

Overview of IBI VizEdit

IBI VizEdit is a program built using RShiny. It is designed to assist in the manual editing of inter-beat interval files that are derived from photoplethysmogram (PPG) recordings. Unlike the electrocardiogram signal (EKG or ECG), PPG signals are characterized by a slow-moving waveform, which presents a different set of challenges when the true signal becomes contaminated with motion artefacts and other sources of noise.

Though increasingly popular due to their ease of use, most heart rate editing software that exists to date was designed and optimized for the detection and editing of inter-beat interval files derived from EKG signals. IBI VizEdit provides a new suite of tools for researchers who find themselves working with messy PPG files.

Please note that IBI VizEdit is beta software. It has not been fully tested, and there are likely numerous bugs and opportunities to optimize code and performance. Any and all feedback is welcome.

As of right now, IBI VizEdit is only supported for use on Windows 7/8/10.

Please cite as:

Barstead, M. G. (2018). IBI VizEdit v.1.0: An RShiny Application [Computer software]. University of Maryland.

Features and Settings

1. Supported File Types

IBI VizEdit can work with any raw PPG (or even EKG) signal that is saved as a tab-delimited `.txt` file. The PPG data should exist in a single column, though the presence of other data in other columns is not an issue. If header information exists, there is no need to remove it prior to loading the data into VizEdit. You will be presented with an opportunity to specify the number of header rows that exist before you load the raw file into the program (IBI VizEdit will discard these rows when reading in the data).

The program supports files sampled at a rate of up to 2000 Hz, though it is **strongly** recommended that you make use of the downsampling feature within IBI VizEdit to reduce the file size and overall computation time. You will definitely notice the difference in speed when attempting to use any of the advanced imputation features. You may also find some of the graphics slow to refresh when using even the basic features if raw files are particularly large. The current version of the program (v1.0) has an **overall file size limit of 150MB**.

2. Selecting a Working Directory

One slight downside in working with RShiny is that it can be slow in navigating a system's file structure. To help speed this process up, before you go to use IBI VizEdit, place all files you would like to edit in a specific folder. This includes the timing file (more on that below). This folder should be accessible to the specific user profile logged into the computer. When working in IBI VizEdit, you will specify this folder as your working directory, and it should be your very first step in the program (assuming you have organized all of your files accordingly). After you have selected the appropriate folder, choose the file you would like to edit.

Set Working Directory:

IBI VizEdit v1.0.0

Data Entry

Processing Panel

Basic Editing Panel

Advanced Editing Panel

Select File and Directory:

Select Directory

Directory: WARNING - no directory selected!

Select HR File

File Chosen: WARNING - no file selected!

File ID and Information:

Subject ID:

Time Point:

(Optional) Study ID:

Editor Name:

Data Details:

Data is in column:

2

Number of header lines in file:

15

File Sampling Rate in Hz:

2000

Preferred Downsampling Rate:

100

Note: Larger values increase computation time

Optional Settings:

Select Timing File

File Chosen: No file selected

Peak Detection Iterations

100

Output Epoch Options:

☒ 10s

☒ 15s

☒ 20s

☒ 30s

☒ 45s

Load file using current settings

Reset fields to change existing file

Save Edited File

Save Edited File and Close

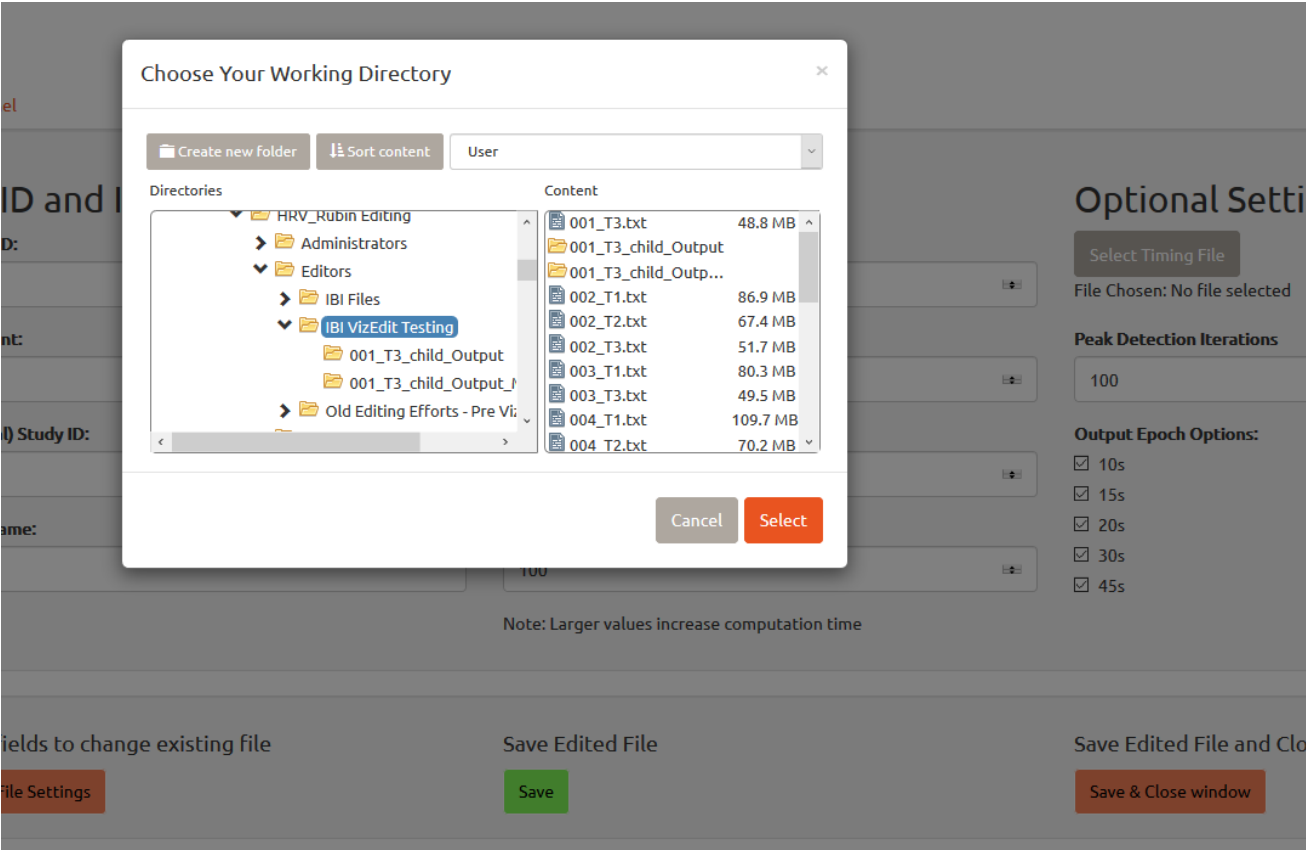
Load File Settings

Reset File Settings

Save

Save & Close window

Select Folder:



When you save your processed and edited files, the program will create a new output folder that will contain a `Case Processing Summary.rtf` file, a raw `.txt` file containing the downsampled version of your PPG data, a separate time series `.csv` for each epoch interval you selected on the opening screen, a overall summary `.csv` file containing heart rate and heart rate variability scores by task, both edited and raw versions of your processed IBI files (as `.txt` files), and finally, separate IBI `.txt` files separated by task (see image below).

Output Folder Example:

Choose Your Working Directory



Create new folder

Sort content

User

Directories

Content

HRV_Rubin Editing

Administrators

Editors

IBI Files

IBI VizEdit Testing

001_T3_child_Output

001_T3_child_Output_M

Old Editing Efforts - Pre Viz

001_T3_child_10s_E... 3.2 kB

001_T3_child_15s_E... 2.1 kB

001_T3_child_20s_E... 1.6 kB

001_T3_child_30s_E... 1.1 kB

001_T3_child_45s_E... 722 B

001_T3_child_Clown... 148.4 kB

001_T3_child_Clown... 2.1 kB

001_T3_child_Clown... 2.6 kB

001_T3_child_Introd... 101.0 kB

001_T3 child Introd... 1.3 kB

Cancel

Select

3. Selecting File Settings

After you have identified your working directory, the next step is to select the correct raw file. Click the `Select HR File` button just below the `Select Directory` button and choose the file you would like to edit.

When initially loading your raw file, there are several important inputs and decisions required. First, to standardize file processing and naming, IBI VizEdit requires that files are named using the following convention: `ID#_Timepoint.txt`. The ID of the participant should be the study ID used by the researcher and the `Timepoint` can be any mix of legal filename characters that specify a study time point (e.g., T1, T2, etc), a group assignment (e.g., Tx, Ctrl), or a study task or condition (e.g., Task1, Condition2, etc.).

Windows Explorer Example of Working Directory Files:

	Name	Date modified	Type	Size
Quick access	001_T3_child_Output	2/14/2018 3:22 PM	File folder	
Dropbox	001_T3_child_Output_MB example	2/17/2018 2:53 PM	File folder	
Desktop	001_T3	6/8/2015 12:10 PM	Text Document	47,609 KB
Downloads	002_T1	3/21/2015 11:32 AM	Text Document	84,888 KB
Documents	002_T2	5/11/2015 10:01 AM	Text Document	65,852 KB
Pictures	002_T3	6/14/2015 2:17 PM	Text Document	50,494 KB
Box Sync	003_T1	4/4/2015 10:06 AM	Text Document	78,374 KB
CU meta-analysis	003_T3	6/13/2015 10:19 AM	Text Document	48,324 KB
Graphics_Folder	004_T1	3/19/2015 1:54 PM	Text Document	107,106 KB
Included Article Files	004_T2	4/29/2015 2:27 PM	Text Document	68,554 KB
Supporting_Documents	004_T3	6/12/2015 10:26 AM	Text Document	50,887 KB
Box Sync	007_T2	5/5/2015 6:39 PM	Text Document	52,780 KB
Creative Cloud Files	007_T3	6/20/2015 10:20 AM	Text Document	47,075 KB
Dropbox	009_T1	4/3/2015 2:19 PM	Text Document	79,284 KB
OneDrive	009_T2	5/2/2015 9:00 AM	Text Document	64,163 KB
This PC	009_T3	6/17/2015 4:31 PM	Text Document	51,320 KB
Network	010_T2	5/15/2015 2:03 PM	Text Document	64,253 KB
Homegroup	010_T3	6/8/2015 10:17 AM	Text Document	57,463 KB
	013_T2	5/14/2015 10:53 AM	Text Document	68,488 KB
	013_T3	6/20/2015 1:28 PM	Text Document	50,370 KB
	014_T1	4/23/2015 4:57 PM	Text Document	89,217 KB
	014_T2	5/15/2015 12:57 PM	Text Document	68,787 KB
	014_T3	6/12/2015 2:31 PM	Text Document	53,112 KB
	Time Stamping Log C1	2/12/2018 11:32 AM	Text Document	2 KB

After you have input the necessary file information, you have the option of specifying an additional identifier for your output files. For instance if your raw file contains several heart rate signals from separate individuals, you may want to specify which one you are working on using this identifier (e.g., subjA, subjB, etc.). In our lab, we collect simultaneous data from parents and children and we use these fields as follows to help track our processing and cleaning efforts:

File Information Fields:

File ID and Information:

Subject ID:

Time Point:

(Optional) Study ID:

Editor Name:

Although it is not strictly necessary for the program to run, it is probably good habit to track who is editing each file for the purposes of determining reliability and maintaining editing integrity.

A component that *is* necessary is a timing file, even if you don't have any tasks you want to use to separate your output. Absent any meaningful timing files, the researcher should create a timing file with a column of 0's and a column total with rows indexed by the ID names of the files. Timing files can be created in excel or any other general spreadsheet software, but should be converted to tab-delimited `.txt` files before attempting to load them into IBI VizEdit.

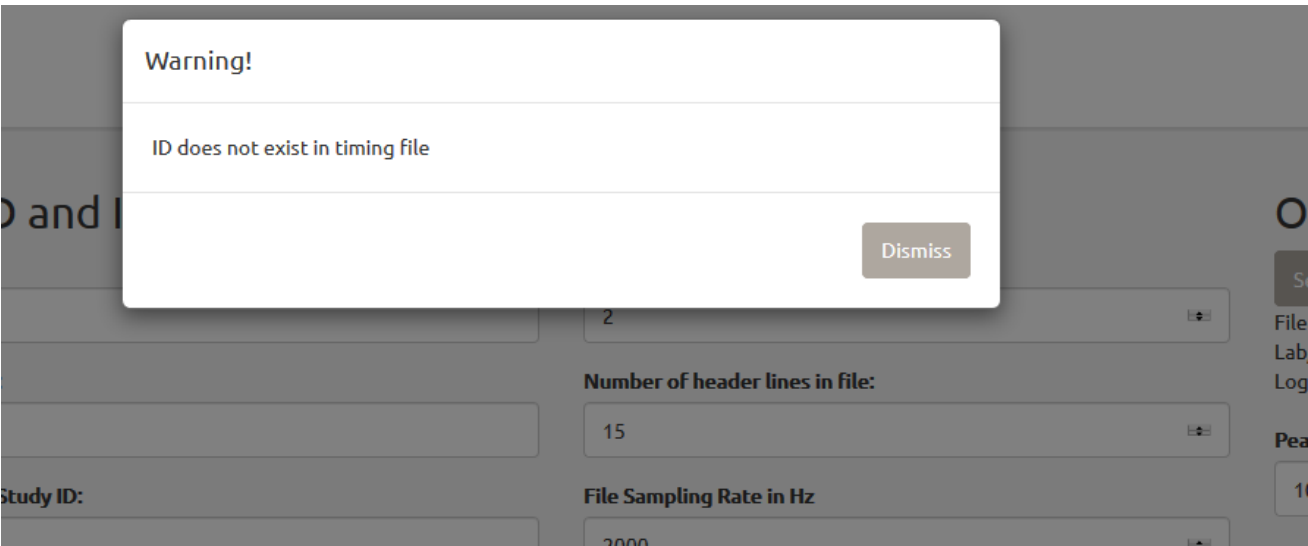
Timing File Example:

Time Stamping Log C1 - Notepad

File Name	Video_1	Video_1	Clown	Clown	Video_2	Video_2	Kids	Kids	Introduction	Introduction	Video_3	Video_3
001_T3	98.7	239.8	248.1	306.15	315.55	456.4	482.1	547.95	569	608.4	609.05	749.85
002_T1	409.45	607.4	611.6	687.55	720.95	918.2	953.85	1019.5	1092.8	1183.75	1207.6	1406.2
002_T2	127.7	340.05	351	415.3	435	615.4	634.5	681.45	701	792.15	809.3	988.35
002_T3	105.05	246.1	260.2	311	318.45	459.25	484.4	526.45	539.05	629.95	635.4	776.25
003_T1	265.6	463.55	473.65	507.25	538.45	735.55	796.45	861.8	904.5	995.3	1021.9	1220.5
003_T3	62.15	203.25	212	271.2	277.25	418.05	441.5	506.7	519.9	610.85	621.05	761.9
004_T1	235.8	433.85	440.6	519.2	535.3	732.45	770.25	835.95	876.9	967.9	985.6	1184.05
004_T2	133.5	314.8	323.95	396.35	407.8	588.35	621.8	688.8	714.9	806.1	844.55	1023.55
004_T3	103.55	244.55	253.3	326.1	334.05	474.8	507.25	572.7	586.4	652.75	657.95	798.8
007_T2	13.45	194.75	199.85	227.85	236.35	416.8	435.4	502.3	516.7	550.45	554.5	733.55
007_T3	70.8	211.9	220.35	252.95	262.3	403.15	425.5	490.8	509.25	579.2	583.95	724.7
009_T1	206.75	404.75	430.65	467.05	487.15	684.2	729.95	795.1	842.05	932.95	980.25	1178.75
009_T2	128.95	310.45	331.25	397.85	406.2	586.7	612.9	680	699.85	761.05	767.05	946.15
009_T3	56.8	197.9	205.15	269.8	277.2	418	440.25	505.9	521.4	612.4	635.9	776.7
010_T2	0.45	137.65	142.3	211.15	262.55	443.05	532.7	599.55	630.8	722.05	755.1	934.15
010_T3	134.2	275.3	317.3	417.95	429.35	570.2	593.2	658.8	680.25	755.2	765.6	906.4
013_T2	174.2	355.8	364.5	435.25	454.6	635.1	657.9	701.15	721.3	812.55	820.45	999.5
013_T3	63.05	204.1	211.05	293.15	300.3	441.1	460.45	525.85	537.35	628.25	639.25	780.05
014_T1	237.15	435.1	458.95	503.4	527.95	725.05	772.1	837.85	904.55	995.4	1032.55	1231.1
014_T2	109.5	291	293.5	353.15	381.5	562.05	596.2	662.95	689.6	780.95	812.55	991.6
014_T3	94.5	235.65	242.65	295.95	314.95	455.75	476.75	541.95	556.9	647.8	668.35	809.2

Note that a key feature of the timing file is the inclusion is `File Name` column. It should have the exact two values that were input in the `Subject ID` and `Time Point` fields separated by a `_`. If the file name for the raw data does not match the values in the timing file, or those input by the researcher, IBI VizEdit will return an error.

Example ID Missing Warning:



Once all of the files are loaded, you should specify the column in the PPG data file with the relevant channel, the number of header rows (if any), the sampling rate of the original file, and the downsampling rate of the final file. Also be sure to select the number of different epoch lengths you would like to see in the timeseries data files created by the program (the default is to output all options).

After you have specified all of the mandatory and optional information on the opening screen, click the green **Load File Settings** located in the bottom left of the browser window. If everything goes according to plan, the directory and files will load and you will see their system paths displayed beneath them as in the example below:

When Loading Works

IBI VizEdit v1.0.0

Data Entry Processing Panel Basic Editing Panel Advanced Editing Panel

Select File and Directory:

Select Directory
Directory: C:\Users\Mbars\Box Sync\Child and Family Relationships Lab\HRV_Rubin Editing\Editors\IBI VizEdit Testing
Select HR File
File Chosen: C:\Users\Mbars\Box Sync\Child and Family Relationships Lab\HRV_Rubin Editing\Editors\IBI VizEdit Testing\001_T3.txt
Select Timing File
File Chosen: C:\Users\Mbars\Box Sync\Child and Family Relationships Lab\HRV_Rubin Editing\Editors\IBI VizEdit Testing\Time Stamping Log C1.txt

File ID and I
Subject ID:
001
Time Point:
T3
(Optional) Study ID:
child
Editor Name:
MB

Load file using current settings
Load File Settings

Reset fields to chan
Reset File Settings

Additionally, if everything has loaded correctly, when you navigate to the **Processing Panel** you will see the timing information for the specific file displayed on the right side of the window.

Timing Information in IBI VizEdit

Event Summary Timing:

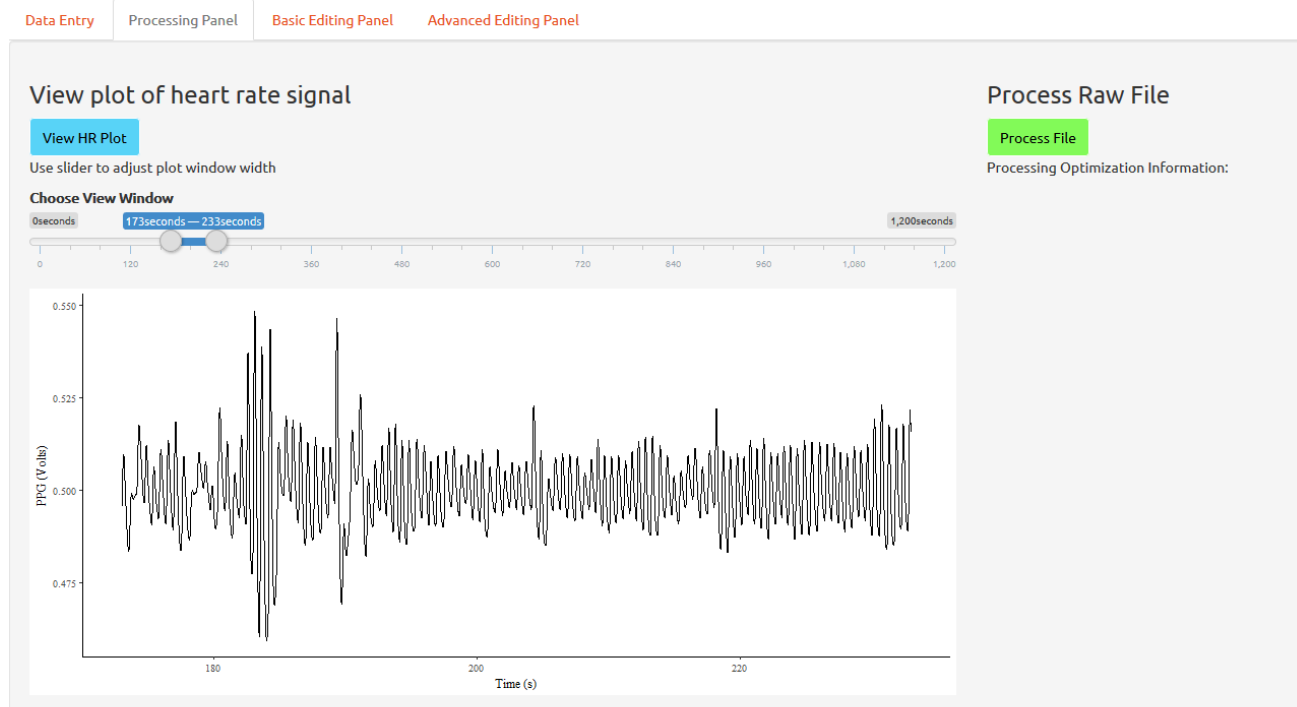
Time	Task	Label
98.70	Video_1	Video_1 Start
239.80	Video_1	Video_1 End
248.10	Clown	Clown Start
306.15	Clown	Clown End
315.55	Video_2	Video_2 Start
456.40	Video_2	Video_2 End
482.10	Kids	Kids Start
547.95	Kids	Kids End
569.00	Introduction	Introduction Start
608.40	Introduction	Introduction End
609.05	Video_3	Video_3 Start
749.85	Video_3	Video_3 End

Processing Your File

Once you have loaded the various settings for the program, your next task is to process the PPG file and identify the peaks. First, use the View Plot button on the second panel to ensure that the data has loaded correctly.

Checking Your Data

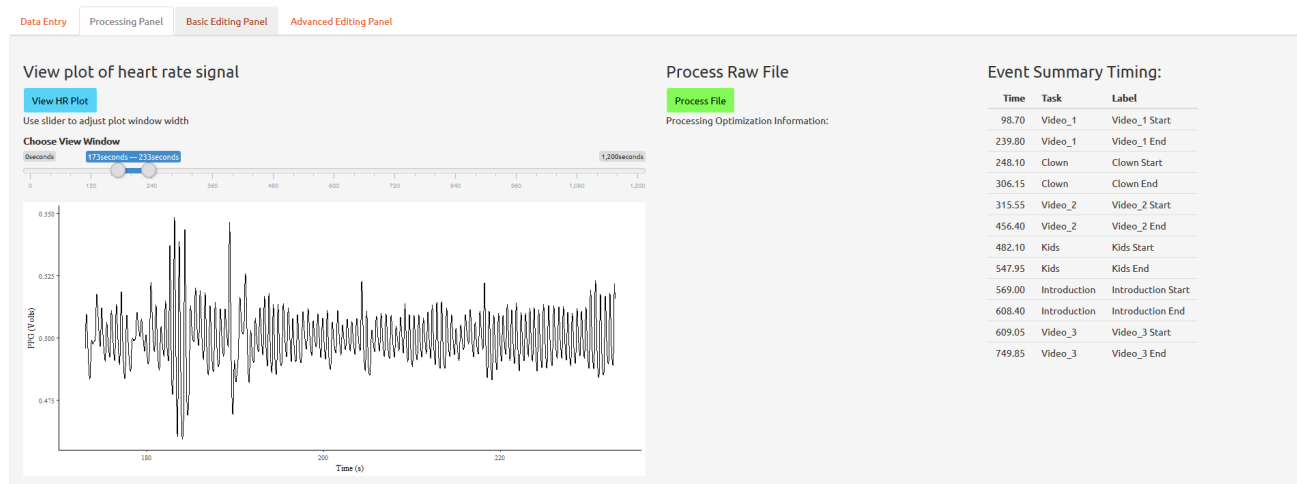
IBI VizEdit v1.0.0



If you are satisfied that you have the right file loaded, click the "Process File" button. The peak detection algorithm will iteratively identify an optimal processing bandwidth and return a raw interbeat interval file. A tracker will appear in the bottom right notifying you of the program's progress

Peak Detection Algorithm Tracker

IBI VizEdit v1.0.0

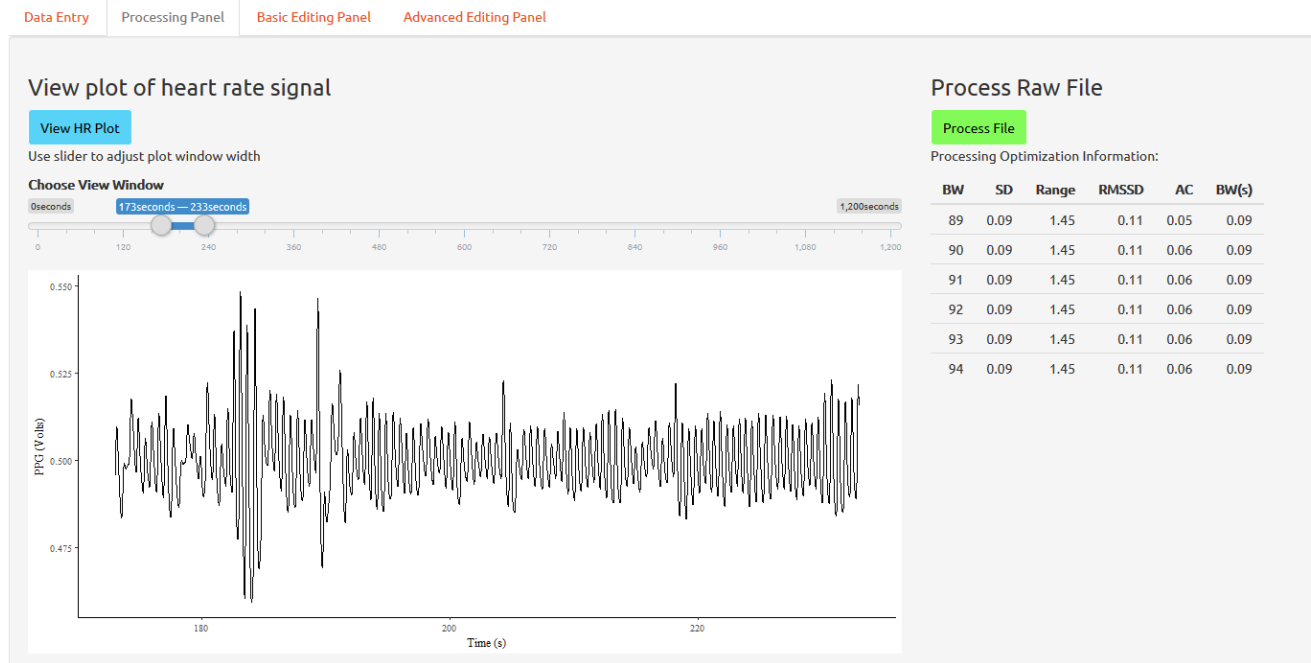


Finding Peaks Pass 7 out of 99

The processing summary will populate in the Processing Panel when the algorithm is complete. The same table will be included in the Case_Processing_Summary.rtf output when you have finished editing your file.

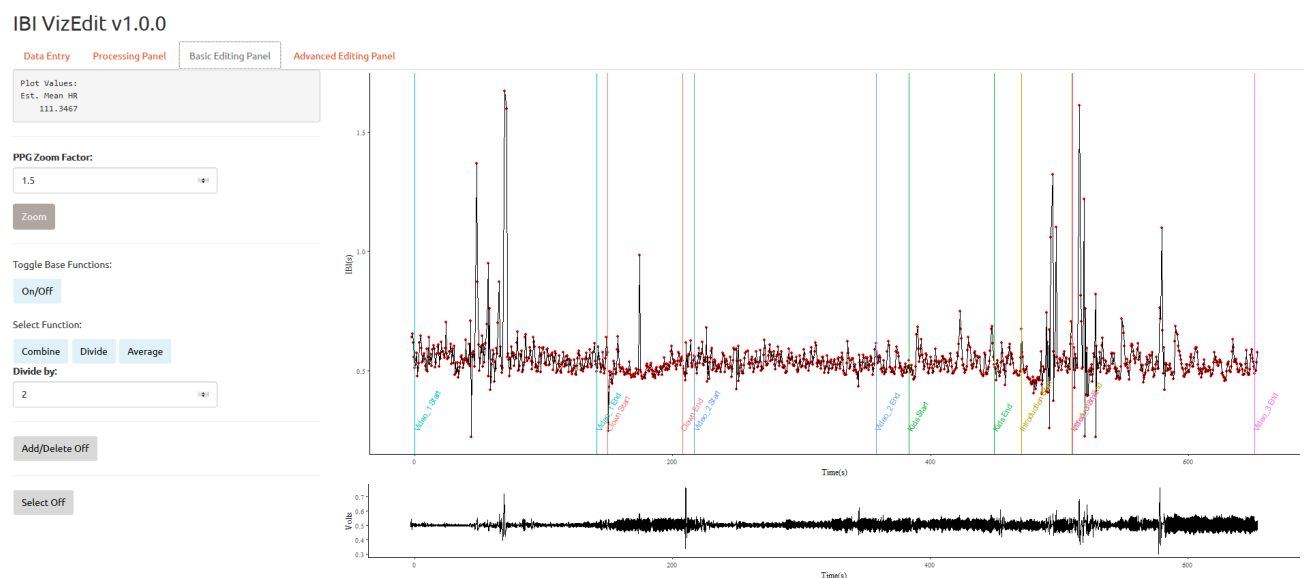
Peak Detection Summary Table

IBI VizEdit v1.0.0



Once this step is complete, you should be able to move on to the **Basic Editing Panel**. There you will find two graphs initially. The first and largest graph is the complete IBI file for the entire target window (i.e., start of the first task through the end of the last task). The second, smaller graph is the PPG file in its entirety for the same period. Vertical, colored bars mark the start and end of each task or segment of the file, based on what is defined in the timing file.

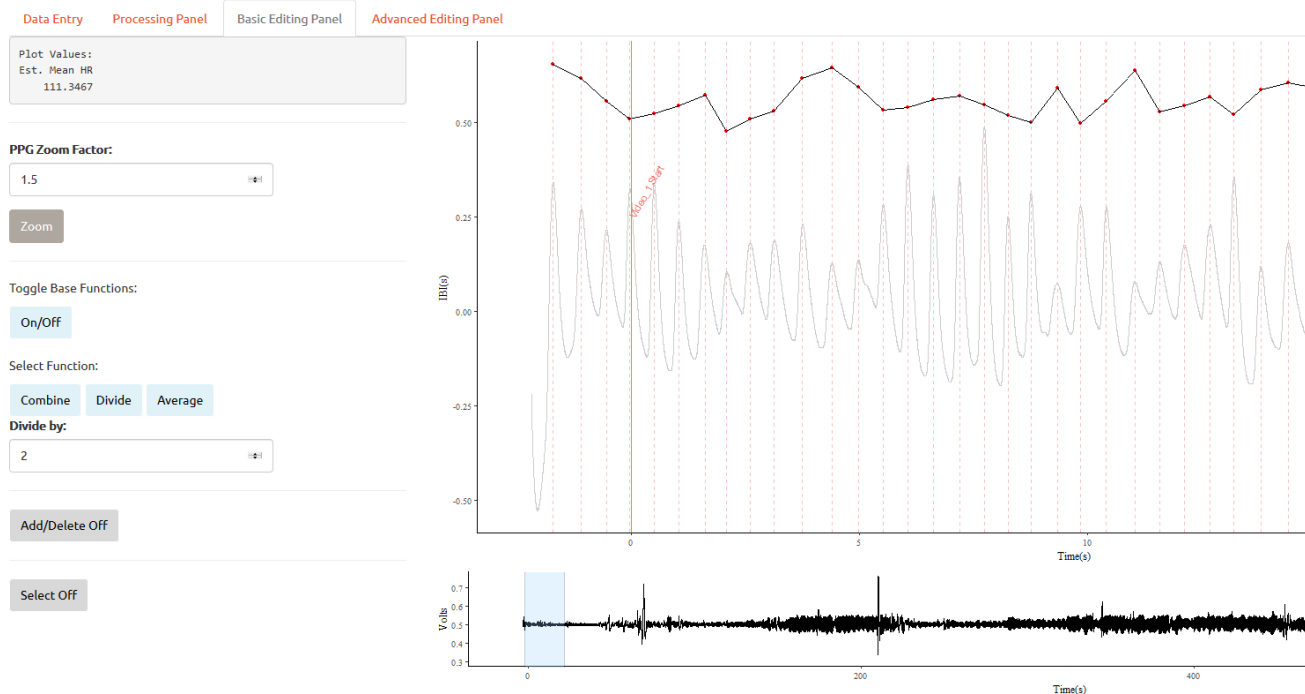
Basic Editing Panel Example:



In order to begin inspection a section in more detail, highlight a section of the file to examine by clicking and dragging your cursor over an area on the smaller PPG graph.

Selection a Section to Edit:

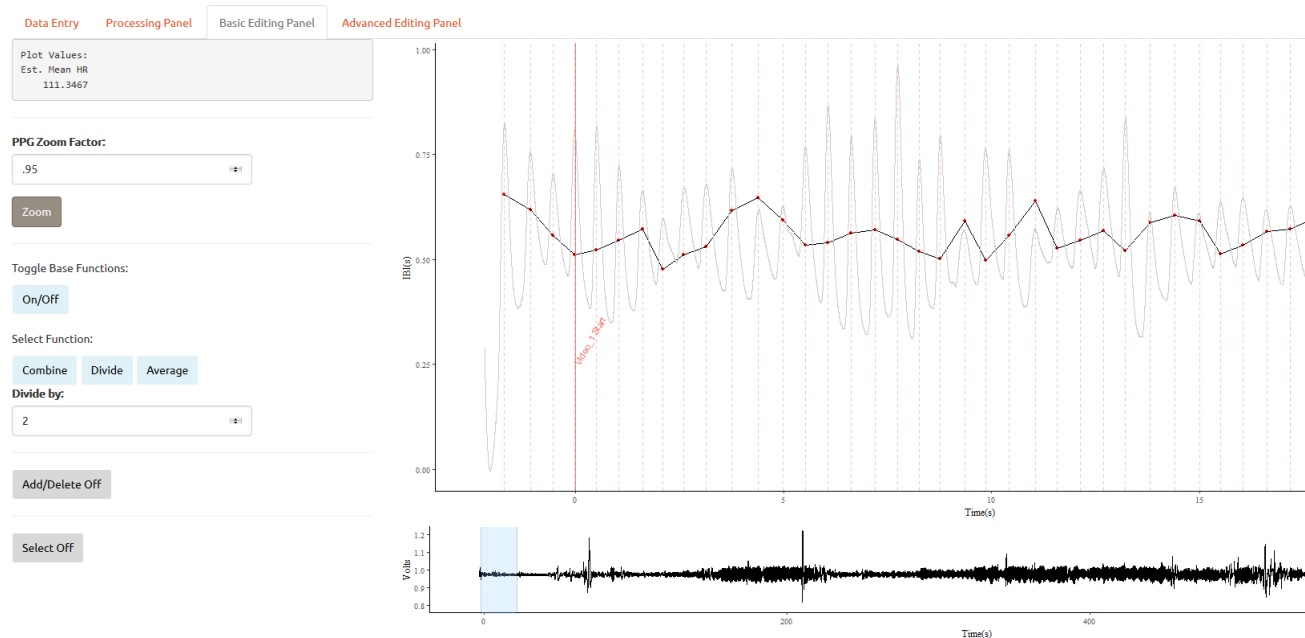
IBI VizEdit v1.0.0



Note that the IBI values and the PPG signal are likely to be on different scales. You can use the **PPG Zoom** Function: to change the scaling of the PPG waveform. Using this function will also center the PPG wave near the IBI time series. I choose to rescale, and slightly reduce the amplitude of the PPG wave form relative to the IBI values in the example below (note this rescaling does not alter the location of local maxima used to identify interbeat intervals, just their relative values).

Rescaling PPG Signal Example

IBI VizEdit v1.0.0



As intra-individual PPG amplitudes may change over the course of an observation, you may need to rescale the PPG waveform several times during a single editing session. Any value over 1 will increase the relative amplitude of the PPG signal, any value below 1 will decrease the relative amplitude. Currently, a 10X increase is the maximum.

Editing Your File

There are two different editing panels as part of IBI VizEdit. The specific portion of the file you decide to view and edit on either the "Basic" or the "Advanced" panel is controlled by the small horizontal graphic at the bottom of the "Basic Editing Panel". Simply use your mouse to highlight a section of the overall file and VizEdit will display that portion of the file in visual editing interface on both panels.

The basic panel allows you to perform several simple functions.

1. With add/delete turned on you can manually **ADD** a peak with a single click at the exact point (referenced to the x-axis) you believe a beat should have been identified.
2. **DELETE** incorrectly identified points.
3. **COMBINE** two or more interbeat intervals that were incorrectly identified by the peak detection algorithm.
4. **DIVIDE** a point where the peak detection program "skipped" over the identification of previous heart rate points.
5. **AVERAGE** nearby IBIs when there are issues with detection peak detections.

The advanced panel offers a new suite of data imputation techniques that, as of yet, have not been included in previous heart rate editing packages. Chief among these techniques is the incorporation of Gaussian process models.

Gaussian process models are incredibly flexible, albeit computationally demanding. In IBI VizEdit, data imputation via Gaussian process models is implemented using Stan with R's Stan interface package `rstan`. Use of this feature requires separate installation of Stan and `rstan` (for more information visit this site).

Depending on the downsampling rate, the size of your file, the amount of time that requires imputation, and the consistency of the surrounding data will determine how long the model takes to run. See the IBI VizEdit manual for more information about the Gaussian process models implemented in IBI VizEdit.

IBI VizEdit also implements a simpler seasonal decomposition approach in order to aid researchers in identifying peaks. While useful for small sections of data, this technique will underestimate variability in heart rate relative to the more involved Gaussian process technique outlined above.

What is in Your Output

Once you have finished editing your document and you have selected the "Save" button on the main panel, a separate output directory will be created in your working directory folder that includes:

1. `ID#_Optional(ID)_Timepoint_Case_Processing_Summary.rtf`: This file includes summary information about the your file and editing choices:
2.
 - o The output of the peak detection algorithm and the final bandwidth used for identifying peaks.
 - o Average heart period and heart rate variability for the entire file as well as split by task/condition.
 - o An editing summary that identifies every unique edit made including the value of the edited IBI, the time point of the edit, and the type of edit made.

- A summary of the results from each Gaussian Process used to impute data, including the final output for parameters estimated by the models.
2. `ID#_Optional(ID)_Timepoint_Hz_PPG.txt` : The downsampled file of the original signal.
 3. `ID#_Optional(ID)_Timepoint_raw_IBI.txt` : The unedited version of the original IBI file as produced by the peak detection algorithm.
 4. `ID#_Optional(ID)_Timepoint_Xs_Epochs.csv` : A time series file with summary statistics computed for heart period (HP), root mean square of successive differences (rmssd), and standard deviation (sd) by user-specified epoch length. If the researcher selects multiple epoch lengths when setting up the editing session, multiple separate files will be included in the output.
 5. `ID#_Optional(ID)_Timepoint_edited_IBI.txt` : The complete edited file. Edited IBI files are also output by task.
 6. `ID#_Optional(ID)_Timepoint_edited_Task.csv` : Summary values (e.g., HP, rmssd, and sd) separated out by task/condition.

Advice on Editing Choices

There are more detailed instructions for using the program in the IBI VizEdit manual. Briefly, it is worth highlighting that in granting researchers more freedom to edit their PPG heart rate files, even greater responsibility is placed on the researcher to check his or her work.

To ensure responsible and effective use of the program you should ensure that:

1. You have successfully edited the practice files that are included in this repository. On average, your error rate should be no greater than _____. [The actual value to be determined based on incomplete pilot work.]
2. When editing your own data, be sure to perform post-editing checks. As part of your editing, you can see a running plot in the RStudio plot viewer that plots the number of edits along with the rmssd. In an ideal situation, you would see no correspondence between the number of edits and heart rate variability. This is useful, though probably not a sufficient check to ensure that your edits are not adding any systematic source of variation from the choices you make.

Stan and `rstan` in IBI VizEdit

Stan is a program external to R that allows researchers to easily and quickly implement a variety of Bayesian models. As opposed to other Bayesian modeling software packages such as JAGS or BUGS, Stan runs its models in compiled C++. This means that the first time a model is run and (requiring the relevant Stan program is compiled) can be a bit slower than subsequent runs. The increased speed in running a compiled program more than makes up for this minor inconvenience.

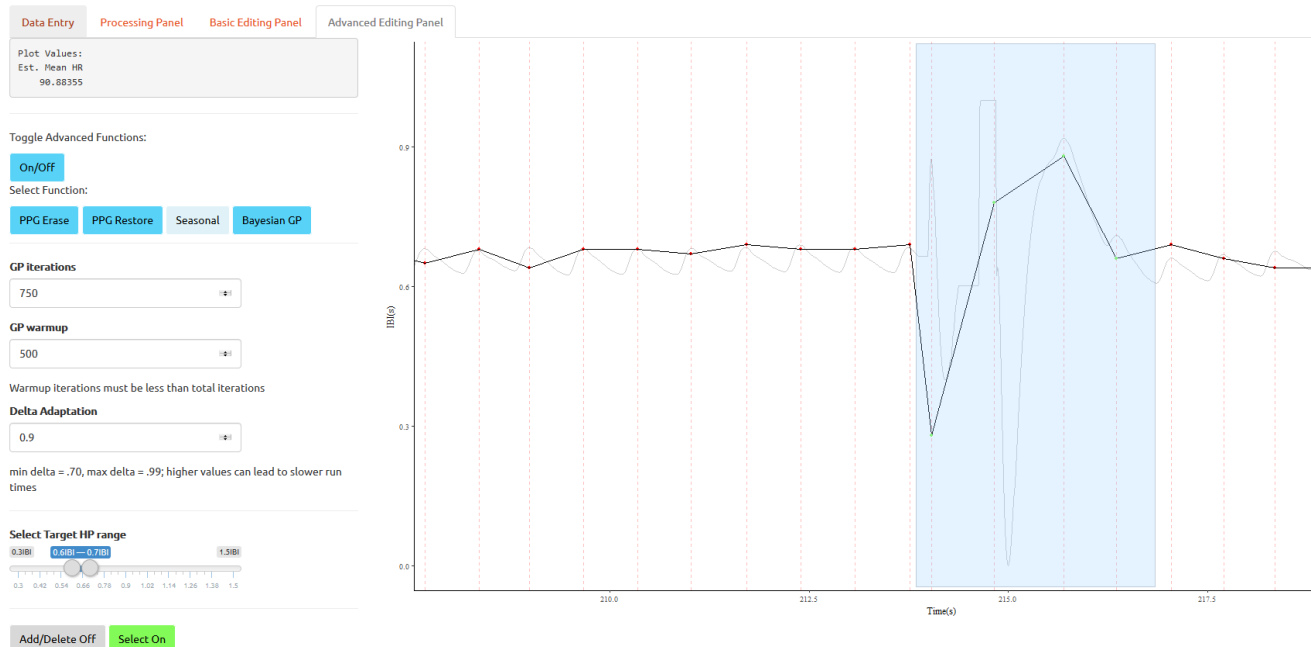
Stan has an active [developer community on GitHub](#), and more information can be found at mc-stan.org. Its incorporation into IBI VizEdit does require some additional setup, however. Detailed instructions for setting up Stan can be found [here](#). Be sure to follow the instructions precisely in order to guarantee a clean setup.

As a reminder, the current version of IBI VizEdit is only supported on Windows 7/8/10.

Gaussian Process Modeling

A key novel feature incorporated into IBI VizEdit is the use of Gaussian process models for imputing PPG data in regions where the signal has become corrupted by motion artefact or some other similar source of noise.

IBI VizEdit v0.5



The result of running the program, which admittedly takes up to 5 minutes or so on a 7th generation i7 processor with 16 GB of RAM (and more importantly a maximum processing speed of 3.50 GHz).

Using the default settings for Gaussian process imputation in IBI VizEdit, on the section of messy PPG data depicted above results in the following estimated waveform:

[TO BE ADDED]

Gaussian process models utilize different covariance functions to model the covariance between timepoints in a univariate time series. More details on the specific features of the covariance functions incorporated in IBI VizEdit's Bayesian GP feature can be found in the manual (which is not finished yet... but then again neither is the program)

Briefly, three different covariance functions are included:

1. A squared exponential covariance function (a common covariance function - to the point that the Stan Development Team has incorporated a specific function for it in their base code).
2. A quasi-periodic covariance function based on the individual's heart rate before and after the corrupted section of data.
3. A periodic covariance function again based on proximal heart rate, but with the added feature that the heart rate can vary as a function of the participants' average respiration rate.

Details on the specific formula, code and rationale for these functions can be found in the forthcoming IBI VizEdit manual.