on Creating parametric sound stimuli). The table columns organize the stimulus parameters. Table rows display every permutation for the parametric stimulus and each row will present an ABR block. The most informative parameters - those with values that vary the most - will be displayed in the leftmost columns of the table. The first column of the table is used to enable/disable the row by checking/unchecking the corresponding box. The Schedule is used by the Control Panel to manage the stimulus playback. Each time you acquire an ABR block using the Control Panel, stimuli will be presented in order from top to bottom of the schedule. Only checked rows will be presented. Unchecked rows will be skipped.



	...	Level [dB]	Frequency [kHz]	Start Phase [deg]	Duration [ms]	Onset Delay [ms]	polarity	windowFcn	Window R/F Time [ms]	windowOpts
1	☑	80	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
2	☑	70	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
3	☑	60	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
4	☑	50	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
5	☑	40	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
6	☑	30	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
7	☑	20	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
8	☑	10	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
9	☑	0	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
10	☑	-10	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
11	☑	-20	1.0000	0	2	0	[-1 1]	blackmanharris	0.1000	~
12	☑	80	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
13	☑	70	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
14	☑	60	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
15	☑	50	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
16	☑	40	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
17	☑	30	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
18	☑	20	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
19	☑	10	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
20	☑	0	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
21	☑	-10	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
22	☑	-20	1.5849	0	2	0	[-1 1]	blackmanharris	0.1000	~
23	☑	80	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~
24	☑	70	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~
25	☑	60	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~
26	☑	50	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~
27	☑	40	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~
28	☑	30	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~
29	☑	20	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~
30	☑	10	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~
31	☑	0	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~
32	☑	-10	2.5119	0	2	0	[-1 1]	blackmanharris	0.1000	~

Sorting on Column

ABR blocks are acquired in the order of the Schedule from top to bottom. To reorder the stimuli to suit your needs, click any cell under the parameter you would like to sort by (maybe "Frequency [kHz]") and click the Sort on Column button. This will sort the values of this column in ascending or descending order. Click the button again to reverse the sort order. You can sort on multiple columns by sequentially selecting a column cell and clicking the Sort on Column button again. The sequence in which you sort the columns may yield different results.

Remove Rows

Deletes selected or unselected rows (choose in a dialog box that appears after clicking the button). You can restore the original Schedule by clicking the Reset button.

Reset

Resets the Schedule to its original form.

Select/Deselect All

Selects or Deselects all rows in the Schedule.

Custom

Allows you to use a Matlab expression to determine which rows should be selected. You can use this in multiple ways.

Simple: The length of the Schedule is accessed using the variable `M`. Any custom Matlab expression must return a vector of logical values. For example, you can select every third row using `1:3:M`. You can also combine statements using brackets to concatenate expressions, ex: [1:5:M 2:5:M].

Advanced: You can create your own Matlab function to return a custom selection. To do this, create a new Matlab function and place it somewhere on Matlab's search path. You can have this function return a vector of logical values to determine which rows in your Schedule are selected.

You can optionally pass a variable, `D`, to your function which contains all of the Schedule data for a more complex block selection capability. `D` will be of the table data type. Your function must return a vector of logical values with the number of rows in `D` which is equal to `size(D,1).`

Note that the row names are slightly different than the column names. You can figure out the actual names you need to use by adding the line, `properties(D`, to your custom function. You can comment out or delete this line later.

Toggle

Toggles each row's selection.

5. Acquiring Auditory Brainstem Response

5.1. MABR Control Panel

5.2. Live ABR Display

5.3. Trace Organizer

5.4.