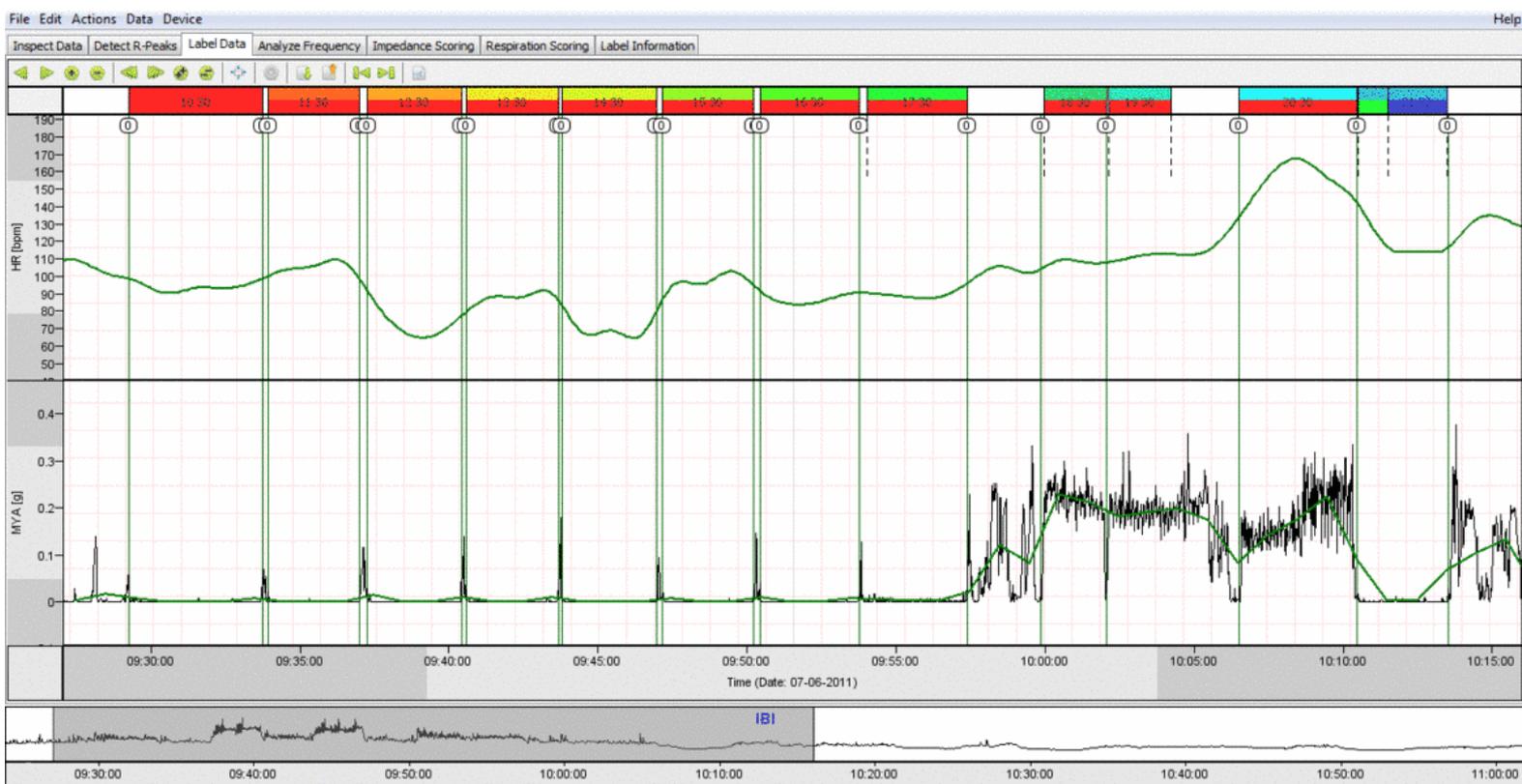


Data Analysis and Management Software (DAMS) for the Vrije Universiteit Ambulatory Monitoring System (VU-AMS)

Manual version 1.5 29 January 2019 (written for VU-DAMS v4.0)



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1. Recording with the VU-AMS device

1.1 Requirements

- Two AA batteries: Use 1.2V rechargeable NiMH batteries or non-rechargeable 1.5V alkaline batteries. Make sure the bottom contact sticks out (in some batteries it is covered by an outer plastic ring; these won't work properly with the VU-AMS). Leave rechargeable batteries in the charger up till the very last moment.
- Compact Flash card: External memory card. The VU-AMS5fs has been extensively tested with the 1GB 80x Compact Flash card from Transcend (TS1GCF80), the 2GB Ultra Compact Flash card from SanDisk (SDCFH-002G-U46) and the 4GB Ultra Compact Flash card from SanDisk (SDCFHS-004G-G46).
- Compact Flash card reader: Card reader unit to extract the VU-AMS data from the Compact Flash card after recording and to erase the card for a next recording. Any brand or built-in Compact Flash card reader will do.
- Electrodes: Typically, seven electrodes are needed for a single recording. We use the 'Kendall ARBO H98SG' single use ECG electrode with Wet Gel for the ICG and ECG. For skin conductance we use the Biopac TSD203 combined with their isotonic electrode gel (GEL101).
- Lead wire connector: A blue lead wire connector with 7 lead wires is used for the recording of the ECG and thorax impedance. Optionally a second yellow connector for skin conductance recording is needed.
- VU-AMS5fs: The ambulatory recording device.
- VU-AMSi (for RS232 or USB): An infrared interface cable that either connects to the RS232 serial port of a PC or to an USB port.

Flashcard with latest firmware (optional):

The VU-AMS device comes with the latest firmware installed. From time to time updates will be posted on the VU-AMS website (www.vu-ams.nl). These need to be installed once from an update flash card. Detailed instructions on how to install the update are on the VU-AMS website.

Data Analysis and Management Software (DAMS).

The VU-AMS device is configured using this program (referred to as 'DAMS') and measurements can be started and stopped with the program. The DAMS program is also used for primary data extraction and for data reduction. It can be downloaded from the VU-AMS website (www.vu-ams.nl).

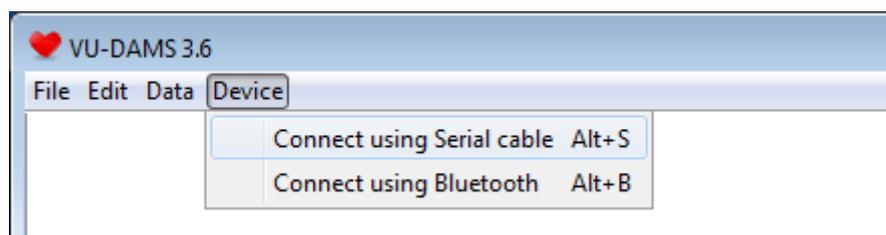
1.2 Preparing the VU-AMS device

Always use an empty Compact Flash card with all previous files removed from the card before each new measurement. Put the flash card bottom up in the VU-AMS and then place two completely charged AA batteries in the battery holder. Battery clips are vulnerable so do this carefully. Successful placement is signaled by a triple beep tone.

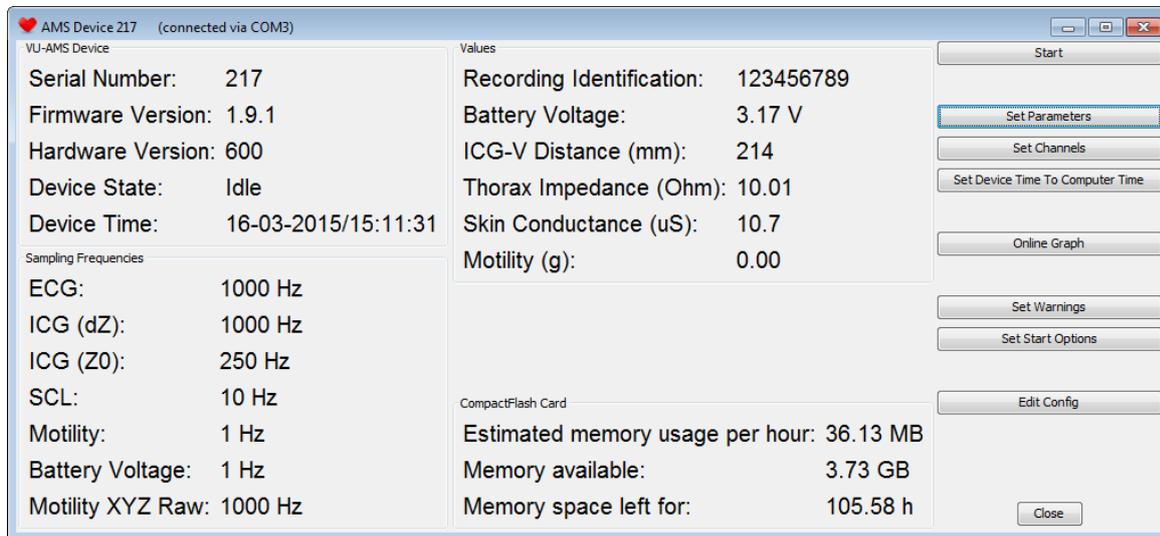
The VU-AMS is now on standby and the green light will flash twice every ten seconds. This indicates the VU-AMS is ready, but not recording. When the VU-AMS is recording the green light will flash once every three seconds.

1.3 Configuring the VU-AMS device for recording

Connect the VU-AMS to the PC with the interface cable. Connect the infrared end of the interface cable to the VU-AMS; the electronic end of the interface cable goes to the serial port or the USB port of the PC. Start the DAMS program and select the *Device* tab in the main menu. Choose to *Connect using Serial cable*.



You will now see the configuration screen:



1.3.1 Clock Synchronizing

Before starting, make sure to set date and time of the PC correctly. All dates and times in the VU-AMS data files will be based on the time and date read from the PC at start-up, so it is important to make sure your PC has the correct time and date. Do this by clicking on *Set Device Time To Computer Time*.

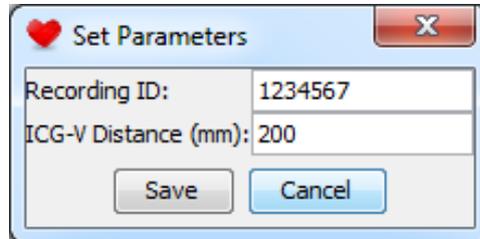
TIP: Synchronize the watch of the subject/observer to the exact time of the PC used to start up the VU-AMS for optimal time-locked self-report diaries and physiological data. When electronic diaries are used make sure that their clocks are synchronized with the configuration PC too.

1.3.2 Battery Types

Check battery voltage indication (should be about 3.1 Volt for alkaline and about 2.7 Volt for rechargeable NiMH batteries) and re-check time and date. Though battery voltage gives an indication of battery capacity left, for 24 hour recordings it is safest to start with new alkaline batteries or batteries that were in the charger up till the very last moment.

1.3.3 Set Parameters

Click *Set Parameters* and fill in the recording identification field. Also fill in the distance measured in millimeter between the two front ICG electrodes for later stroke volume estimations.

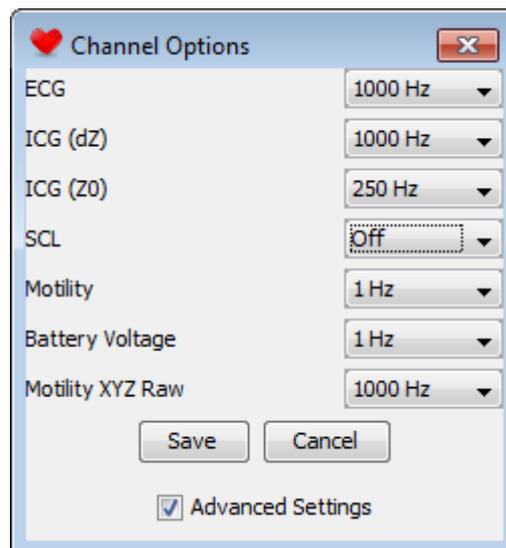


Recording ID:	1234567
ICG-V Distance (mm):	200

Save Cancel

1.3.4 Set Channels

The typical sampling frequencies are as shown in the figure below. By clicking on *Set Channels* you are allowed to set sampling frequencies for the various signals. You can disable signals by setting them to 'Off' (like we did with the SCL signal). When changing any setting, make sure to save the settings to the device before closing the DAMS program!



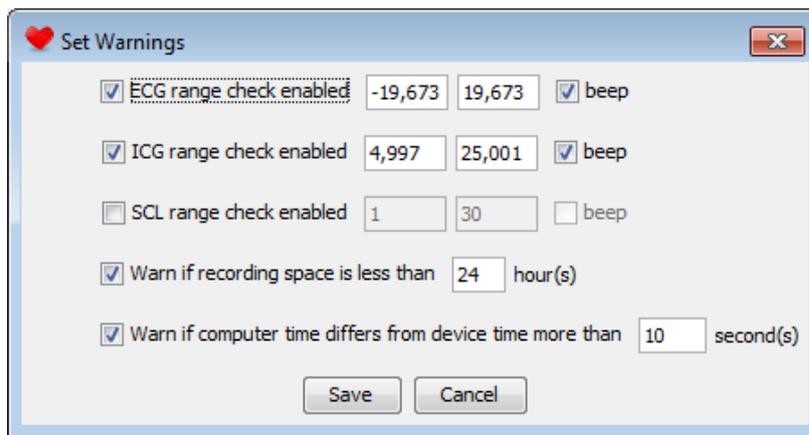
ECG	1000 Hz
ICG (dZ)	1000 Hz
ICG (Z0)	250 Hz
SCL	Off
Motility	1 Hz
Battery Voltage	1 Hz
Motility XYZ Raw	1000 Hz

Save Cancel

Advanced Settings

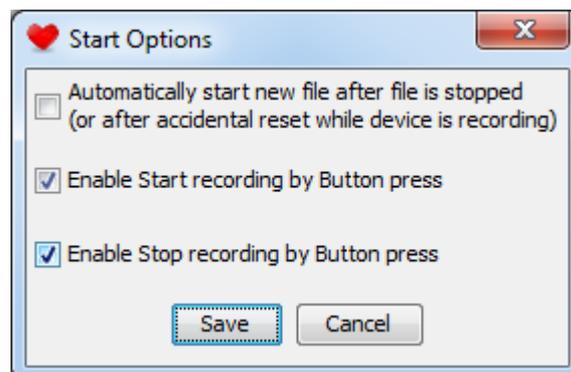
1.3.5 Set Warnings

Here you can activate or deactivate audio warning signals when ICG, ECG or SCL signals exceed their boundary values. You can also activate warning for low recording space and time-sync problems. These beeps are useful in field recordings when subjects are able and sufficiently instructed to reconnect electrodes themselves. Otherwise it is advisable to turn the warning signals off because the beeps will persist as long as the electrodes are not properly reattached.



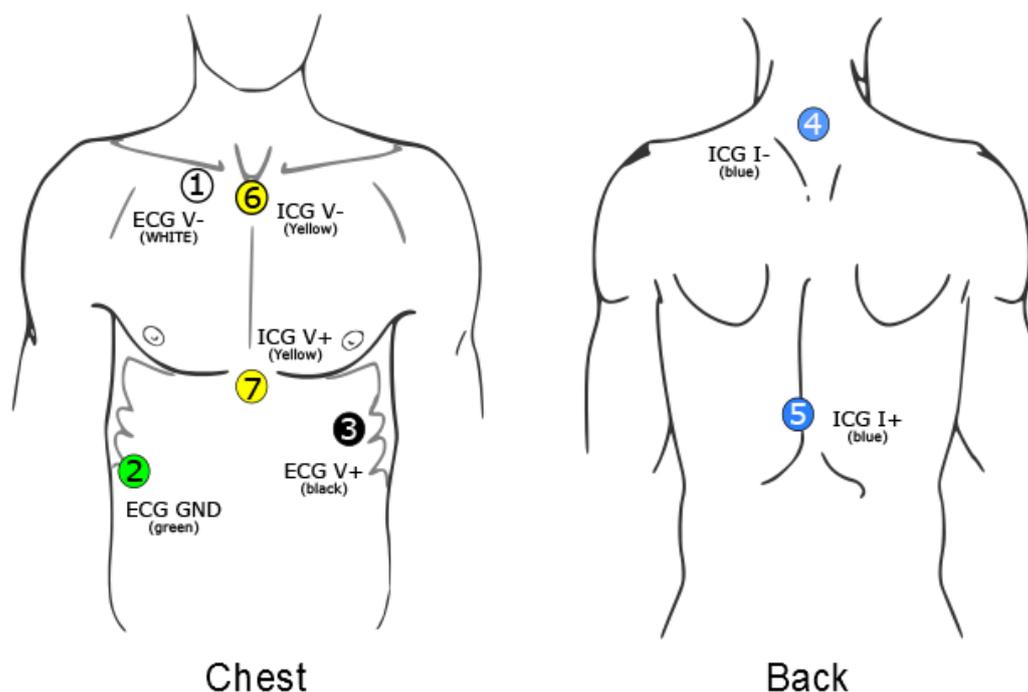
1.3.6 Set Start and Stop Options

Pressing the button on the VU-AMS device shortly always results in a time marker in the data file. Hence the button can be used as an event marker by the subject during field recordings. You can further program the button on the VU-AMS device to act as a start and/or stop button. If the event marker function is used it is advised to either disable the stop button or to explicitly instruct your subjects to only *shortly* press the black button to mark specific events. Accidentally pressing the button for more than 3 seconds may otherwise stop the recording.



When the top option is selected recording will continue by itself when the battery is replaced (which may be needed during recordings lasting longer than 48 hour) or even when a subject tries to stop the recording using the black event button. In fact to only way to really stop the recording is using the DAMS program.

1.4 Electrode hook up



1.4.1 Attachment of the ECG/ICG electrodes

Clean the skin at the 7 positions indicated in the figure. Rub the skin firmly with an alcohol soaked tissue or, if alcohol is not available, with a clean dry tissue. Attach an electrode by pressing the sticky plastic brim of the electrode on the skin and subsequently pushing the metal stud at the center of the electrode firmly, to properly spread the contact gel.

ECG:

- 1 Slightly below the right collar bone 4 cm to the right of the sternum
- 2 (GND) On the right side, between the lower two ribs
- 3 At the apex of the heart on the left lateral margin of the chest approximately at the level of the processus xiphodius

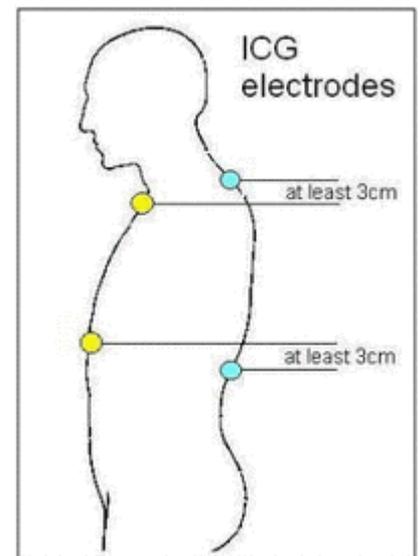
ICG:

Electric current generating electrodes

- 4 At the back, on the spine, at least 3 cm (1") above electrode 6
- 5 At the back, on the spine, at least 3 cm (1") below electrode 7

Impedance measuring electrodes

- 6 At the suprasternal notch above the top of the sternum
- 7 At the processus xiphodius at the bottom of the sternum



1.4.2 Attachment of SCL electrodes (optional)

To measure electrodermal activity we recommend placing a dedicated SCL electrode (for example Biopac EL507) on the thenar eminence of the non-dominant hand and a regular ECG electrode on the lower arm as a ground. The thenar site should not be pre-treated, but for some individuals additional micropore tape helps keep the electrode in place. The site of the ground electrode should be lightly abraded with a sponge or fine sandpaper for optimal results.



The VUAMS also allows for other electrode configurations, such as Velcro straps with an electrode holder filled with gel on the medial phalanges of the index and middle or ring finger, or SCL electrodes at both the thenar and hypothenar eminences of the hand palms. However, we have found the configuration above advantageous in terms of both signal quality and feasibility and tolerability in extended ambulatory recording.

As the sweat ducts acts as parallel conductors it is essential to keep the surface area of measurement constant across subjects by using the same electrodes and electrode positioning within a single experiment.

1.4.3 Attachment of the lead wires and lead wire connector

The blue ECG/ICG lead wire connector has to be plugged in the blue socket. Optionally, the yellow SCL lead wire connector is plugged into the yellow socket.

1.4.4 Wearing the device

Put the VU-AMS device in its carrier bag with the lead wire connector facing up. Fasten the device with the strap in the bag and gird it on with the VU-AMS belt (you can also supply your own belts). Make sure the device is attached in a vertical position.

**Please also see the “Recording with VU-AMS” tutorial video for a demonstration:*
www.vu-ams.nl/support/tutorials/hardware/vu-ams-recording

1.5 Signal Quality Control

After connecting the ECG/ICG lead wire plug to the VU-AMS device, the *Online Graph* option should be used to display the ECG, Z0, dZ (\approx change in impedance due to respiration and heartbeat) and dZ/dt (= Impedance CardioGram) to check for proper quality of the recorded signals.

1.5.1 ECG

The ECG registers the electrical activity of the heart. Before contracting, cardiac muscle cells depolarize. Three different stages of depolarization are usually visible on the ECG.

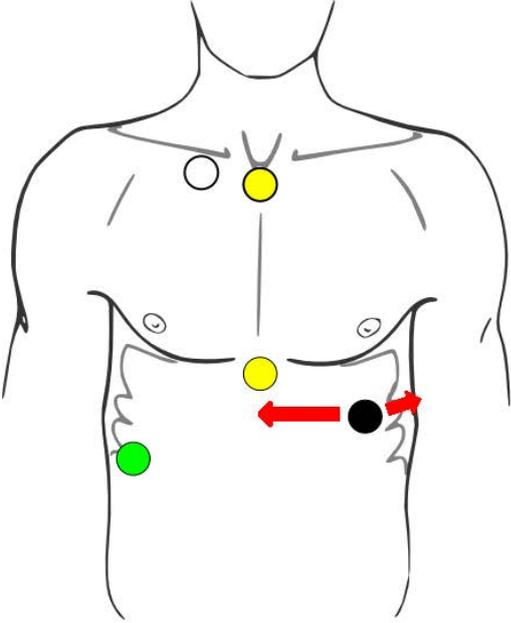
1. P wave: depolarization of the atria
2. QRS complex: depolarization of the ventricles
3. T wave: repolarization of the ventricles

The R peak in a normal ECG has a much higher amplitude than the P wave, because there is more muscle involved. This makes the R peak easy to detect for an algorithm.

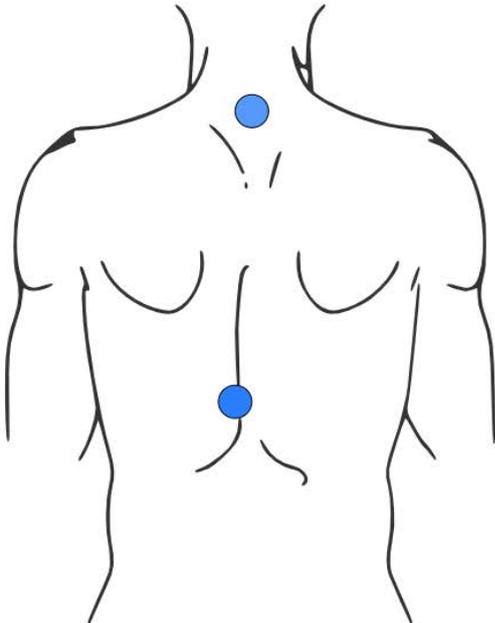
A clear QRST-complex should be detectable in the ECG. The R-wave should be upward and it should be the peak with the largest (absolute) amplitude.



If either S-wave or T-wave are of comparable magnitude re-attach the black(+) ECG electrode first more laterally then more medially until a satisfactory QRS complex is seen (see below).



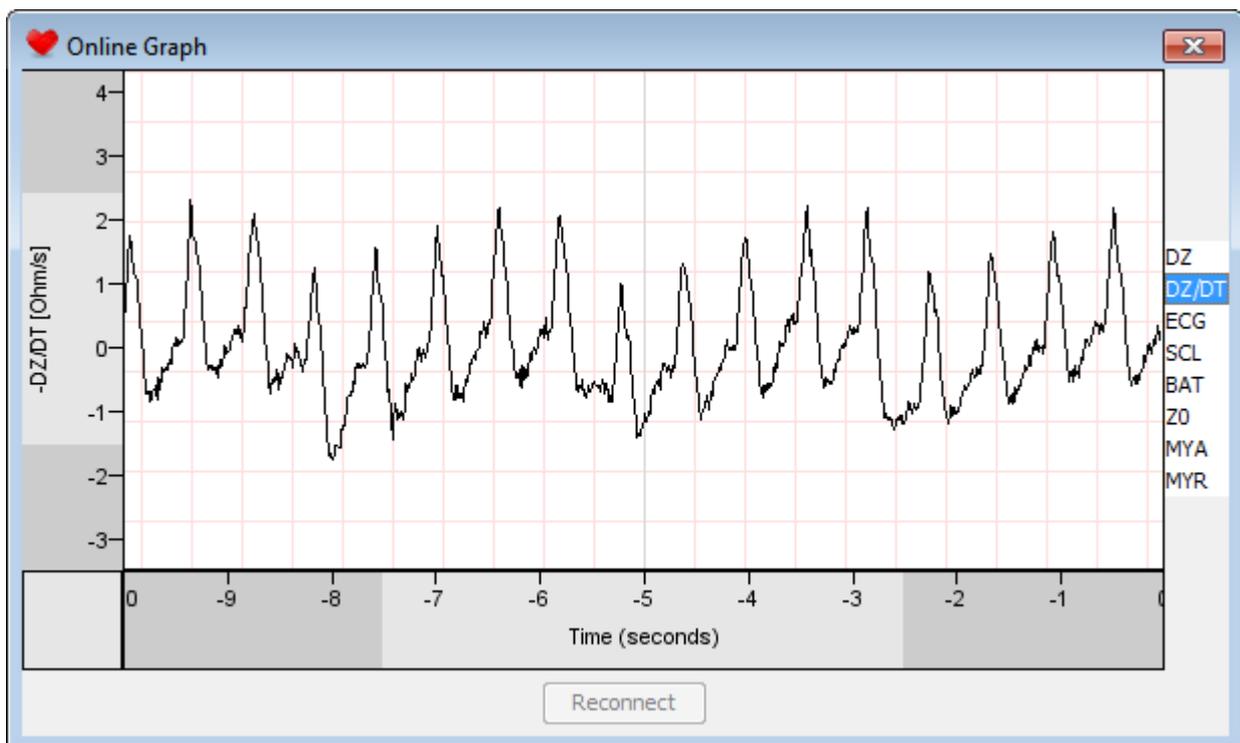
Chest



Back

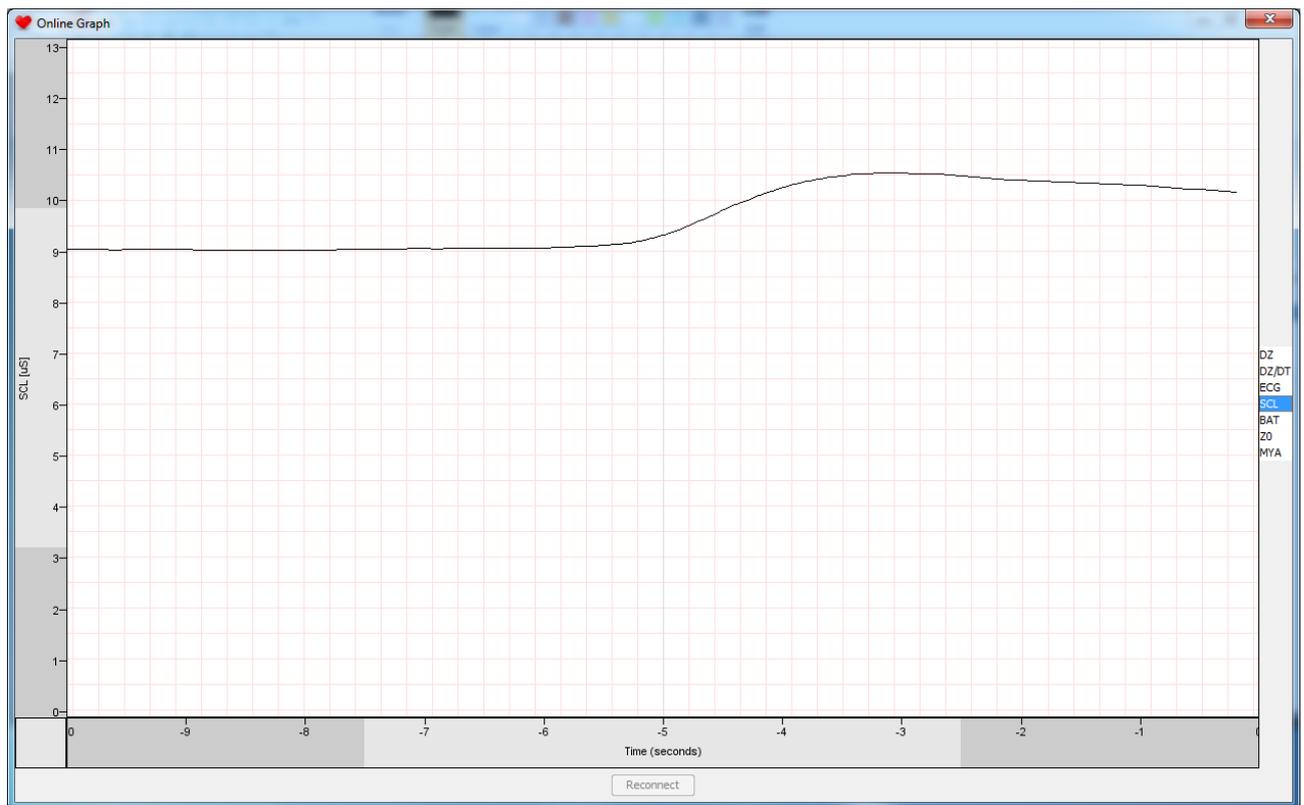
1.5.2 Z0, dZ, dZ/dt

The dZ should be within -0.5 and +0.5 Ohm most of the time. Z0 should always stay within an 8 to 20 Ohm range. The dZ signal should reflect deep breathing clearly and stay in range (between -1 and +1 Ohm). In the ICG the typical upward waveform of the cardiac ejection phase should be clearly detectable. Light movement of the subject should not overly distort it. If these criteria are not met, re-attach the electrodes in the order 7,6,1,3,4,5,2 (see illustration at [1.4 Electrode hook up](#)) until satisfactory signals are obtained. The scrollbar on the Y-axis of the *online graph* can be used to scale the signals (or hit F5 to auto scale).



1.5.3 SCL

Levels of skin conductance depend heavily on the type and configuration of electrodes used. When using the recommended electrode configuration, the SCL signal should be above 2 microSiemens but, depending on electrode type and positioning, it is not uncommon to see signal levels of 40 to 50 microSiemens or higher. Spontaneous phasic responses should be discernible in most subjects and an orienting response to a sudden unexpected stimulus should also give a phasic increase (e.g. clapping hands behind the back of the subject).



Resulting in close to vertical lines in your data when watching at a several minute time scale:



NOTE: In ambulatory paradigms, online signal inspection is your only opportunity to re-attach faulty electrodes.

1.6 Starting a measurement

When satisfied, start data recording by pressing *Start* in the configuration screen. A beep will be heard to acknowledge the start of the recording and the green light will start flashing once every three seconds. Close the configuration screen of the DAMS program and disconnect the VU-AMS device from the interface.

1.7 Marking special events

A small black button is placed on top of the VU-AMS device next to the two lead wire plug connectors. To mark a special event during the recording, push this button shortly. Pushing it will be confirmed by a short beep.

1.8 Is the VU-AMS device recording?

A small indicator light on top of the device will be flashing once every three seconds as long as the VU-AMS is recording.

1.9 Stopping a measurement

The measurement by the VU-AMS device can be stopped by:

- 1) Reconnecting the device to the PC and connecting again by serial cable by choosing the appropriate action in the DAMS menu under *Device*. You can now press *Stop*. This is the preferred method. Close the DAMS program and then disconnect the device from the interface cable.
- 2) Pressing the event button for more than three seconds. This requires that the option of stopping with the event button was **enabled** in the *Set Start Options* menu. After this action the light will flash every 10 seconds to indicate standby mode. The method is preferred when subjects have to stop the recordings themselves at home at a designated time. N.B.: When the device is returned to you after a day of ambulatory research, make sure to check whether (1) the measurement has been stopped already with the button (the light flashes twice every ten seconds), (2) is still recording (the light flashes every three seconds), or (3) has stopped because of empty batteries (the light does not flash at all).
- 3) Removing the batteries. This is strongly discouraged as it will lead to corrupted data files (OKB).

Once the VU-AMS has stopped recording, the yellow and/or blue lead wire plug(s) may be disconnected from the VU-AMS device and the lead wires from the

electrodes. Now remove the batteries and place the Compact Flash Card in the card reader. Move the *.5FS* data file to a designated directory.

1.10 Saving an .amsdata file

Double click the *.5FS* data file to open the recording. When you close DAMS it will automatically save the data in a new file with the extension *.amsdata*. This file can be opened by using the *Open data* option in the main menu or just double-clicking it. Using *.amsdata* files (once these are created) will make DAMS load the data much faster. Also all manual scoring will be saved in the *.amsdata* file. Please archive the *.5fs* raw data file.

*N.B.: you can batch convert .5fs files to the .amsdata format. Files recorded with the older AMS 4.6 system can be converted too, but no visible ECG signal will be present as only the inter beat intervals were stored with this device and not the ECG signal itself. If label information was present there are two ways to keep the labels intact while the batch conversion from .5fs to .amsdata is done. One option is to place the .lbl and the .cfg files in the same folder as the .5fs files. In the second option, a text file which holds information about the start time and end time of the labels together with the label codes is provided (see further Explanation in [2.3.3](#)). Click on **Batch convert data files** in the menu and select the folder with all .5fs or .ams raw data files . After conversion the folder will contain an .amsdata file for each of the raw data input files.*

1.11 Merging multiple .5FS files

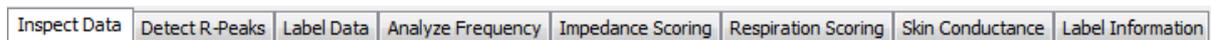
If the recording has been interrupted by the experimenter or by the subject (because the participant took a shower or batteries have been replaced), multiple *.5FS* data files with different start times will be generated. There is a possibility to use a standalone tool, *AmsMerge*, that concatenates the *.5FS* files into a single *.5FS* file that spans the entire recording. The *AmsMerge* program can be found in Start menu >> Programs >> VU-DAMS folder from version 2.2 and up.

2. Data Analysis and Management with the DAMS program

Use the DAMS program to process the VU-AMS data. Double clicking on a *.5FS* file will open the file once the DAMS program is set to be the default program to open it with.

The typical flow of VU-AMS data analysis and management is represented by a series of tabs in the main screen:

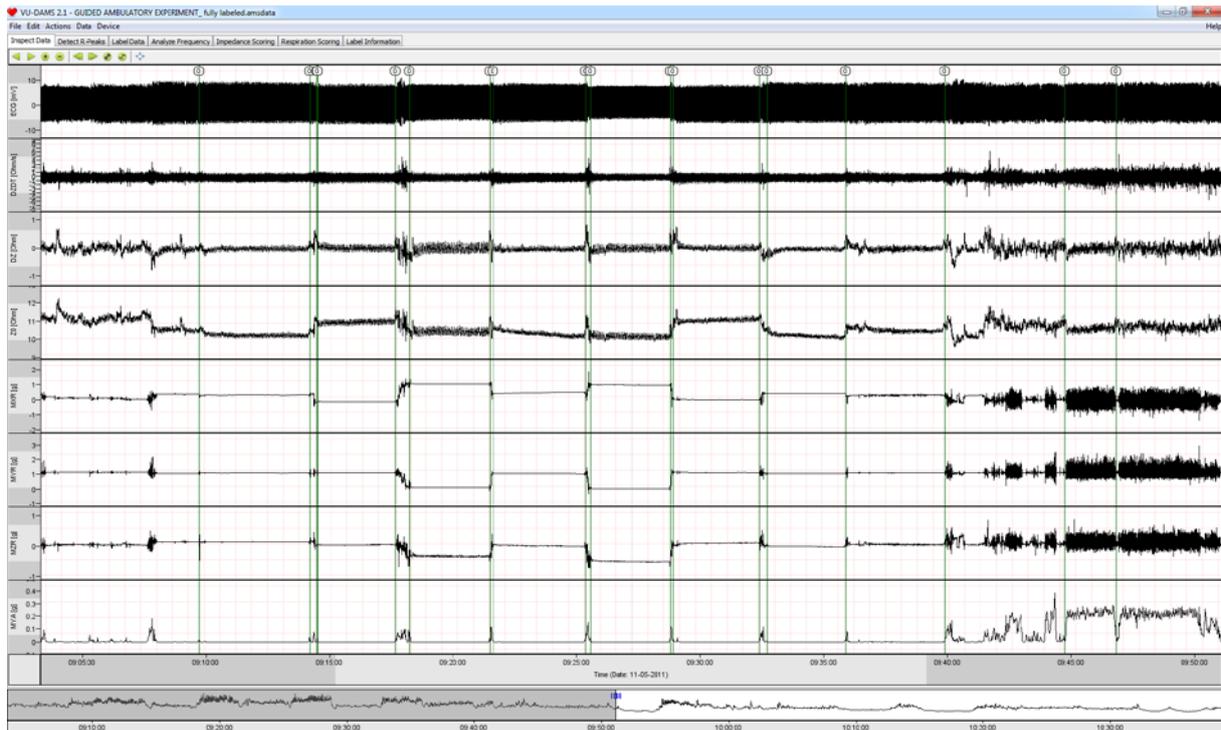
1 2 3 4 5 6 7 8



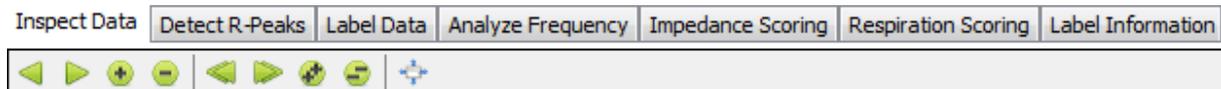
1. Inspecting the raw data
2. R-peak detection and correction
3. Labeling your data
4. Spectral analysis
5. Impedance scoring
6. Respiration / RSA scoring
7. Skin Conductance
8. Exporting the results (label-based)

2.1 Inspect Data

The *Inspect Data* tab simply gives you an overview of your data. All recorded signals are shown as continuous time series. Recording time is at the lower line. Above the recording time, the Inter Beat Interval (IBI) time series is given as extracted from the ECG. The clock time and IBI signal of the entire recording will be presented in all data analysis tabs and will function as orientation point. Zooming can be done by changing the size of the hatched rectangle in the IBI window (select one of the borders of the rectangle and drag with the mouse cursor). Vertical lines represent the times at which the event button was pressed.



All actions for the *Inspect Data* tab are presented in the form of buttons:



These actions and their keyboard shortcuts are also available in the dropdown menu *Actions*. This setup goes for all tabs in the DAMS program. Only the type of actions will differ per tab.

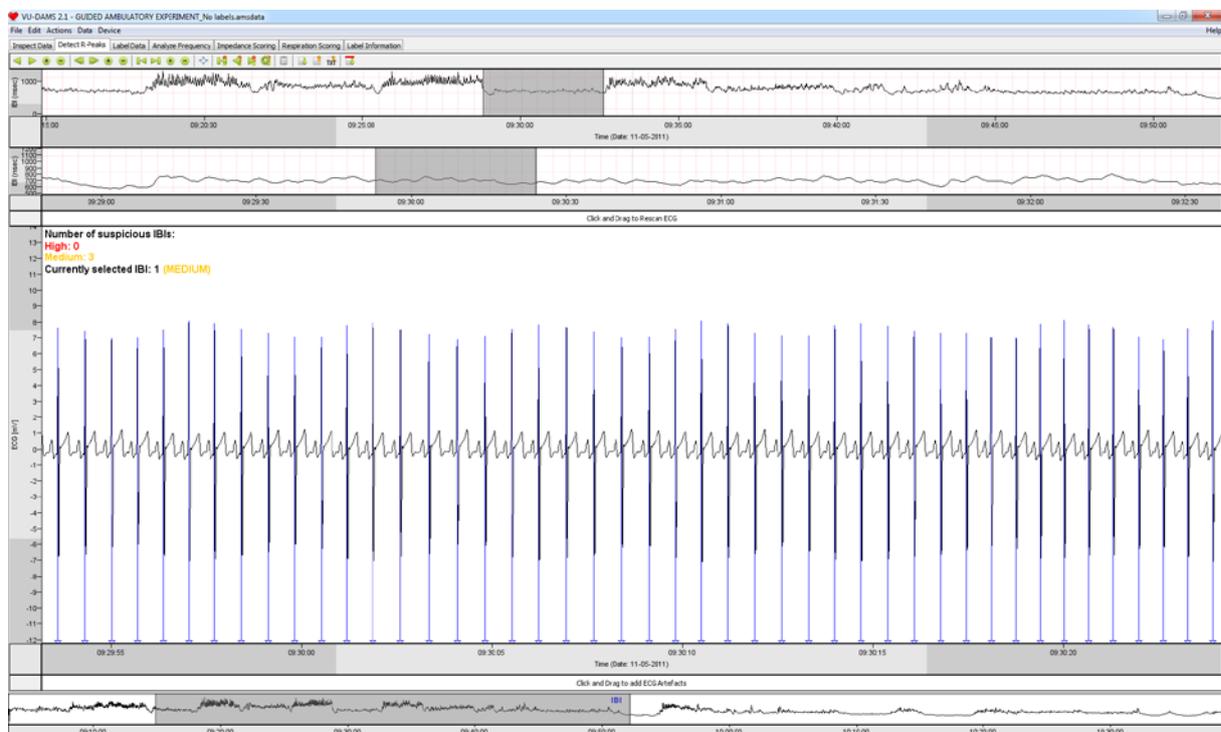
Actions	Data	Device
Move Left ¼ Screen		Left
Move Right ¼ Screen		Right
Zoom In 2X		Up
Zoom Out 2X		Down
Move Left 1 Screen		Page Down
Move Right 1 Screen		Page Up
Zoom In 4X		NumPad +
Zoom Out 4X		NumPad -
Autoscale All		F5

The function of these buttons should be self-explanatory. Hovering the mouse cursor over a button will display a short description. The mouse can also be used to zoom in and out; by using the mouse wheel a shorter or a longer period of the recorded data can be shown. Zooming can also be done by dragging the darker grey rectangle just below the time line. Moving the lighter grey rectangle in the middle will move the data either right or left.

Each of the signals can be autoscaled separately by right clicking on the Y-axis of the signal.

2.2 Detect R-Peaks

The *Detect R-Peaks* tab will assist you to create an artefact free IBI signal as fast as possible by applying automated artefact and peak detection. The mandatory visual inspection and correction of the resulting IBI signal is made as easy as possible by multiple zoom levels and an automated suspicious beat detector. The default settings of this detector work well on most of the ECG recordings but changing the peak detection settings can be required in case of noisy or strongly deviant ECGs. After opening either the raw *.5FS* or a saved *.amsdata* file click on the *Detect R-Peaks* tab.



The QRS detector software runs three separate automated analyses on the ECG signal. The first automated analysis detects and marks periods with missing data or clipping of the electrocardiographic signal. These periods are called artefacts. A second automated analysis of the QRST waveform detects the occurrence of all R-peaks. The R-peaks are converted to the inter beat intervals time series which is simply the distance in milliseconds between two consecutive R-peaks plotted against time, giving rise to the continuous line seen in the lower and upper top windows. The third automated analysis checks the plausibility of the duration of each IBI in the context of its surrounding interbeat intervals. This feature was created to ease visual inspection and user-driven correction of the IBI time series.

All actions for the *Detect R-Peaks* tab are presented in the form of buttons:



Actions	Data	Device
Move ECG Left ¼ Screen		Left
Move ECG Right ¼ Screen		Right
Zoom ECG In 2X		Up
Zoom ECG Out 2X		Down
Move ECG Left 1 Screen		Page Down
Move ECG Right 1 Screen		Page Up
Zoom ECG In 4X		NumPad +
Zoom ECG Out 4X		NumPad -
Move Middle IBI Left ¼ Screen		Open Bracket
Move Middle IBI Right ¼ Screen		Close Bracket
Zoom Middle IBI In 2X		Equals
Zoom Middle IBI Out 2X		Minus
Move Top IBI Left ¼ Screen		O
Move Top IBI Right ¼ Screen		P
Zoom Top IBI In 2X		0
Zoom Top IBI Out 2X		9
Autoscale All		F5
Move to most suspicious IBI		M
Move to previous most suspicious IBI		Comma
Move to next most suspicious IBI		Period
Recheck for suspicious IBIs		Ctrl+R
Delete Beats Under Artefacts		Ctrl+D
Import Beats From File		Ctrl+I
Export Beats To .beat File		Ctrl+E
Export Beats To ASCII File		Ctrl+A
Import Artefacts From File		Ctrl+U
Name Suspicious beats as Artefact		Ctrl+T

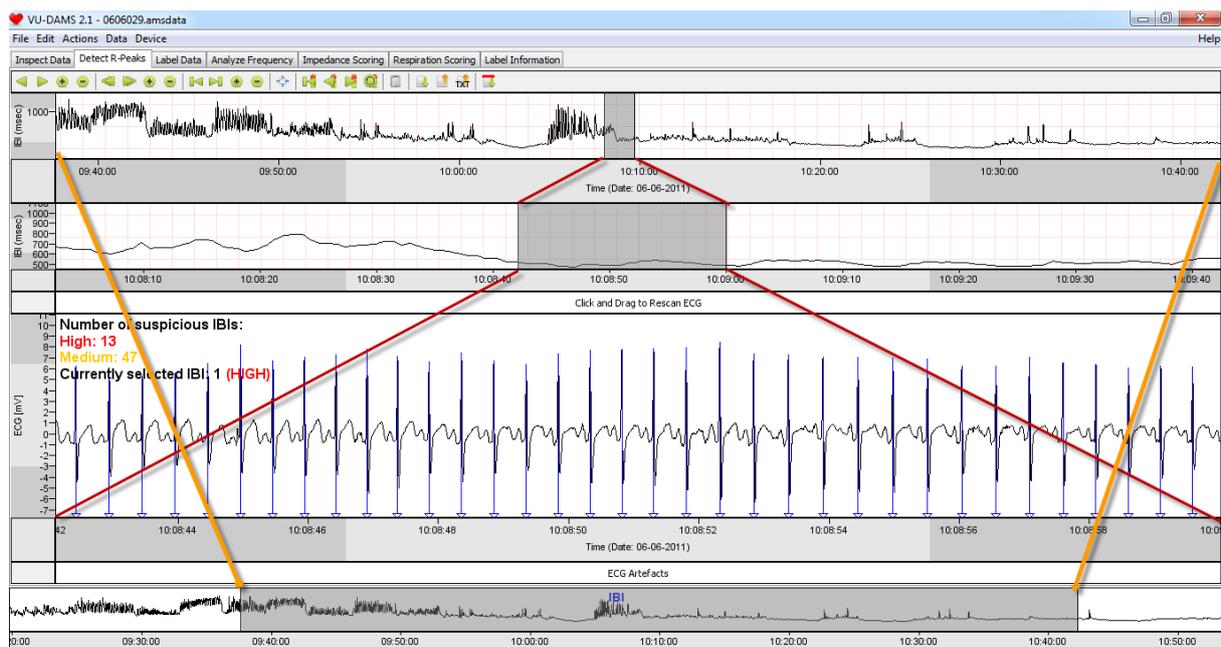
The function of these buttons should be self-explanatory. Like in all other tabs hovering the mouse cursor over a button will display a short description.

2.2.1 Visual inspection and manual correction

Automated artefact labeling reliably detects clipping and signal loss, but detection of noisy ECG is not perfect. Manual selection of bad ECG signal parts may be additionally needed. The three main windows will help you select the parts of the IBI time series that need to be manually labeled as artefacts. The *bottom window* is our

overview of the IBI signal of the entire recording that is also present in the other modules (tabs) of the Data Analysis Management Software.

What is marked as a grey bar in the first top window will be displayed in the second middle window. The X-axis of the IBI time series in these windows represents the time at which a beat was recorded. The Y-axis of the IBI time series is the interval duration of that beat in milliseconds. The third lower window displays the actual ECG signal. You can zoom the ECG window in or out by dragging the dark grey area in either of the IBI time series windows. You can also zoom in or out by using the scroll wheel of the mouse on the part of the data you want to see in more detail. By using the mouse wheel a shorter (scroll forward) or a longer (scroll backward) period of the recorded data can be shown. Selecting a different part of the recording can be done by changing the size of the hatched rectangle in the IBI window at the bottom (select one of the border of the rectangle and drag with the mouse cursor) or by moving the rectangle left (backward in time) or right (forward in time).



2.2.2 Removing artefacts

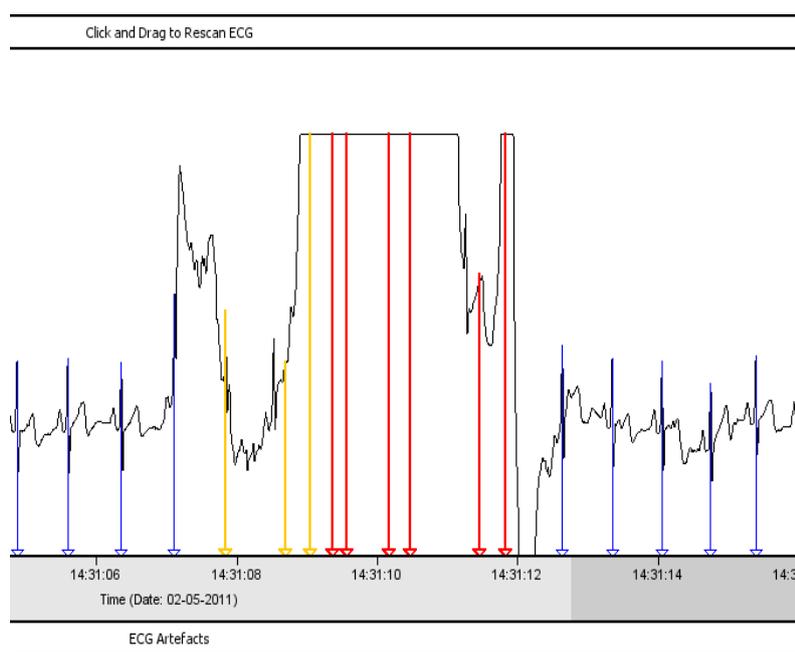
Artefacts can be divided into technical and physiological artefacts. In the *ECG artefacts* Bar all automatically detected artefacts and user-supplied artefacts are labeled by a red bar. These artefacts are deleted from all further data analyses. Technical artefacts will be discussed here and the physiological artefacts will be discussed in the next paragraph.

In the main window with the ECG signal the detected R-peaks are marked by vertical lines, mostly blue. A blue line means that the beat was considered to be correct according to the automatic beat detector. Potential mistakes in automated beat detection are termed 'suspicious beats' and are flagged by a red or yellow color. Some parts of the data might not be bad enough to be detected by the automated artefact detector and at the same time they are too noisy for the R-peak detector. Hence the R-peak detector will try to make something out of noise and may still score occasional beats as being correct (blue) where they are not. These periods of noisy data will also contain a lot of red and yellow lines which makes them easy to detect.

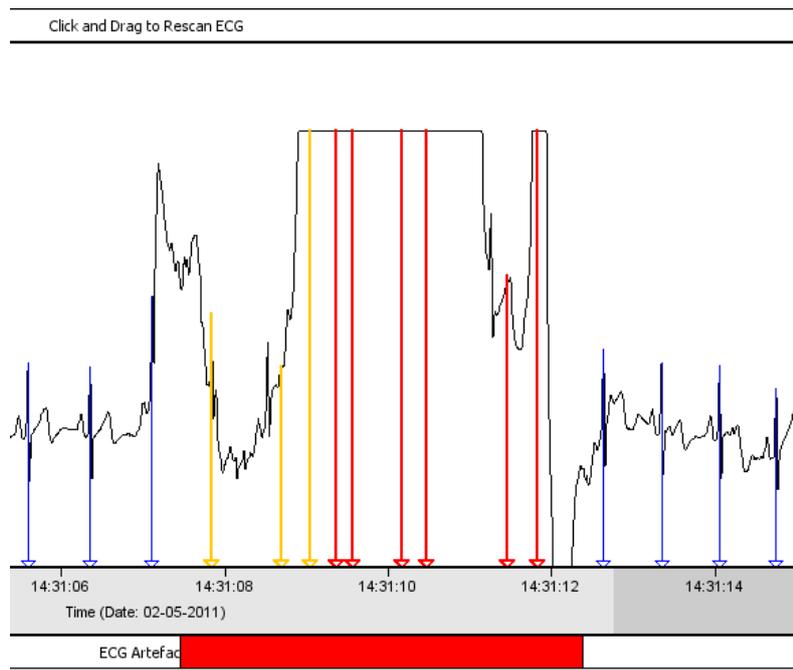
These noisy parts may arise because an electrode became (partly) detached. This is known to happen occasionally in unsupervised ambulatory recordings. To find noisy parts from the IBI signal, search for deviant parts in the bottom IBI time series window. The IBI time series will be highly irregular with sharp peaks/spikes in the IBI time series wherever the detector failed (as it assigns inter beat intervals that are disproportionally long or short). Zoom out so the entire artefact period is visible in your screen to make deleting easier.

To mark the bad ECG as an artefact, click with the left mouse button in the artefact bar and drag it from left to right until it covers the entire period that is to be marked as an artefact.

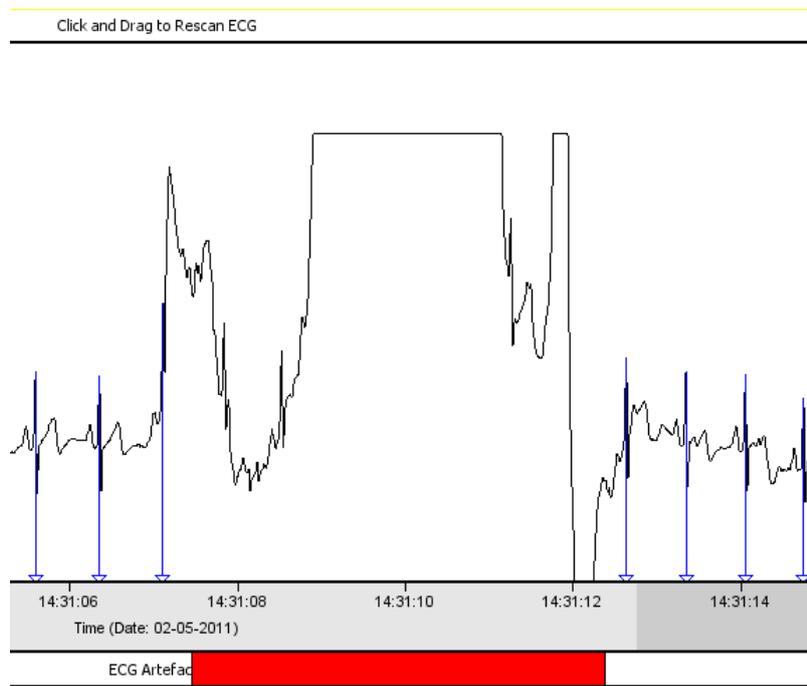
Find the artefact period:



Select the artefact period:

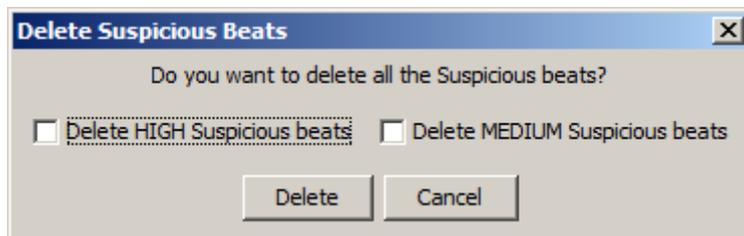


And remove the beats within the artefact period:



You can also wait until all periods with missing data or artefacts have been marked and then use the option *Delete Beats Under Artefact* in the menu bar or use the shortcut Ctrl+D. The IBI signal should look much smoother now. As stated before, the beats within the periods labeled as artefact will be ignored in all further analyses with the Data Analysis Management Software.

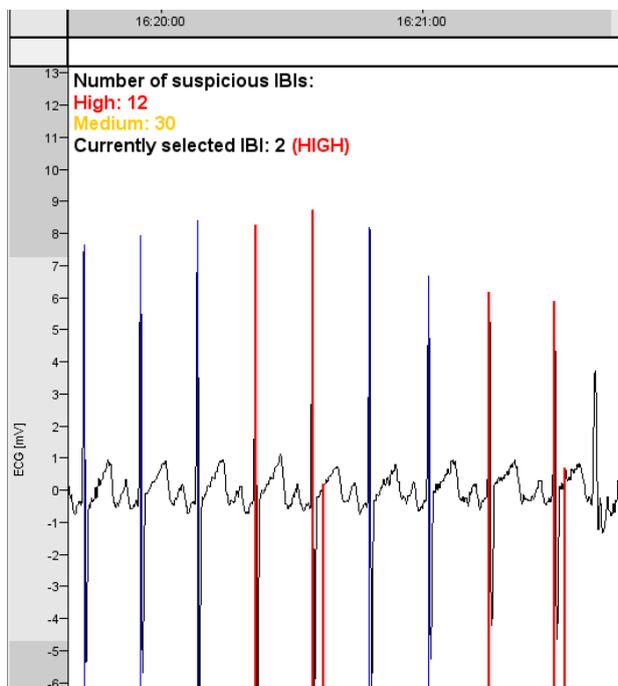
In case of a very noisy long recording (24 hours for example), VU-DAMS offers the option to mark all highly and/or medium suspicious beats as artefacts. You can find this feature by clicking the *Detect R-Peaks* tab → *Actions* → *Name suspicious beats as Artefact*.



Note that this feature is meant exclusively for long recordings with very much noise that would take too much time for the researcher to delete manually. Before deleting all suspicious beats, **make sure** that all highly/medium suspicious beats are in fact noise and not heart rate variability. *Not all suspicious beats are wrong per se* (read more on this topic in the next paragraph).

2.2.3 Suspicious beat correction

In the main window's top left corner the number of suspicious beats are displayed. For highly suspicious beats the R-peaks are marked in red. R-peaks in less suspicious beats are marked in yellow and R-peaks marked by blue lines are considered to be correct.

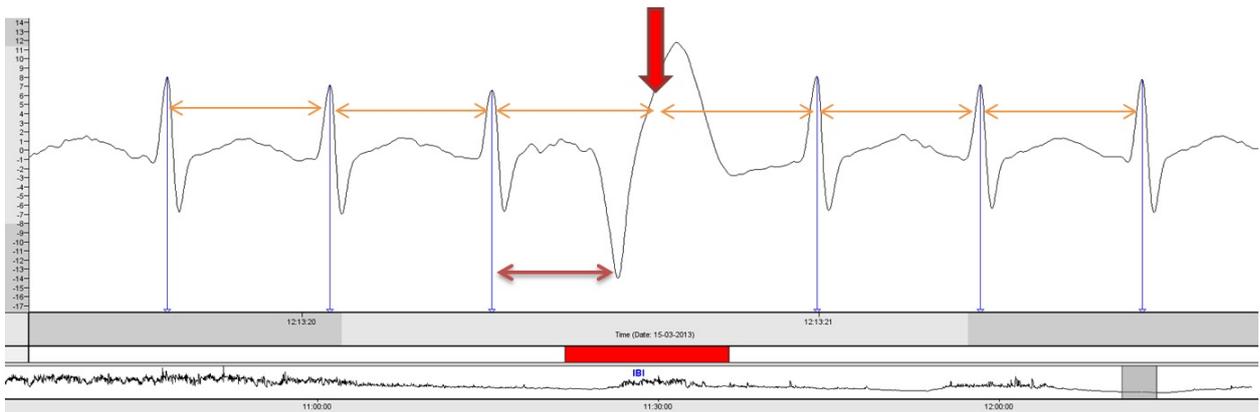
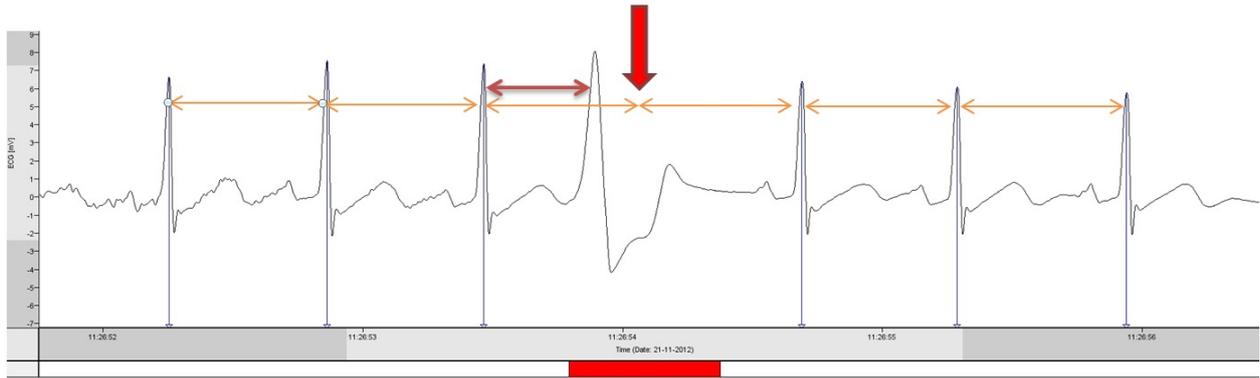


You can easily browse through all suspicious beats from most to least suspicious by pressing *Dot/right pointer* keyboard key for next, and *comma/left pointer* keyboard

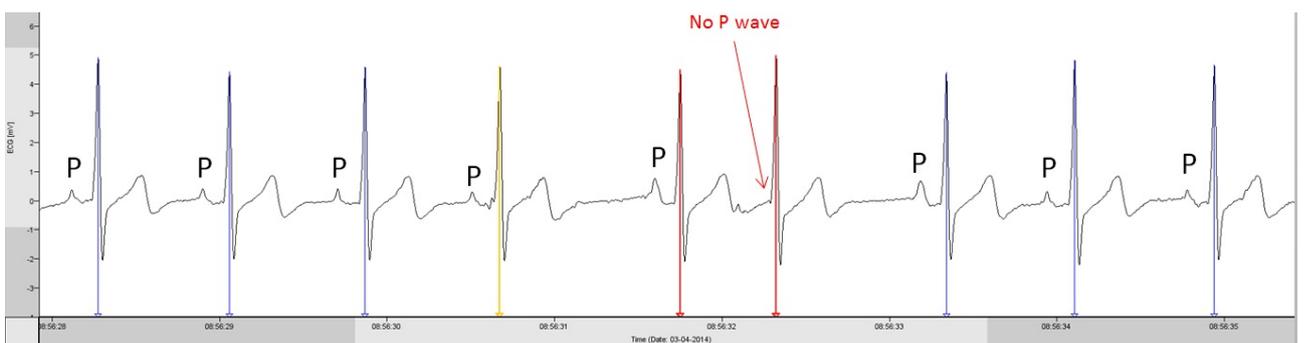
key for previous suspicious beat. Or you can simply use the menu buttons at the top of the window. When you are at a suspicious beat you can either delete a beat by right clicking on it, e.g. when a beat was placed in an obvious wrong location in between beats. Or you can add a beat by left clicking on the correct location of the R-peak, e.g. when a beat was completely missed. Notice that the surrounding beats might also change color when adding or deleting a beat. You can also move a beat by placing the left mouse button on the vertical line and then move it left or right. Releasing the mouse button will lock the vertical line to its new location.

In HRV analysis, the aim is to examine the sinus rhythm modulated by the autonomic nervous system. Hence, physiological artefacts should be excluded from analysis. Physiological artefacts include ectopic beats and arrhythmic events or more generally: beats not originating from the sinus node. When <5 successive beats are deleted, the VU-DAMS software interpolates the IBI times using a cubic spline.

Normally, the electrical activity starts in the sinus node; the natural pacemaker of the heart. Electric current will travel through the atria and then is momentarily delayed in the AV node as a result of slow conduction. Thereafter, the current travels through the bundles of His to depolarize the ventricles in an organized manner (starting at the apex). This normal, organized electrical activity will result in the known P-QRS-T morphology. Generally, there are two main types of ectopic beats; those originating from the ventricles and those originating somewhere else. An ectopic beat originating from the ventricles is called a premature ventricular contraction (PVC). You can recognize these beats by an early, broad QRS complex. Below, two examples of PVCs are shown (both are PVCs, the different morphology is due to a different site where the PVC originates in the ventricles). You can see the beat is early (premature) since, looking at the surrounding IBIs, it was expected at the big red arrow pointing downwards. Also, The QRS complex is clearly wider compared to the sinus beats.



When an ectopic beat originates above the ventricle, the electrical current will travel through the bundles of His down the ventricle, thus giving a normal narrow QRS complex. When one sees a short IBI and the P wave (representing the depolarization of the atria) has a different morphology or is not present at all, this is most likely a premature atrial contraction (PAC). Below, an example is shown.



VU-DAMS gives an option to mark these ectopic beats as 'premature ventricular contraction' or 'premature atrial contraction'. The count of PVC's or PAC's per label (if present) are included in the final output.

Note that, when there is a period of a lot ectopy, you might have to delete the period entirely when computing HRV, instead of the single ectopic beats as the HRV variables cannot be calculated reliably.

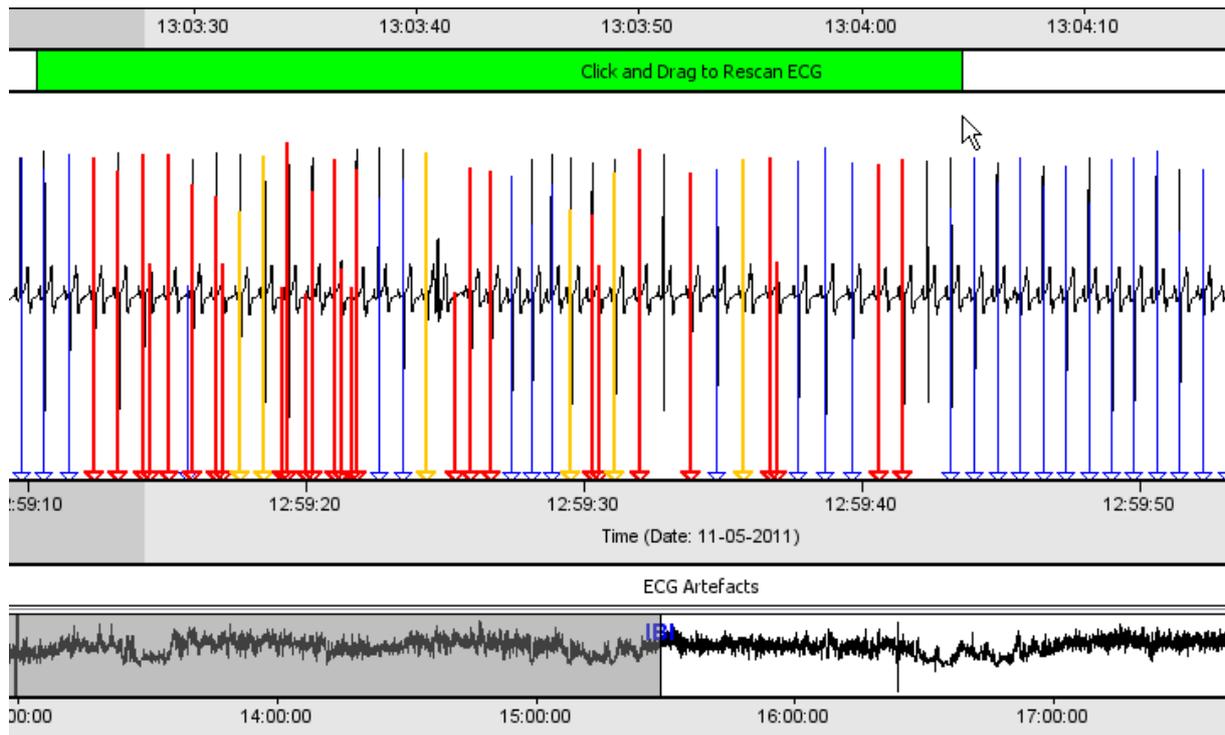
After your corrections (or in fact at any time) you can select the menu button *re-check suspicious IBI's* to see how many beats are still considered suspicious. ***Just remember that suspicious is not wrong per se!***

It can happen that you can have a perfect IBI time series with no misplaced beats, but that the DAMS program still reports some suspicious beats. This is because strong sinus arrhythmia may throw the beat detector off and extrasystolic beats always will. Clearly, suspicious is not always guilty.

NOTE: You can also choose to export the interbeat time interval series to a text file for use in different software packages like the CarSpan or Kubios by clicking on the menu buttons 'Export Beats To ASCII File'. Chose the appropriate directory and file name and save the IBI time series as a text file.

2.2.4 Adjustment of R-peak detection in deviant ECG signals.

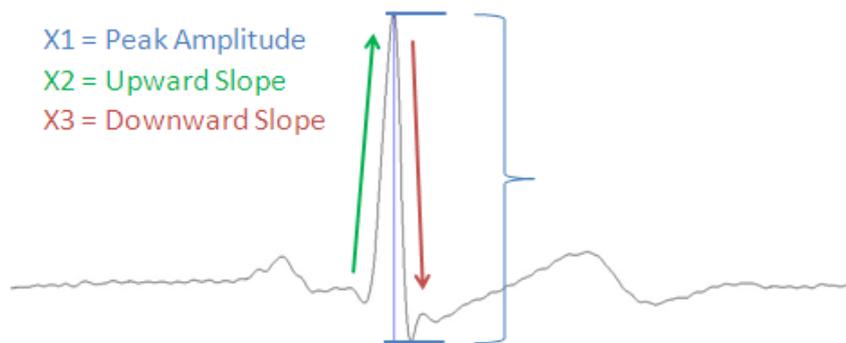
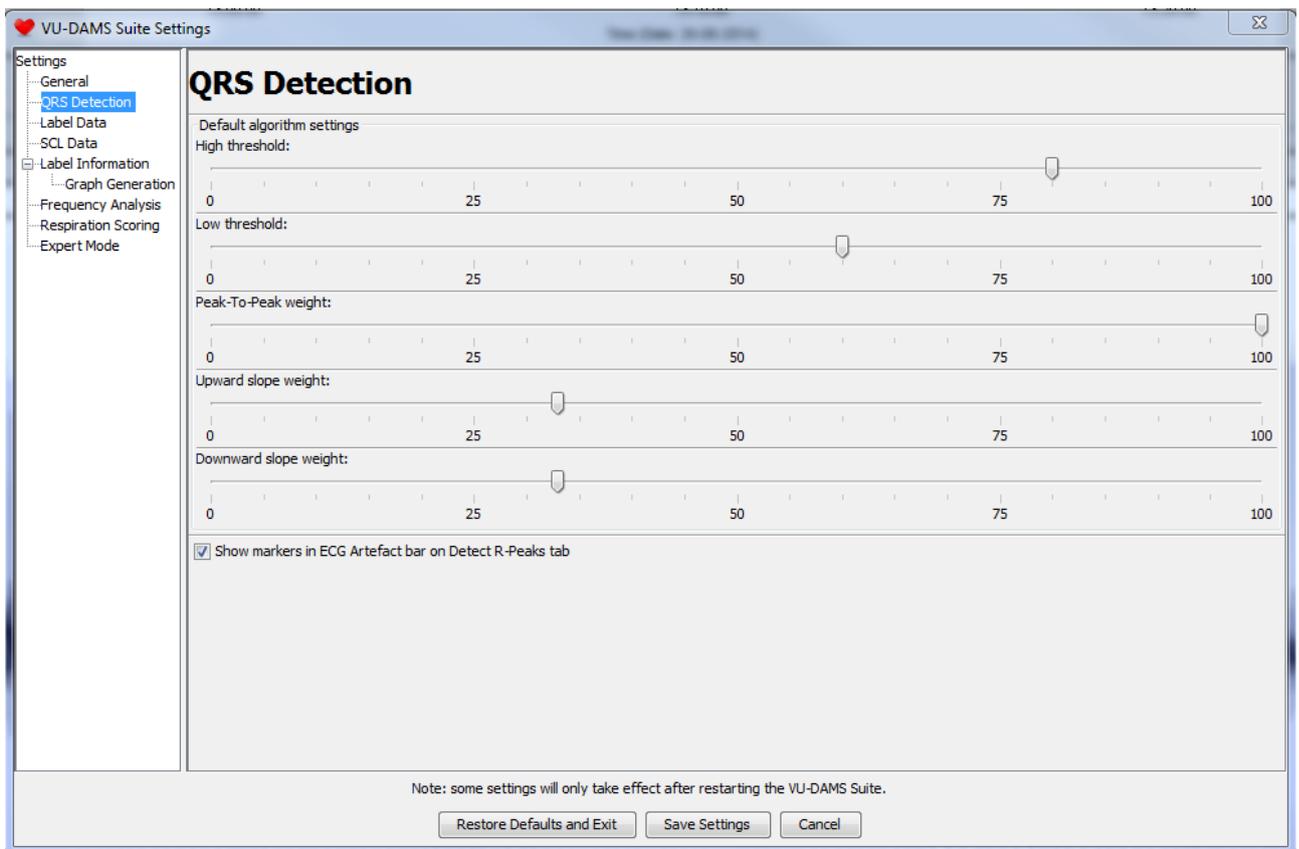
When an ECG signal is of good/reasonable quality but you can clearly see that the automatic detector placed the beats anywhere but on top of the R-peak, you should rescan the complete ECG signal with different settings for the detection algorithms. The default settings for the algorithm upon opening the *.amsdata* file can be changed in the main menu by selecting *Edit* → *Settings* → *QRS Detection*. You can also use the Rescan bar to select only a certain part of the recording. Drag your mouse across the incorrectly scored part of the ECG (minimum rescan length is 10 seconds) in the Rescan bar while holding the left mouse button.



A pop up screen with 5 sliders (the same as in the settings screen) appears. You see a high and a low Threshold slider and three Relative weight sliders that change the weight of the peak amplitude, the downward slope and the upward slope. The algorithm calculates a Peak score based on the sum of these parameters multiplied by their weights and then divides this by the sum of the weights. The R-peaks of the selected area will be rescored when clicking on Rescan. This peak score will be used in combination with the threshold sliders/settings, such that all peaks with a score between the low and the high thresholds will be considered an R-peak. Set the sliders as desired and press Rescan to apply the new settings on the selected part of the ECG signal. Adjust the settings until satisfied.

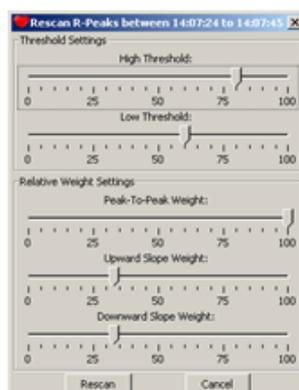
**Please also see the “R-Peak Detection” tutorial video for a demonstration: www.vu-ams.nl/support/tutorials/software/r-peak-detection*

The default values can be changed in the settings screen:



$$\text{Peak score} = \frac{(\text{Weight 1} * X1) + (\text{Weight 2} * X2) + (\text{Weight 3} * X3)}{W1 + W2 + W3}$$

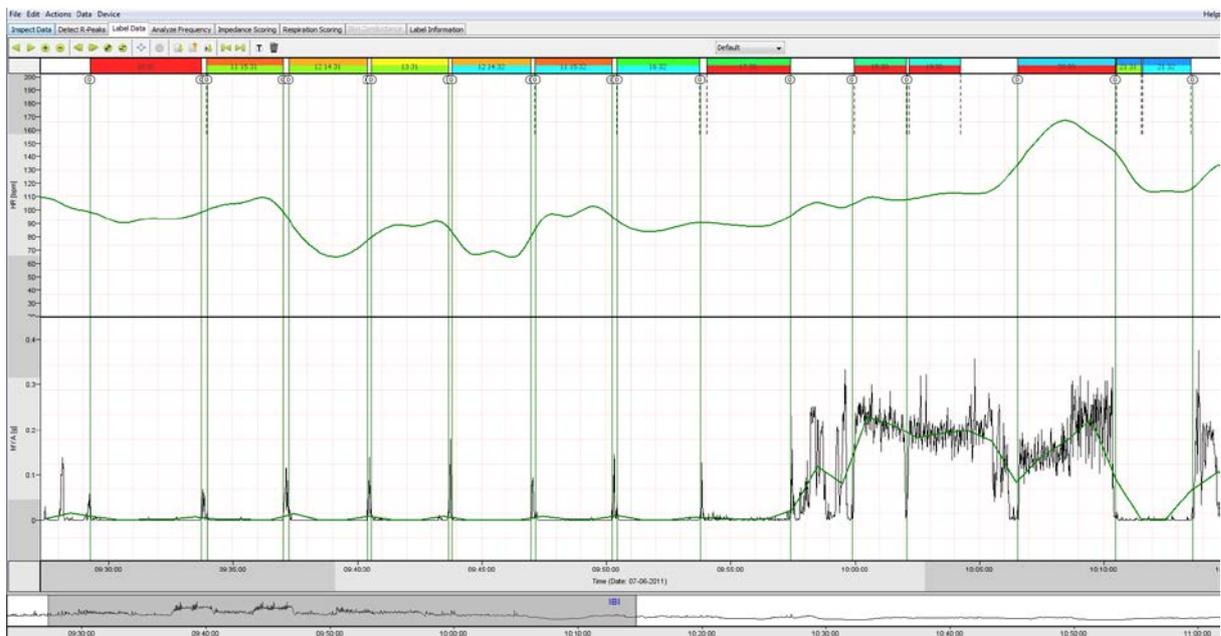
Peak Amplitude Weight
 Upward Slope Weight
 Downward Slope Weight



2.3 Labeling your data / dividing your data into separate pieces

Here you divide the continuous data collected with the VU-AMS device into logical periods for further analysis. We call this labeling. The aim of labeling is to get an average value for each available parameter, such as HR, PEP and RSA, for each experimental condition or ambulatory activity.

Click on the *Label Data* tab. In the upper window we see the raw IBI time series and/or the smoothed (and hence lightly time lagged) heart rate signal. Because the heart rate signal is dependent on the quality of the IBI time series, make sure the R-peaks have been detected correctly in the *Detect R-Peaks* tab. In the lower window we see the 'motility' signal. This signal is based on the Y axis of the tri-axial accelerometer. The clock time and IBI time series are presented in the two bottom windows, which will help us to quickly locate our current position in the total recording.



All actions for the *Label Data* tab are presented in the form of buttons:

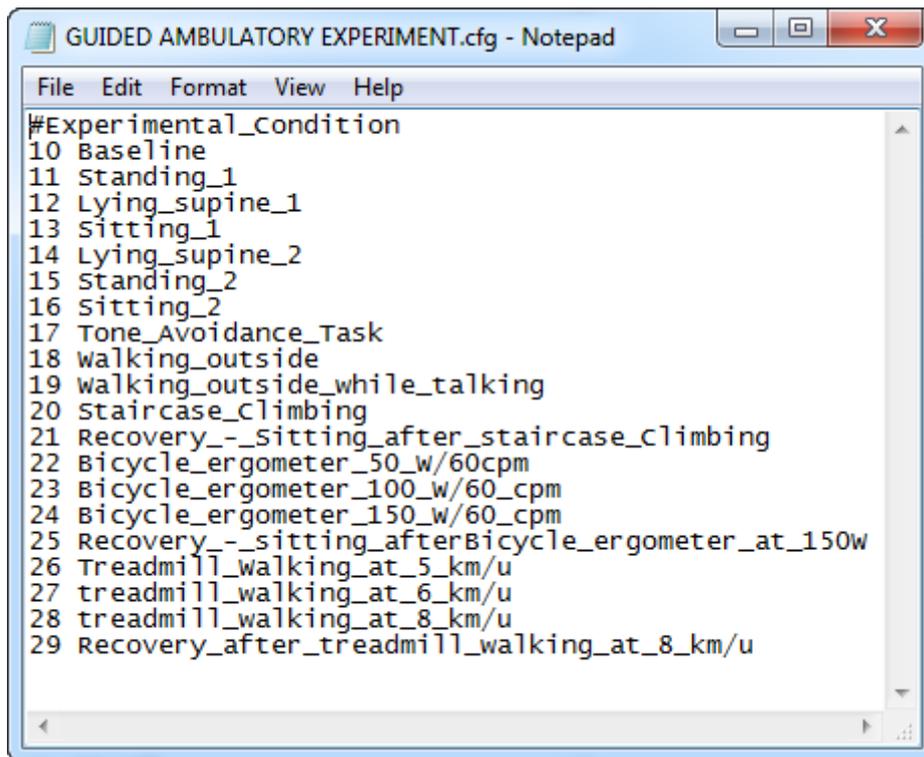


Actions	Data	Device
Move Left ¼ Screen		Left
Move Right ¼ Screen		Right
Zoom In 2X		Up
Zoom Out 2X		Down
Move Left 1 Screen		Page Down
Move Right 1 Screen		Page Up
Zoom In 4X		NumPad +
Zoom Out 4X		NumPad -
Autoscale All		F5
Edit Label Configuration		E
Import Labels From File		Ctrl+I
Export Labels To lbl File		Ctrl+E
Create Labels using Events		Ctrl+M
Previous Panel		Comma
Next Panel		Period
Add Time-Based Labels		Ctrl+T
Delete all Labels		Ctrl+A

The function of these buttons should be self-explanatory.

2.3.1 Creating a Label Configuration File

Before we can actually begin labeling the data, we need to create the blueprint for all possible labels first. This blueprint lists all the experimental conditions or ambulatory activities in our experiment. This is done in the label configuration file (.cfg file). The easiest way to create a label configuration file that suits your purpose is by manually creating or editing a text file. A main category is always indicated by a hash key, (#) followed by the name you want for that main category. Then each level of that category, in the example below these were all the experimental conditions, needs to have a unique numerical value followed by a name for each condition. Save it under a logical name with the extension .cfg. (Choose “All Files (*.*)” for “Save as type:”)

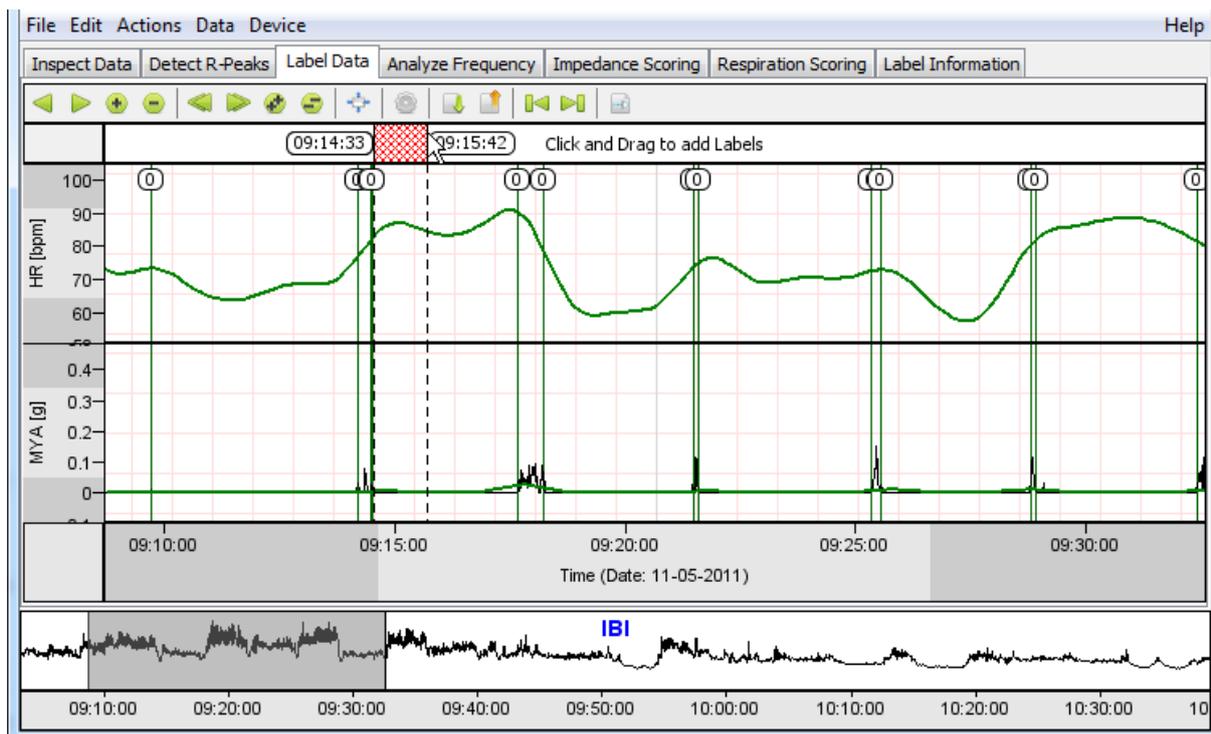


```
GUIDED AMBULATORY EXPERIMENT.cfg - Notepad
File Edit Format View Help
#Experimental_Condition
10 Baseline
11 Standing_1
12 Lying_supine_1
13 Sitting_1
14 Lying_supine_2
15 Standing_2
16 Sitting_2
17 Tone_Avoidance_Task
18 walking_outside
19 walking_outside_while_talking
20 Staircase_Climbing
21 Recovery_-_sitting_after_staircase_climbing
22 Bicycle_ergometer_50_w/60cpm
23 Bicycle_ergometer_100_w/60_cpm
24 Bicycle_ergometer_150_w/60_cpm
25 Recovery_-_sitting_afterBicycle_ergometer_at_150w
26 Treadmill_walking_at_5_km/u
27 treadmill_walking_at_6_km/u
28 treadmill_walking_at_8_km/u
29 Recovery_after_treadmill_walking_at_8_km/u
```

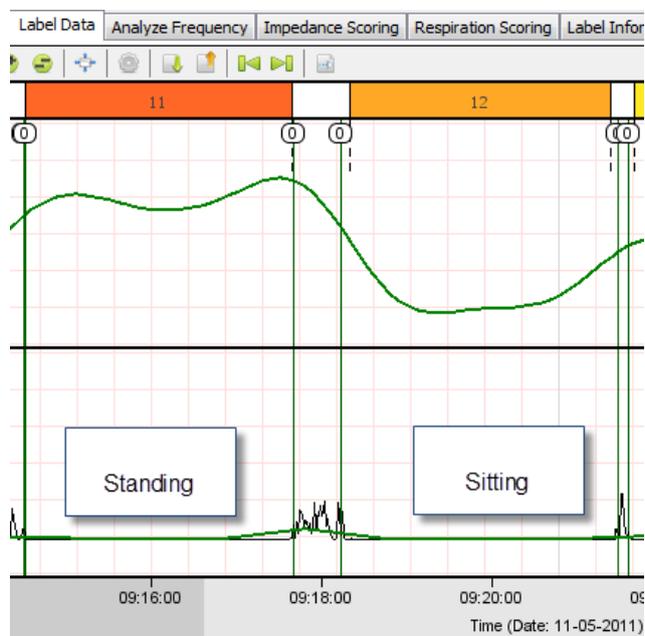
When you are done creating the label configuration file you need to make sure that the DAMS program recognizes this file. To do this click the *Label Data* tab → *Actions* → *Edit Label Configuration* → *Import Label Config From File*. Now select the label configuration file you manually created and click *open*. When the same label configuration file is used for a longer time, like for an entire research project, you could click on the option *Set Label Configuration As Default*.

2.3.2 Labeling your data

Now you can start the actual labeling of your data. If you have notes containing the start and stop times of each condition, you can use the top bar where it says “Click and Drag to add Labels”. When hovering the mouse on the bar you will see an indicator of the time window appear. This will help you place the starting point of your label accurately. Click with the left mouse button in the top bar at your starting point and drag the mouse to the right until the desired end time of the label is reached.



A dashed vertical line will also appear on both ends of the label extending into the motility signal. This may help you remove the transition periods with movement between two experimental conditions from the final labeled data.



NOTE: The motility signal becomes indispensible when labeling VU-AMS data from self reported activities in diaries as often done in 24-hour ambulatory recordings.

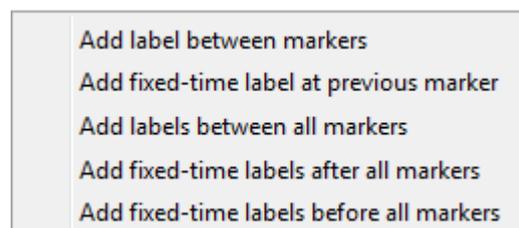
A pop up screen with our previously defined categories will appear upon releasing the mouse button. From our category “Experimental_condition” we choose the level “Baseline” and click *OK*. The pop up window will close now and a colored bar appears representing the new label. You can verify the information in the label by hovering with the mouse on top of it. If you want to edit or delete a label, just right click on it and choose the required action from the popup menu. If you want to change the length of the label click and drag with the mouse on the edges of the label. To reposition a label, click and hold the left mouse button on the label to grab and move it around.

Repeat the labeling process until all relevant periods (i.e. all experimental/ambulatory conditions) are labeled. Each label will be represented by a row in the excel sheet obtained under the *Label Information* tab.

2.3.3 Use of event button marker lines

In case of an experiment you have the option to use the event button of the VU-AMS device to mark the beginning and ending of each condition. Shortly pressing the event button on the VU-AMS device creates a marker in the data at the exact time the button was pressed. These markers are displayed as lines here and help us to more easily detect the start and stop times of each experimental condition. So, we can use the marker lines or our notes with start and stop times or a combination of both, to make sure we label the correct periods for all conditions.

When working with the marker lines generated by the event button of the VU-AMS device you have the possibility to automatically place a label exactly between two marker lines. By clicking with right mouse button on the label bar, the following pop-up screen appears. The labels can now be placed automatically by using one of these options.



Another way to automatically place labels using marker information is to simply create a formatted text file and import this file by clicking the *Label Data* tab → *Actions* → *Create Labels using Events*. One can also use this in batch mode when choosing *File* → *Batch convert data files*

The file always starts with the header line “*SM, EM, D1, D2, LC*”. The first column corresponds to the Start Marker (SM), an integer specifying which marker to use as a reference for the label. The second column corresponds to the End Marker (EM), and is only used to specify a label between the SM and the EM, in which case it is an integer specifying at which marker the label ends, otherwise it is set to missing (-9999). The third column is Duration1 (D1), meaning the interval from desired label start to the SM in seconds (where negative values indicate the label should start *after* the marker, and positive values have the label start *before* the marker). The fourth column is Duration2 (D2), meaning the interval from the SM to the desired label end in seconds. The fifth column is the Label Code (LC), or the integer describing which experimental condition the label corresponds to. These variables can be used to generate labels in several ways. An example text file used for automated labeling is shown below:

```

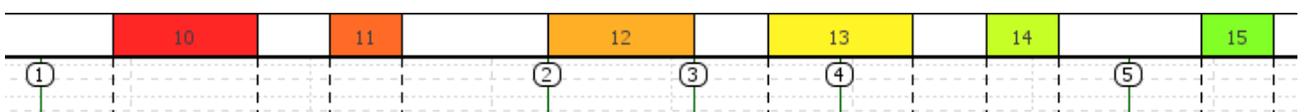
CreateLabelsUsingMarkers.txt
1 SM, EM, D1, D2, LC
2 1, -9999, -1, 3, 10
3 1, -9999, -4, 5, 11
4 2, 3, -9999, -9999, 12
5 4, -9999, 1, 1, 13
6 5, -9999, 2, -1, 14
7 5, -9999, -1, 2, 15
8

```

In the above example:

- Lines 2 and 3 create labels 10 and 11 after marker 1.
- Line 4 creates label 12 in between marker 2 and 3.
- Line 5 creates in label 13 around marker 4, one second before (D1) and one second after (D2).
- Line 6 creates label 14 before marker 5.
- Line 7 creates label 15 after marker 5.

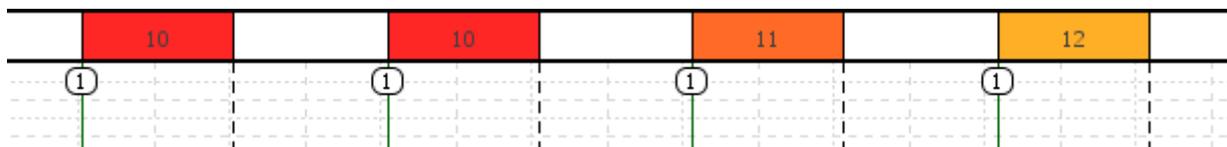
This would result in the labels 10 to 15 below.



In recordings with non-unique marker codes, e.g. when the markers originate from a button press on the VU-AMS device and all have marker code 0, one can also repeat text lines to place the same (or different) label after a later instance of that marker like in the example below. Note a to-be-placed label will only be placed if the middle of the to-be-placed label is not on an existing label.

```
CreateLabelsUsingMarkers2.txt x
1 SM, EM, D1, D2, LC
2 1, -9999, 0, 1, 10
3 1, -9999, 0, 1, 10
4 1, -9999, 0, 1, 11
5 1, -9999, 0, 1, 12
6
```

This would result in the labels 10 to 12 below.



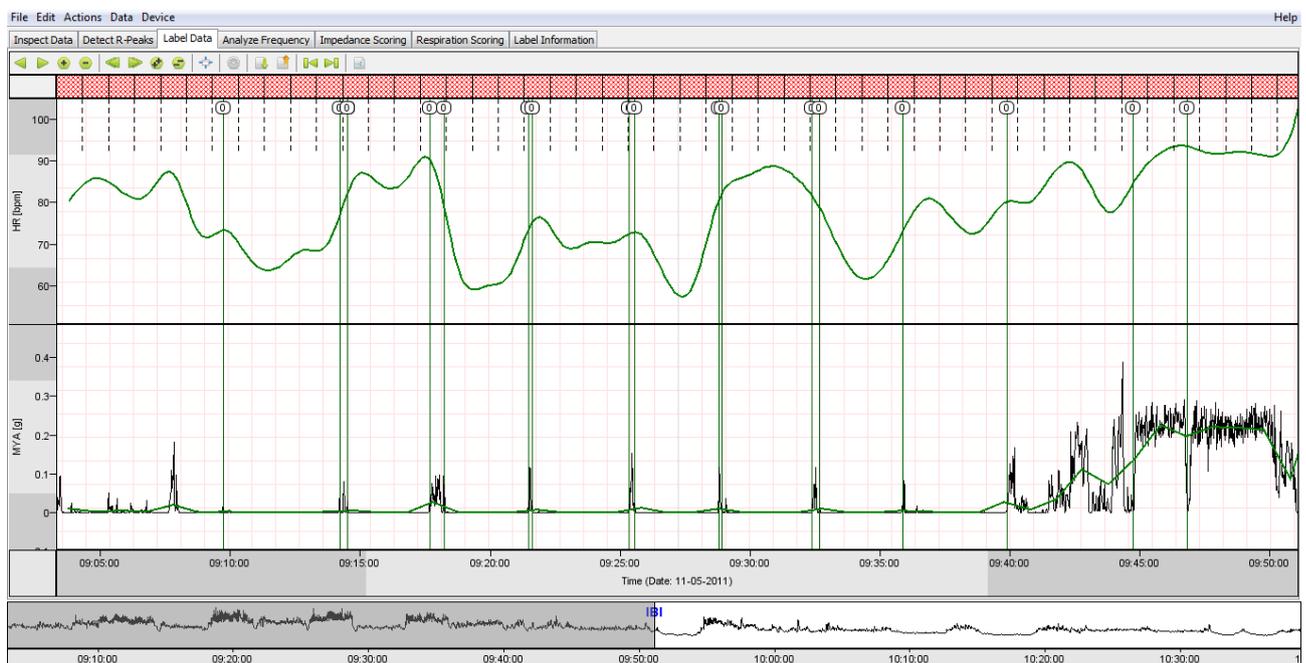
NOTE: *Text files in any of the three formats which were supported in previous versions of VUDAMS are still accepted for backwards compatibility.*

NOTE: *In laboratory studies that use a stimulus computer, this computer can be used to send markers through the VU-AMSi infrared interface cable. Please refer to VU-AMS website: www.vu-ams.nl/support/downloads/extras*

2.3.4 Time based labels

Instead of predefined category labels representing a specific condition, you can also choose to create time-based labels, where all labels represent a fixed amount of time that can last in duration between 10 seconds and 1 hour. This is especially useful if you want to generate continuous 60 sec ensemble averages of the impedance cardiogram for PEP scoring instead of a large scale ensemble average that spans an entire condition.

To do this click the *Label Data* tab → *Actions* → *Add Time-Based Labels* and type in the amount of seconds you want each label to be. The entire data is now cut up into labels with your pre-defined length. The experimental label information, if present, can optionally be included in these time based labels.



*Please also see the Data Labeling tutorial videos for a demonstration: www.vu-ams.nl/support/tutorials/software/data-labeling

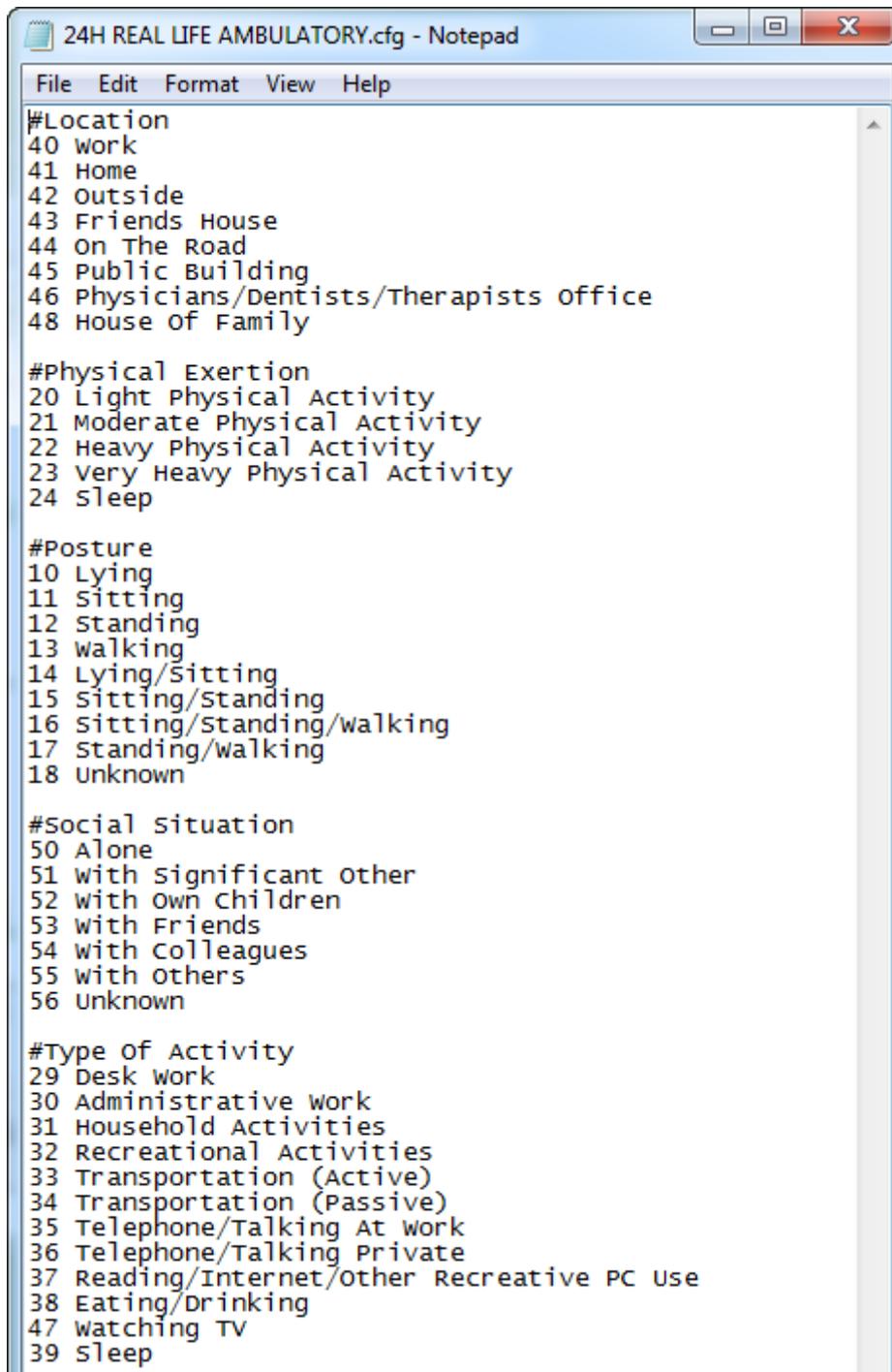
2.3.5 Labeling Naturalistic Recordings

The previous example assumed a supervised setting with fixed experimental conditions of which start and end times were under the experimenter's control. This is of course not the case in ambulatory recordings in naturalistic settings. Still many of the principles apply, as "real life" can also be divided into periods of 'fixed' and frequent occurring activities.

To create a label file that will capture most daily activities of the subjects in your target population is a crucial but feasible step in ambulatory data analysis. As the autonomic nervous system is highly sensitive to changes in posture and physical activity it is first of all very important to obtain information about these aspects of a subject's daily routine. This is usually done by asking all subjects to keep a detailed diary (paper-and-pencil or electronic hand held devices) during the ambulatory measurement day. This diary information about (changes in) posture and physical activity is then used during the labeling procedure. The VU-AMS device also contains a tri-axial accelerometer to support this self-report with objective data. Further categories to be used in the ambulatory labels will entirely depend on the research question and the target population. Here are some examples of categories that could be considered:

Category	Levels of Category
Type of activity	Reading, attending a meeting, eating, dancing, PC work, conversing, watching TV, exercising, attending a musical, driving a car, ironing, etc.
Posture	Sitting, standing, lying, walking, etc.
Physical activity	Heavy, moderate, light, none
Social situation	Alone, with significant other, with friends, with colleagues, etc.
Location	At home, at the office, travelling, at a restaurant, etc.
Time of day	Work, leisure time, sleep
Mood state	Angry, friendly/happy, sad, anxious, tired

When you have decided on the type of categories you want to use during labeling you again need to summarize these in a *label configuration file* (default name *label.cfg*). An example for a 24-hour recording project is given in the figure below.



```
24H REAL LIFE AMBULATORY.cfg - Notepad
File Edit Format View Help
#Location
40 work
41 Home
42 Outside
43 Friends House
44 On The Road
45 Public Building
46 Physicians/Dentists/Therapists Office
48 House Of Family

#Physical Exertion
20 Light Physical Activity
21 Moderate Physical Activity
22 Heavy Physical Activity
23 Very Heavy Physical Activity
24 Sleep

#Posture
10 Lying
11 Sitting
12 Standing
13 walking
14 Lying/Sitting
15 Sitting/Standing
16 sitting/standing/walking
17 standing/walking
18 unknown

#Social Situation
50 Alone
51 with significant other
52 with own children
53 with Friends
54 with colleagues
55 with others
56 unknown

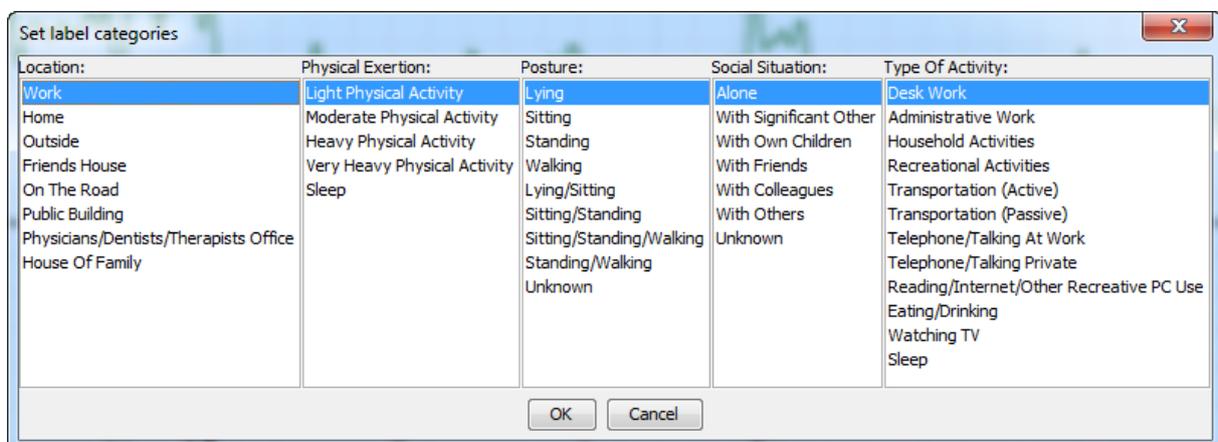
#Type of Activity
29 Desk work
30 Administrative work
31 Household Activities
32 Recreational Activities
33 Transportation (Active)
34 Transportation (Passive)
35 Telephone/Talking At work
36 Telephone/Talking Private
37 Reading/Internet/Other Recreative PC Use
38 Eating/Drinking
47 watching TV
39 Sleep
```

In the label configuration file all ambulatory activities you might want to use as separate conditions in future analyses should be present as all further processing in the DAMS program is tailored to the labels.

When you are done creating the ambulatory label configuration file you need to make sure that the DAMS program recognizes this file. To do this click the *Label Data* tab → *Actions* → *Edit Label Configuration* → *Import Label Configuration From File*. Now select the label configuration file you manually created and click *open*. When the same label configuration file is used for a longer time, like for an entire research project, you could click on the option *Set Label Configuration As Default*.

Now you can start the actual labeling of your data. Using the subjects' diary estimate the start and stop times of each activity. The motility signal can be extremely helpful to detect posture transitions and changes in physical activity which are the natural boundaries of changes in real life activities (e.g. when the subject reports "sitting desk work, walking to my car, driving home" three distinct motility patterns will be evident).

Use the top bar where it says "Click and Drag to add Labels" and click with the left mouse button in the top bar at the starting time and drag the mouse to the right until the desired end time of the label is reached. The popup window that appears after the label is drawn will reflect all categories in the label configuration file:

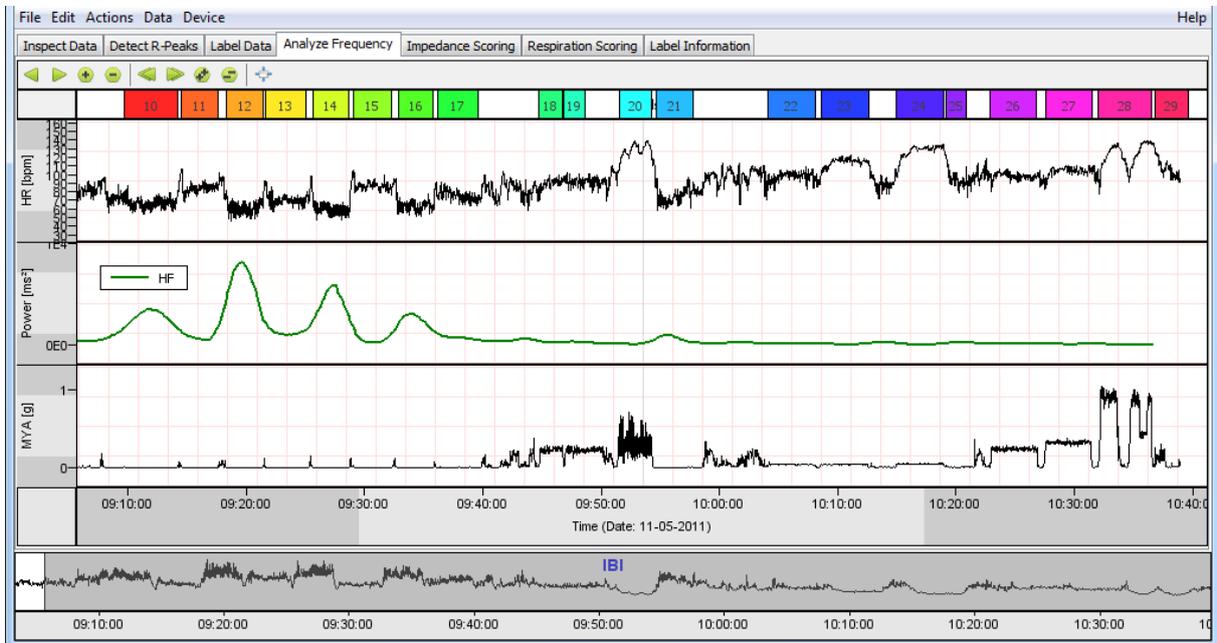


For each labeled period start and end times are given as well as a set of codes and text labels describing the state of subject during that period in terms of location, posture, physical exertion, social situation, type of activity etc..

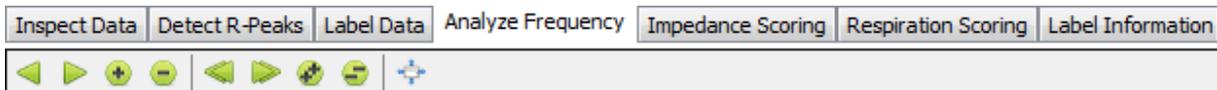
When done, make sure you have labeled all periods that might be considered of interest. There seems to be no urgent need to also label periods that you consider to be "irrelevant" or that are expected to occur in only a few subjects. However, we advise to always label the entire 24 hour recording as completely as possible. With

an average length of labeled periods of 20 minutes this would result in about 72 labels per subject.

2.4 Analyze Frequency



All actions for the *Analyze Frequency* tab are presented in the form of buttons:



Actions		Data	Device
Move Left ¼ Screen	Left		
Move Right ¼ Screen	Right		
Zoom In 2X	Up		
Zoom Out 2X	Down		
Move Left 1 Screen	Page Down		
Move Right 1 Screen	Page Up		
Zoom In 4X	NumPad +		
Zoom Out 4X	NumPad -		
Autoscale All	F5		

The function of these buttons should be self-explanatory.

2.4.1 Analyze Frequency explained

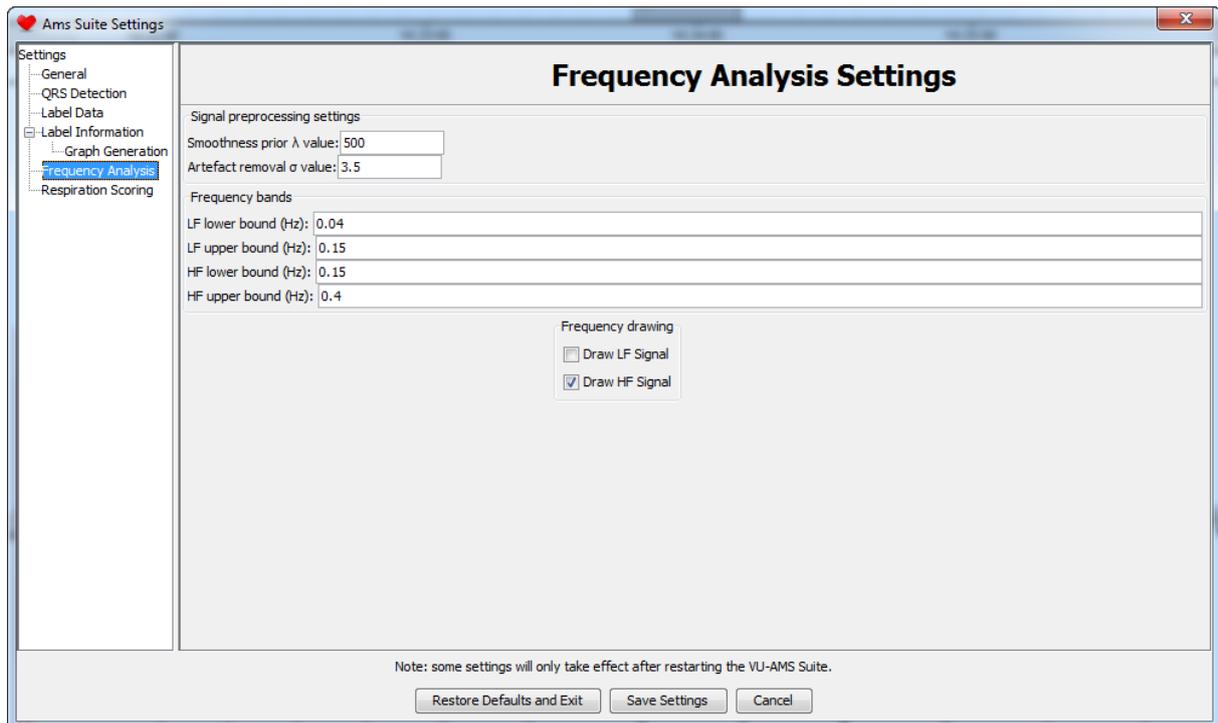
Spectral analysis in the Analyze Frequency tab is performed on the corrected IBI time series according to the following method:

The IBI time series within each label is interpolated with a cubic spline and the resulting function is resampled at 4 Hz. The resampled signal is split into overlapping periods of 256 seconds, each with 1024 data points. The overlap between two consecutive periods is 128 seconds. Periods that have intervals longer than 5 seconds without IBIs are discarded. Missing data from the final period are padded with zero's. Each period of 1024 data points is convoluted with a smoothness prior matrix ([see: An advanced detrending method with application to HRV analysis, Mika P. Tarvainen, Perttu O. Ranta-aho, and Pasi A. Karjalainen](#)) to yield a stationary signal on which a discrete Fourier analysis is performed after additional convolution with a quadratic window. Power values for each of the 1024 data points are then averaged across all available periods in the condition (Welch method). Next the total power in the 0.0001 Hz to 0.4 Hz range is computed (TP) as well as the power in the 0.04-0.15 Hz band (LF) and the 0.15-0.40 Hz band (HF).

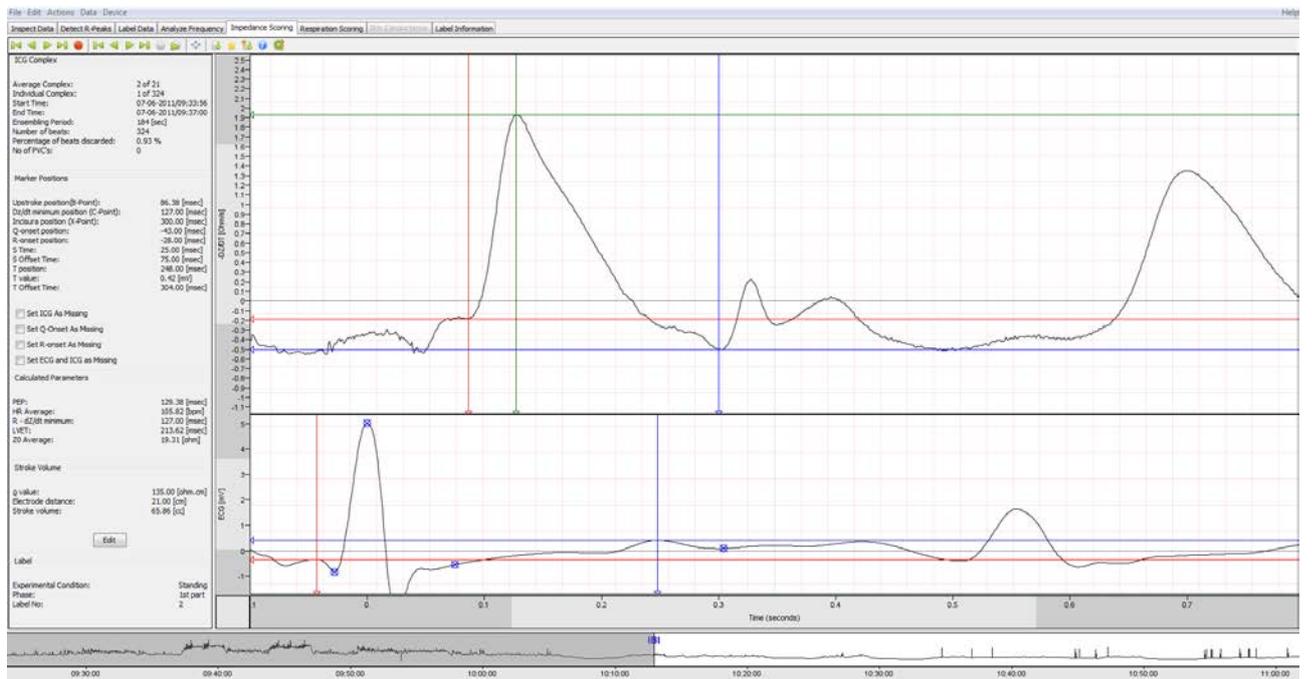
LF power is caused by blood pressure oscillations affecting both sympathetic and parasympathetic cardiac control. HF power is caused by the effects of respiration on vagal control. It is important to note that the IBI time series is first detrended and 'corrected' by interpolation to deal with too short and too long IBIs (e.g. in case of an extrasystolic beat) because slow trends as well as strongly deviant beats can distort the spectrum. Because at least 4 minutes are required to obtain a reliable estimate of the LF power, these values are not supplied for labels with a duration shorter than 4 minutes.

2.4.2 Change Settings

In case you want to change the default settings of the power spectral analysis select *Edit* → *Settings* → *Frequency Analysis*. Settings for preprocessing affect detrending and deviant beat removal ('artefact'). The frequency bands reflect the typical bands now commonly used in literature, but can be changed if desired. By default, only HF signal is drawn. When desired, LF can be as well by checking the designated box in settings.



2.5 Impedance Scoring



All actions for the *Impedance Scoring* tab are presented in the form of buttons:



Actions	Data	Device
First Average Complex		M
Previous Average Complex		Comma
Next Average Complex		Period
Last Average Complex		Slash
Show/Hide Raw Average Complex		Z
First Complex		Down
Previous Complex		Left
Next Complex		Right
Last Complex		Up
Show/Hide Individual Complexes		X
Start/stop looping individual complexes		L
Autoscale All		F5
Save current scoring		Ctrl+I
Show/Hide saved scorings		C
Restore saved scoring		Ctrl+R
Name Points		Ctrl+H
Apply Algorithm Scoring for all the complexes		Ctrl+D

The function of these buttons should be self-explanatory.

2.5.1 Impedance explained

The impedance cardiogram (ICG) is the first derivative of the change in thorax impedance using time as the basis (dZ/dt). This characteristic ICG waveform derives from the change in thorax impedance caused by left ventricular ejection of blood into the descending aorta during the systolic phase of the cardiac cycle. To improve signal quality, the ICG waveform is often obtained by ensemble averaging over beats within in a fixed time period, time locked to the R-wave peak. The typical period for ensemble averaging is one minute. In DAMS we deviate from this practice and instead compute a Large Scale Ensemble Average across the entire label ([see: Riese et al., 2004 for the rationale](#)).

The most important variables extracted from the ICG are the pre-ejection period (PEP) and the Stroke Volume. The PEP is an index of contractility which is only influenced by sympathetic but not parasympathetic activity in humans making PEP the measure of choice to monitor changes in cardiac sympathetic activity non-invasively. The PEP is defined as the interval from the onset of left ventricular depolarization, reflected by the Q-wave onset in the ECG, to the opening of the

aortic valves, reflected by the B-point in the ICG signal ([Nederend et al., 2017](#) ; [Lozano et al., 2007](#); [Sherwood et al., 1990](#); [Willemssen et al., 1996](#)).

Stroke volume (SV) is the average amount of blood ejected during the cardiac cycle. When multiplied by heart rate this yields the cardiac output (CO), the total amount of blood circulated through the body per minute. SV is computed from the ICG by using the product of the maximal amplitude of the dZ/dt and the ejection time, weighing for blood resistivity, baseline thorax impedance and the total volume enclosed by the measuring electrodes.

N.B.: The reliability of between-individual differences in Stroke Volume (SV) computed by impedance cardiography remains a heavily debated issue. With ambulatory SV the concerns are even more valid, because movement artefacts and the lack of a phonocardiogram do NOT increase SV reliability. In addition, spot electrodes pick up only half of the impedance measured by band electrodes, and without correction for this, the Kubicek formula yields supraphysiological SV's. If you use percentual changes in SV strictly in a within subject design all these concerns are greatly reduced.

2.5.2 Filtering the ICG signal

Because the ICG signal is highly susceptible to even subtle movement artefacts, it is necessary to filter the signal to overcome the noise confound and assure reliable detection of the inflection points in the ICG curve. The ICG signal is passed through a low pass filter with a cut-off frequency of 60 Hz. By default, this filter is set to "OFF" because that was its original setting and it is ill-advised to change the settings within a single project, i.e. having part of the signals scored with and part without filtering. The filter can be enabled by clicking *Edit* → *Settings* → *Expert Mode* and turn the filtering "ON". A text is displayed next to the ICG curve in the Impedance Tab indicating that the filtering is "ON".

2.5.3 Automatic detection

The DAMS program runs an automatic scoring algorithm, which tries to detect three specific locations in each ICG waveform (termed 'ICG complex') and one in the ECG:

B-point or upstroke, the opening of the aortic valves, marking the end of the electromechanical systole and the beginning of the left ventricular ejection time. The upstroke occurs somewhere in the middle of the first heart sound. An increase in heart rate is usually accompanied by a shift of the B-point to the left (increased sympathetic activation) and a decrease in heart rate by a shift of the B-point to the right (decreased sympathetic activation). However, heart rate may also change purely by changes in parasympathetic activation, in which case no shift in the B-point may be seen.

dZ/dt min or C-point, the point where the velocity of ejection is at its maximum and impedance at its minimum (in the graph, it is drawn in reverse polarity, so the dZ/dt minimum is shown as a maximum by the program).

X-point or incisura, the closing of the aortic valves, marking the end of left ventricular ejection time (LVET). The X-point corresponds well to the first high frequency component of the second heart sound. As the LVET is typically between $\frac{1}{3}$ (low heart rate) and $\frac{1}{2}$ (high heart rate) of the total cardiac cycle time, an increase in heart rate (shorter cardiac cycle) should be accompanied by a shift of the X-point to the left and a decrease in heart rate should be accompanied by a shift of the X-point to the right.

Q-wave onset in the ECG, marking the start of the ventricular depolarization. The Q wave represents depolarization of the interventricular septum. Q onset is scored using the crossing of the red lines in VU-DAMS (see below).

N.B.: In some subjects, no Q wave is visible. Check the "set Q-Onset as missing" box in the left panel. VU-DAMS will now estimate this point by subtracting 12 ms from the Q point.

R-onset in the ECG is scored using a blue point in VU-DAMS (see below).

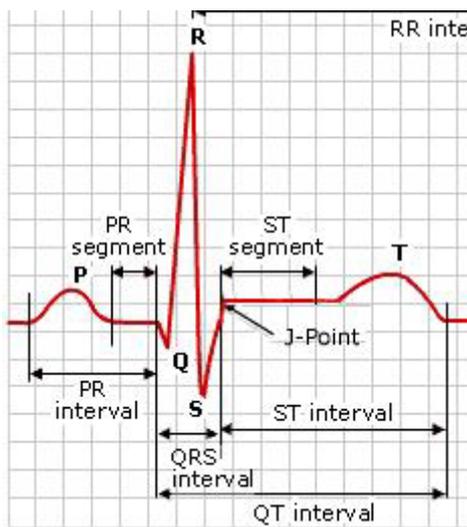
S-point in the ECG marks the lowest point in after the R peak and is scored using a blue point.

S-offset in the ECG marks the end of ventricular depolarization (S-offset is often called J point in literature).

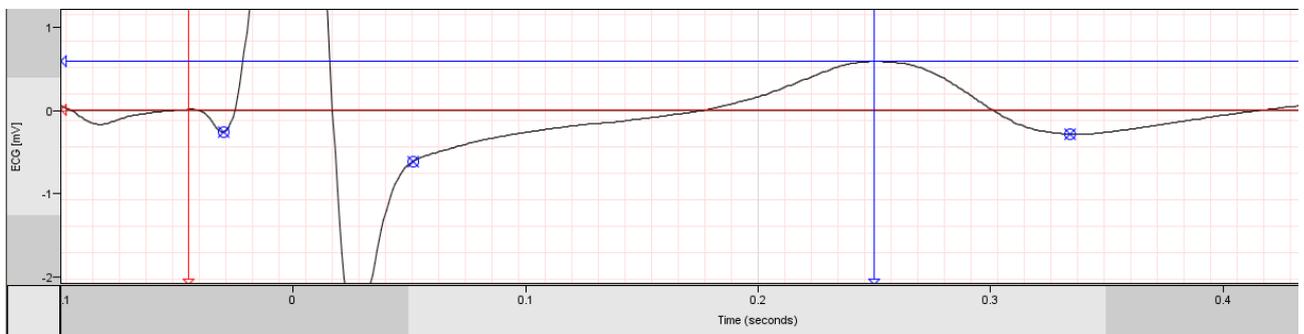
T-point in the ECG marks the maximal positive peak of the T-wave. The T-wave indicates the repolarization of the ventricles. T-wave is scored using the crossing of the blue lines in VU-DAMS (see below).

T-offset marks the end of ventricular repolarization and is scored using a blue point.

NOTE: VU-DAMS still expects 50mV p-p range, therefore ECG values should be divided by 3.6



ECG points and intervals



Points and lines as scored in VU-DAMS

N.B.: zooming in on the Y axis in the ECG is necessary in order to visualize and score the different points correctly.

2.5.4 Visual Inspection and manual correction

Ensemble averaging improves automated detection of the crucial landmarks in the ECG and in the ICG but even after ensemble averaging substantial errors in positioning of the B-point remain (Nederend et al., 2017 ; Lozano et al., 2007; Willemsen et al., 1996; Berntson et al., 2004). The number of algorithms proposed

to score the impedance cardiogram is countless. We have tried quite a few at the Vrije Universiteit. Our current stance is that automatic scoring simply will not work for all signals. We therefore visually inspect every ensemble averaged ICG complex and manually correct the locations of the 3 key time points when needed. Scoring of the Q-point in the ECG also always needs to be inspected and, when necessary, corrected. Manual scoring is inherently subjective but it does lead to reliable and valid results. To safeguard reliability, scoring should be ideally repeated by [multiple raters](#).

NOTE: Our automatic scoring algorithm is only applied to each ensemble average upon displaying it in the impedance scoring tab, an attempt to skip visual inspection and proceed immediately to data export will result in missing values for all ICG measures. We further recommend reading Sherwood et al.'s "[Methodological Guidelines for Impedance Cardiography](#)" published in Psychophysiology before starting with scoring and analyzing the impedance cardiogram.

After clicking on the *Impedance Scoring* tab the window is displayed as in the figure on the start of this paragraph. On the right side of the window there is a graphical representation of the current ICG complex. On the left side there is a text box with several frames:

ICG complex

ICG Complex	
Average Complex:	2 of 21
Individual Complex:	1 of 324
Start Time:	07-06-2011/09:33:56
End Time:	07-06-2011/09:37:00
Ensembling Period:	184 [sec]
Number of beats:	324
Percentage of beats discarded:	0.93 %
No of PVC's:	0

Average Complex: This is the number of the ensemble averaged ICG complex (the second one out of 21 is drawn in this example)

Individual Complex: This is the ICG complex of one valid single beat within the current label (in this example we are at the first beat out of 324 valid beats that are present in the second averaged complex). You can make the individual ICG

complexes (light grey line) visible in the back of the ensemble averaged complexes (black line) by toggling the button *Show/Hide Individual Complexes* in the menu bar. This is helpful when the B-point is not completely clear in the ensemble ICG. The individual complexes can sometimes give you a hint on where to score the B-point. You can even let DAMS play the individual complexes in the background of the ensemble averaged complex by toggling the button *Start/stop looping individual complexes*.

Start Time: Start time of the current ensemble averaged complex.

Stop Time: End time of the current ensemble averaged complex.

Ensembling Period: Duration of the label on which the ensemble average ICG complex was based (regardless of number of discarded beats within the label).

Number of beats: The number of valid beats within the label (this is the total amount of beats within the label minus the beats that were discarded by the artefact detector in the R-peak detection tab).

Percentage of beats discarded: The percentage of individual ICG complexes within the label that are discarded by the impedance scoring algorithm due to bad ICG signal quality. When this percentage is high it will turn red, which should caution the user to consider whether the ensemble average is representative enough of the interval, and whether the ICG should be scored or set to missing for this interval . With the button *Show/Hide Raw Averaged Complexes* you can show the original (raw) ensemble averaged signal (red line) that contains all beats within the label regardless of the quality of the ICG on top of the 'clean' ensemble averaged signal (black line) that contains only beats with high quality ICG complexes.

Marker positions

Marker Positions	
Upstroke position(B-Point):	44.00 [msec]
Dz/dt minimum position (C-Point):	128.00 [msec]
Incisura position (X-Point):	301.00 [msec]
Q-onset position:	-43.00 [msec]
R-onset position:	-28.00 [msec]
S Time:	25.00 [msec]
S Offset Time:	59.53 [msec]
T position:	248.00 [msec]
T value:	0.42 [mV]
T Offset Time:	304.00 [msec]

<input type="checkbox"/> Set ICG As Missing
<input type="checkbox"/> Set Q-Onset As Missing
<input type="checkbox"/> Set R-onset As Missing
<input type="checkbox"/> Set ECG and ICG as Missing

The distance from the ECG R-peak to all marker lines are given in the left panel under the heading 'marker positions':

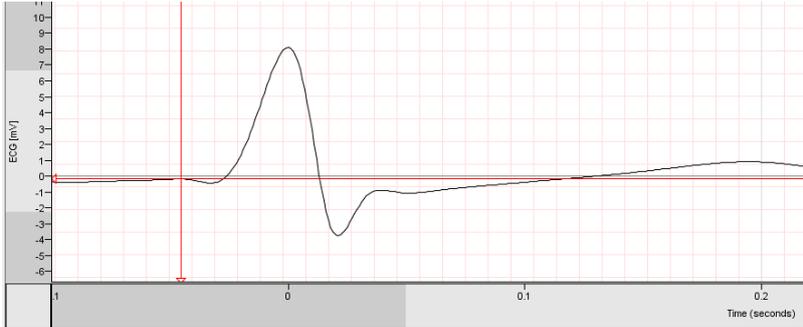
- *Upstroke position*: B-point, position of the dZ/dt upstroke relative to R-Peak in [msec]
- *dZ/dt minimum position*: C-point, Position of the dZ/dt minimum relative to the R-Peak in [msec]
- *Incisura position*: X-point, Position of the incisura relative to R-Peak in [msec]
- *Q-onset position*: Position of the Q-wave onset relative to R-peak in [msec]
- *R-onset position*: Position of the R-onset relative to R-peak in [msec]
- *T position*: Position of the T-wave relative to R-peak in [msec]
- *T-value*: Amplitude of the ECG signal at the T-wave peak
- *T-offset*: Position of the end of the T-wave relative to R-peak in [msec]

A number of options to set parts of the complex missing are given. Both ECG and ICG can be set to missing or just the ICG leaving the ECG intact for this ensemble average. Sometimes Q-onset and R-onset are scored badly, while the other ECG landmarks are still correct. In this case just the offending element (e.g. Q-onset) can be set to missing leaving the other landmarks in the ECG intact for this ensemble average.

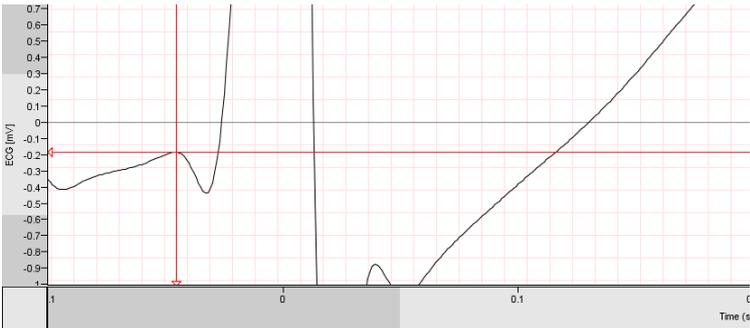
Constant QR vs. Q-point scoring

The ensemble averaged ECG allows for easy Q-point scoring. The Q-point might look obscured but will appear more clearly when zooming in on the Y-axis.

Normal:



Zoomed in on Y-axis:



Calculated Variables

PEP:	87.00 [msec]
HR Average:	105.82 [bpm]
R - dZ/dt minimum:	128.00 [msec]
LVET:	257.00 [msec]
Z0 Average:	19.31 [ohm]

A number of additional variables are computed based on values from the marker positions. The values of these variables reflect the mean across the label. For some variables the values are displayed in the ICG scoring screen:

PEP: Preejection Period (Q-B interval) in [msec].

HR Average: Average heart rate in beats per minute [bpm].

R - dZ/dt minimum: ECG R-peak to ICG C-point in [msec].

LVET: Left Ventricular ejection time (B-X interval) [msec].

Z0 Average: Average thorax impedance in [ohm] during current label.

For other variables values are only given in the *Label Information* tab and in the results files saved from this tab:

Stroke volume: The amount of blood ejected per beat in [cm³]. Calculated with the Kubicek equation:

$$SV = \frac{-\rho_{blood} L e^2 \left(\frac{dZ}{dt} \right)_{\min} t_{lve}}{Z_0^2}$$

, where $t_{lve} = t_{incisura} - t_{upstroke}$

NOTE: The Kubicek equation for SV was originally derived using band electrodes and a correction on the baseline thorax impedance (Z_0) is needed for spot electrodes. We refer to [Nederend et al., 2017](#) for the appropriate correction when using the VU-

AMS: $Z_0 = 7.337 - 6.208 * dZ/dt_{max}$, where dZ/dt_{max} is the amplitude of the ICG signal at the C-point.

Heather index: An alternative contractility measure in [ohm/sec²]. Calculated with the following formula:

$$HI = \frac{\left(\frac{dZ}{dt} \right)_{min}}{t_{R \rightarrow min}}$$

, where $t_{R \rightarrow min}$ is the time between the R-peak and (dZ/dt)_{min}.

Minute volume: The total amount of blood circulated through the body per minute, calculated as:

Stroke Volume * Heart Rate * 0,001 in [l/min]

Label

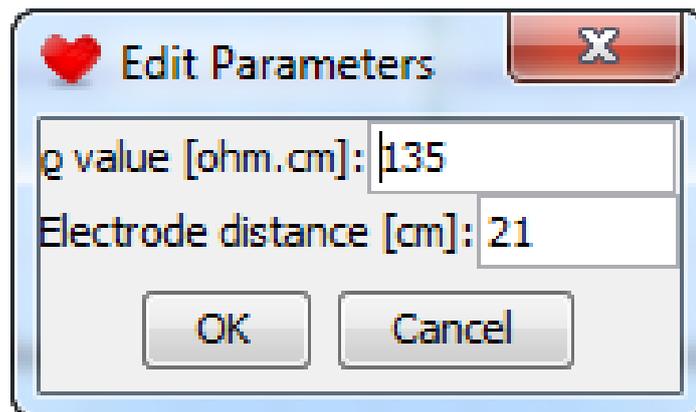
This simply shows the labeled period across which the current ICG complex was ensemble averaged.

Label	
Experimental_Condition:	Standing_1

2.5.5 Setting Stroke Volume parameters

Stroke Volume	
ρ value:	135.00 [ohm.cm]
Electrode distance:	21.00 [cm]
Stroke volume:	141.30 [cc]
<input type="button" value="Edit"/>	

There are two parameters that influence the calculation of the stroke volume: the distance between the measuring (yellow) ICG electrodes (L_e , we advise to provide this information when filling in the subject ID before you start a recording) and the specific blood resistance (ρ). These variables can be changed by clicking the 'Edit' command in the left panel. If hematocrit was not obtained, the standard value of 135 Ohm.cm can be used.



2.5.6 ICG Scoring principles

Below we give 6 scoring principles that can be used during visual inspection and manual correction of the dZ/dt signal. These principles are shown in order of importance:

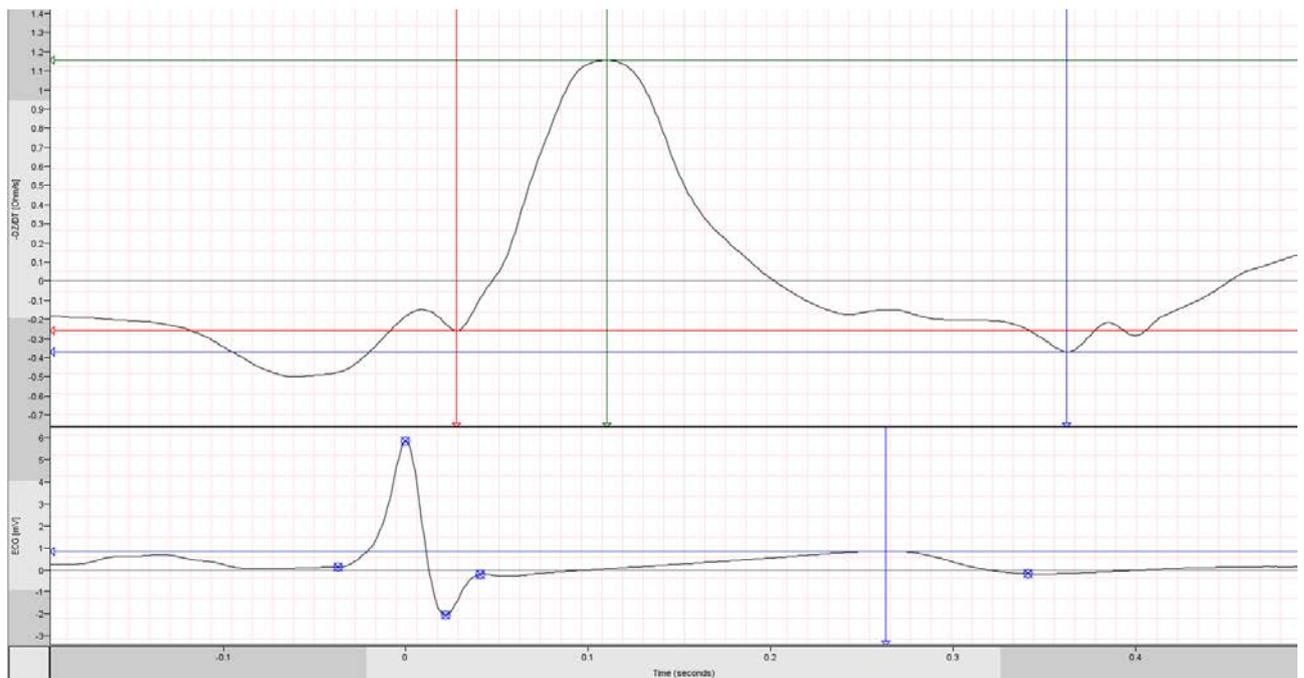
1 - morphology

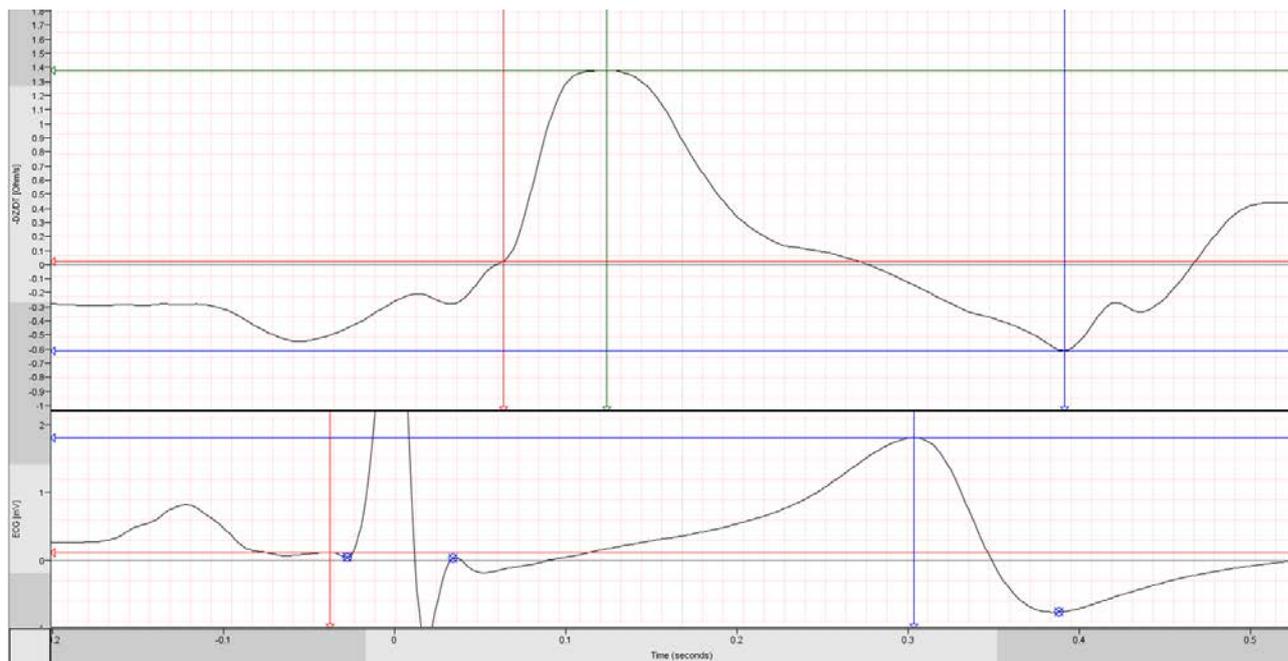
The B-point is in any case after the R peak, as blood outflow will not start before the ventricles are depolarized. It should be at a first or second order zero-crossing in the dZ/dt signal. It should be close to the $dZ/dt = 0$ line, and be the starting point of the longest uphill slope before the dZ/dt_{\min} point. However, rather than appearing as a clear incisura, the B-point may sometimes take the form of a subtle inflexion and may vary considerably from beat to beat. It is therefore very important to inspect the dZ/dt signal closely in order to identify it. Occasionally, there is simply no clearly identifiable point that can be chosen to fit the above description of the B-point. In that case the point of the $dZ/dt = 0$ crossing may be appropriate ([see also Sherwood et al., 1990](#)).

The dZ/dt_{\min} or C-point is normally visible as a clear peak in the window between the B- and the X-point. In some cases the dZ/dt signal shows a double peak, a bit like rabbit ears. If one of the peaks is clearly (40%) higher then this peak is chosen. If the peaks are of comparable magnitude, choose the first peak.

The X-point or incisura is always a local minimum after the dZ/dt_{\min} . Often it is the lowest point in the entire signal, but not necessarily. In the ideal situation it can be seen as a sharp trough in the ICG signal. This is the most clearly identifiable choice for the X-point. In any case, the X-point will never precede the T-wave peak. It may be that two or more troughs lie in close proximity without one being clearly the lowest point in all complexes. The latter part of the ICG waveform then looks like a "W". In this case choose the first trough.

Below we present some ICG morphologies that are often seen, including the scoring we advise.





2 - consistency

Whatever point you choose, choose that point consistently. If a "less-than-ideal" upstroke is present in all complexes, but an "ideal" upstroke is present in some, choose the less-than-ideal one in all complexes, even those featuring a more "ideal" upstroke. Before starting to score the ICG, try browsing through the entire ICG signal first. You can then decide which points can be most consistently identified, and this holds for both for the B-point and the X-point.

3 - in dubio abstine

You may have quite a lot of one-minute ensemble averages. Sometimes 2 out of the 5 ensembles are ugly, possibly because of arm movement artefacts. Don't try to make the best of these 2 if you feel pretty confident about the other 3 ensembles. The 3 good ones will give a good estimate of the ICG parameters during that particular period. Simply reject the other two. In general: when in doubt, reject the complex altogether.

4 - physiological plausibility

If you have doubts on whether the dZ/dt signal is correct, or should be rejected, you might use the following physiological guidelines as an indication of where the B- and X-point should be in an ideal situation. This is hazardous for at least two reasons: firstly, it stains the independency of the rating which should be based on

morphology only; secondly, large individual differences in physiology exist and the general rules may not always apply.

Adults:

HR: 40-60 → PEP: 100-140 → LVET 300-450
HR: 60-80 → PEP: 90-130 → LVET 250-400
HR: 80-100 → PEP: 80-120 → LVET 200-350
HR: 100-120 → PEP: 70-100 → LVET 200-300
HR: 120+ → PEP: < 80 → LVET 150-250
Children (1-18 years)
HR: 40-60 → PEP: 70-140 → LVET 275-375
HR: 60-80 → PEP: 60-125 → LVET 255-355
HR: 80-100 → PEP: 55-120 → LVET 220-320
HR: 100-120 → PEP: 45-105 → LVET 180-290
HR: 120-140 → PEP: 45-85 → LVET 155-272
HR: 140-160 → PEP: 45-80 → LVET 130-250

Again, if your signal shows B- and X-points outside of these ranges, this does not at all mean that your dZ/dt signals should be discarded. The above table is just a general rule of thumb.

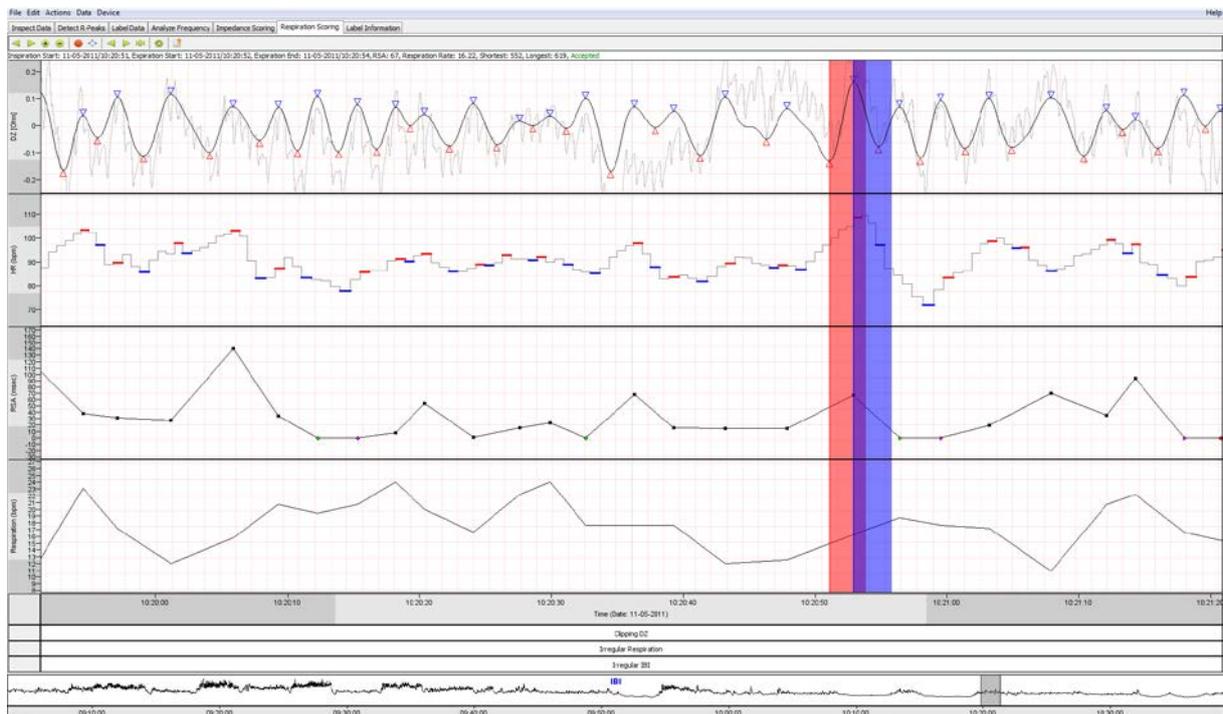
5 - multiple rater comparison

Reliability increases if two (or more) raters score the same data set independently. After interrater reliability is established, the various raters should ideally compare their deviant scoring to converge on a single solution, in view of the consistency principle. Mostly one will have picked a different B-point than the other(s). Averaging the B-point location is meaningless. Consensus has to be reached on the correct B-point location to satisfy the consistency criteria.

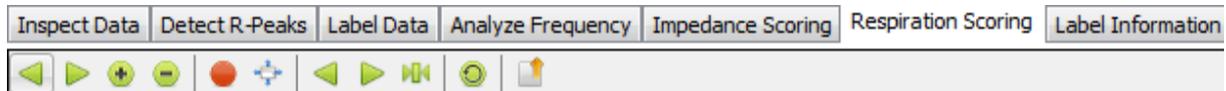
6 - keep score of the quality of your rating

Sometimes scoring is difficult and doubtful, at other times you feel pretty sure. After scoring you might want to generate three parameters for "scoring-quality". Make separate judgments for B-point scoring, X-point scoring and general signal quality on a scale from 0 (yuk!) to 10 (excellent!). Later on, during statistical analysis, request to see the mean of all parameters as a function of your quality rating.

2.6 Respiration / RSA scoring



All actions for the *Respiration Scoring* tab are presented in the form of buttons:



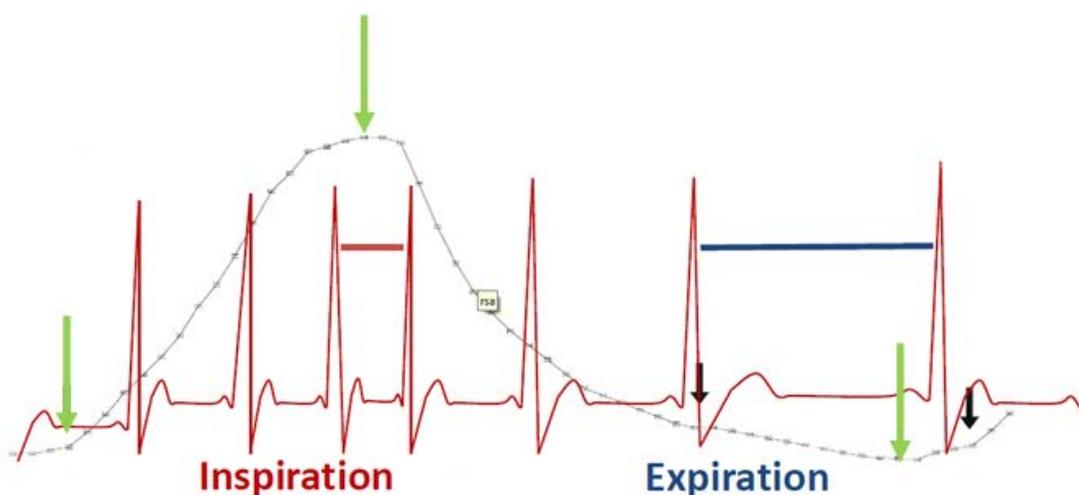
Actions	Data	Device
Move Left ¼ Screen		Left
Move Right ¼ Screen		Right
Zoom In 2X		Up
Zoom Out 2X		Down
Move Left 1 Screen		Page Down
Move Right 1 Screen		Page Up
Zoom In 4X		NumPad +
Zoom Out 4X		NumPad -
Show/Hide Artefact RSA/RR		H
Autoscale All		F5
Previous Respiration Cycle		Comma
Next Respiration Cycle		Period
Set Selected Respiration Cycle To Center Of Screen		M
Recalculate RSA		R
Export To RSR File		E

The function of these buttons should be self-explanatory.

2.6.1 RSA explained

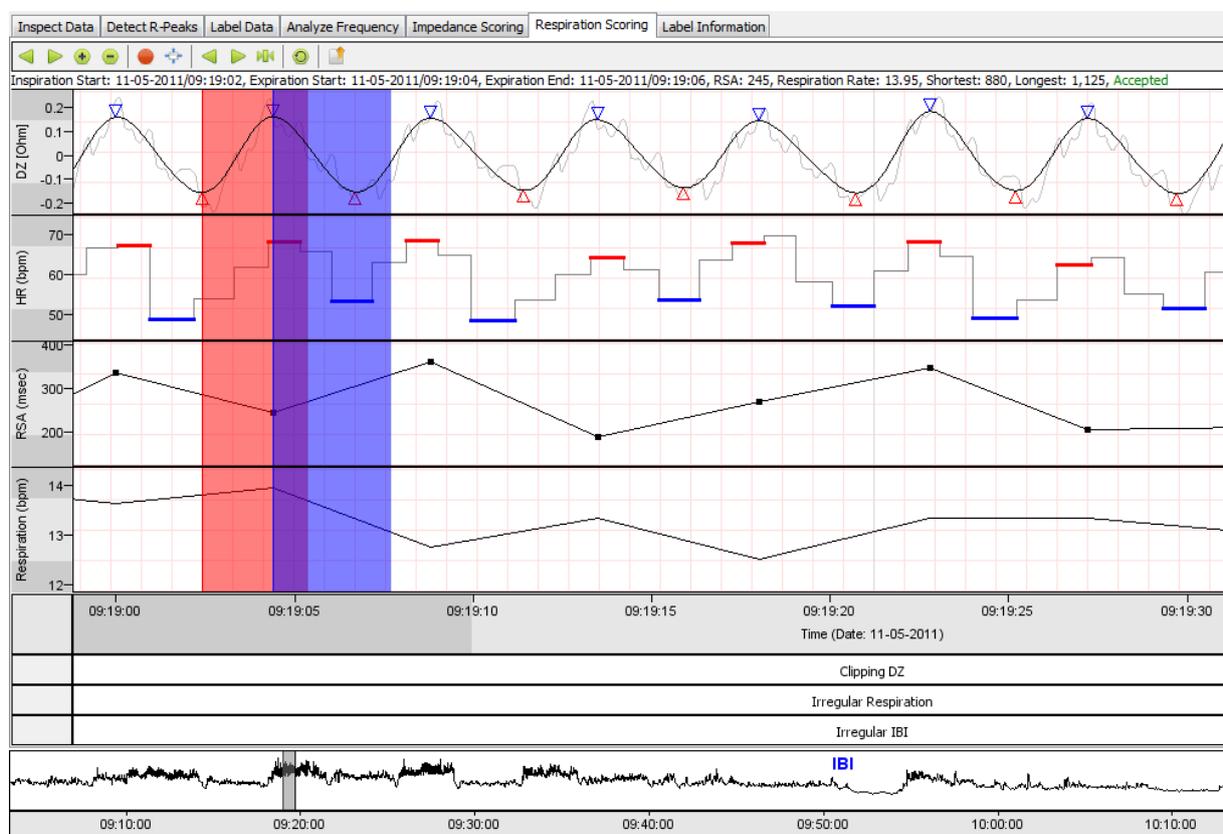
Respiratory Sinus Arrhythmia (RSA) scoring by the DAMS program is based on the peak-valley method ([Grossman, van Beek, & Wientjes, 1990](#) ; [de Geus et al., 1995](#)) that uses the IBI time series extracted from the ECG together with the respiration signal obtained from filtered (0.1 – 0.4 Hz) dZ signal to obtain heart period variability that is associated with respiration. This heart period variability is referred to as RSA. The DAMS program contains an automatic scoring algorithm for detecting the beginning and end of inspiratory and expiratory phases in each respiratory cycle. Inspiratory and expiratory phases include the inspiratory and expiratory pauses which are not detected separately.

For each respiratory cycle the total cycle time between begin of inspiration and end of expiration is extrapolated to a per-minute respiration rate (RR). In addition, RSA is computed per respiratory cycle from two IBIs: The shortest IBI during an interval starting at the begin of inspiration and ending 1000 msec (default) after the end of inspiration and the longest IBI during an interval starting at the beginning of expiration and ending 1000 msec (default) delay after the end of expiration. RSA is calculated by the subtraction of the shortest IBI from the longest IBI, provided that the shortest IBI (highest HR) is part of an accelerating series within the inspiratory interval and the longest IBI (lowest HR) of a decelerating series within the expiratory interval. This is illustrated in the figure below.



If either the decelerating longest or accelerating shortest IBI is missing for a breath cycle, or a negative RSA value is obtained on subtraction, we set RSA in these breaths as missing. Under the *Label Information* tab two different mean RSA variables are calculated: the mean RSA across all breaths in the label with a valid RSA only, and the “RSA-zero” in which the RSA value is set to be zero for breaths with an invalid RSA. The DAMS labels these variables in the results files as RSA and RSA0 respectively.

2.6.2 Visual inspection and manual correction

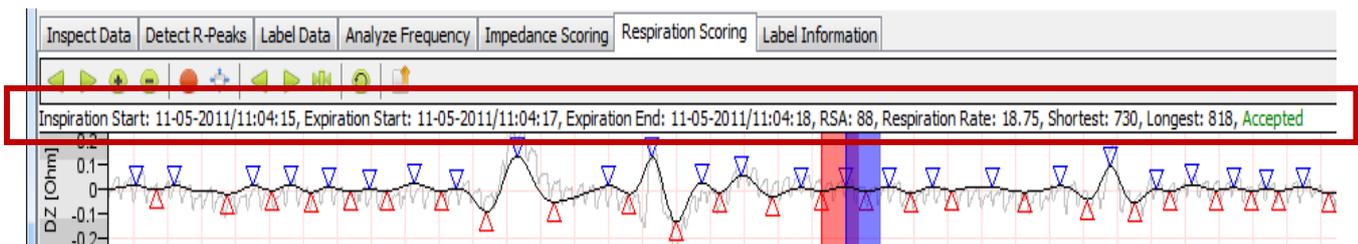


The windows of the *Respiration Scoring* tab shows 2 physiological and 2 derived signals for the time period indicated at the X-axis of the graph:

1. **The raw impedance signal (dZ in Ohm, grey) with the filtered impedance signal** representing respiratory thorax movement plotted on top of it. For each respiratory cycle, red triangles indicate the start of the inspiration and blue triangles mark the beginning of expiration. The currently selected respiratory cycle is indicated by the combination of a red, purple and blue box. The purple box reflects the overlap of the inspiration phase which is extended by a dZ-HR

shift (1000 msec) with the expiration phase. You can activate/de-activate the raw impedance signal in the settings screen. This is accessed from the main menu by selecting *Edit* → *Settings* → *Respiration Scoring*.

2. **CardioTachogram:** A beat-per-beat estimate for the Heart Rate (in beats/min, grey with red and blue marks). On this graph the highest heart rate (shortest IBI) during inspiration, provided that it is part of an accelerating IBI series, is indicated by a fat red mark. The lowest heart rate (longest IBI) during expiration, provided it was part of a decelerating IBI series, is indicated by a fat blue mark
3. **The time series of RSA values across the consecutive breaths** (in msec).
4. **Respiration Rate** (extrapolated from the respiratory cycle time) across the consecutive breaths (in breaths per minute).



When selecting a single breath you will see the following information per breath on top of the upper window: Inspiration start, expiration start, expiration end, RSA (in msec), respiration rate (in breath/pm), shortest IBI (highest heart rate) during inspiration on decelerating slope (msec), Longest IBI (lowest heart rate) during expiration on a accelerating slope (msec) and weather the breath is accepted or rejected. Rejection codes signal one of the following reasons why RSA was not accepted:

- RSA : -1 undetectable 'shortest IBI' (RSA graph: ●)
- RSA : -2 undetectable 'longest IBI' (RSA graph: ●)
- RSA : -3 both 'longest IBI' and 'shortest IBI' were undetectable (RSA graph: ●)
- RSA : -4 'longest IBI' is shorter than the 'shortest IBI' (RSA graph: ●)
- RSA : -5 'Irregular IBI detected' (RSA graph:)
- RSA : -6 'Irregular respiration rate' (RSA graph:)
- RSA : -7 'Clipping dZ' (RSA graph:)

Fortunately, automatic scoring of the respiration signal works quite well in most subjects. Mostly, it will suffice to just load the *.amsdata* file into DAMS and browse through the signal after having set the time axis at a low temporal resolution (e.g. ten minutes per screen). While browsing through the respiration signal from the beginning to the end of the file check the following:

- Did the program mark more than 1/10 of the recording as artefact in either the “clipping dZ”, “Irregular respiration” or “Irregular IBI” bars (pink, blue and yellow markers respectively) at the bottom of the screen? If so, the parameters of the scoring algorithm may need to be changed (see below). When measuring (small) children, you might need to change some settings for respiration. When respiration signal looks good when zooming in but the program deletes a lot, try unchecking “impedance range check” via *Edit* → *Settings* → *Respiration Scoring*. Also, because of the higher heart rate in young children, you might benefit from changing settings for lag time as well. Change phase shift for shortest/longest IBI down.
- Do all inspirations and expirations appear to be appropriately scored in the upper respiration signal (indicated by blue and red triangles)? If erroneous breaths are scored did the program mark them as artefacts in the bar at the bottom of the screen labeled “Irregular respiration”? If this is not the case you can manually delete a fragment of the signal by clicking and dragging the mouse in this window. NOTE: Pay special attention to the breath cycles measured during the night. Some subjects show strong abdominal breathing which seriously affects detection of the respiration signal by thorax impedance. This can often be repaired by ‘rescoring the cycles’ (under the main menu item *Edit* → *Settings* → *Respiration Scoring*) and changing the ‘Relative Threshold’ parameter of the scoring algorithm (see below).
- Check whether the program has rejected all deviant IBIs (spikes) without removing IBIs that reflect large but true heart rate variability. The difference between a spike and a truly high heart rate variability is rapidly gleaned from the shape of the tachocardiogram. If there is a staircase pattern rather than a sudden single-beat change, the subject may have a generally high heart rate variability which can be verified in the RSA window (e.g. RSA > 200 msec). If there is a sudden single-beat drop or jump then there is a spike. Spikes often represent extrasystolic beats or very delayed beats (which often occur jointly). Note that these beats do not represent an error in judgment of the R-wave detection algorithm (which should have been dealt

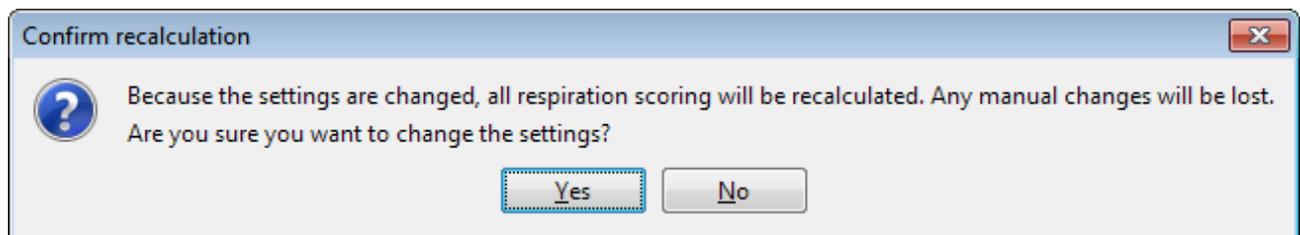
with earlier during R-peak detection and correction). They do result in IBIs that are twice the length or half the length of most of the other IBIs. This can inflate the RSA value for the breaths in which they occur very strongly, and it is advised to remove these. Hence, make sure all spikes are marked as artefacts in the bar at the bottom of the screen labeled “Irregular IBI”? If this is not the case you can manually delete a fragment of the signal by clicking and dragging the mouse in this window.

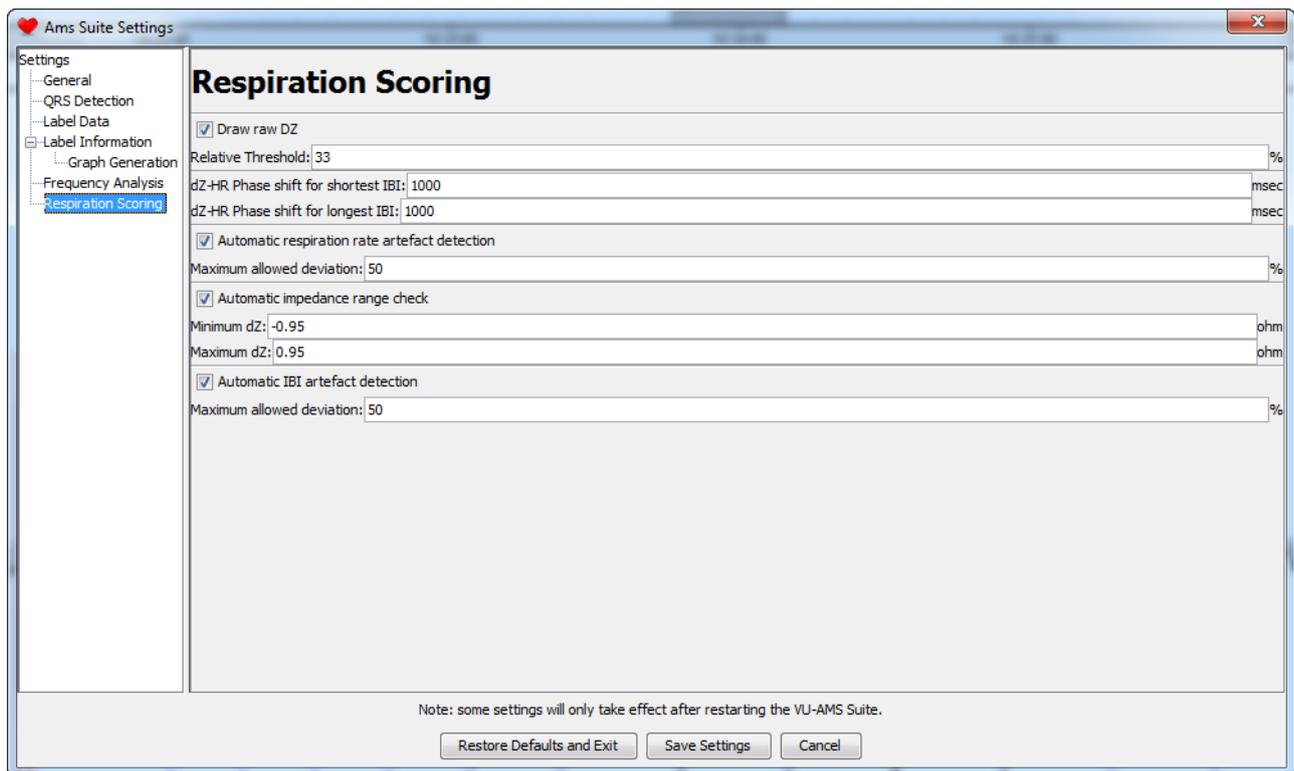
- Finally, check whether the per breath estimate of the respiration rate (in the Respiration window) takes on expected values between 7-14 at night, 12-22 across most daily activities except moderate to high physical activity where respiration rate can increase to 30 breath per minute.

2.6.3 Adjustment in respiration and RSA scoring

The DAMS program filters the raw thorax impedance change (dZ) signal to obtain the respiration signal and then detects the beginning and the end of inspiration and expiration in the entire registration using both amplitude and frequency modulation. The RSA scoring algorithm first uses three artefact detection algorithms: it will check for dZ clipping, irregular respiration rates (based on a maximal percentage for deviation of the duration of consecutive breaths) and irregular IBIs (based on a maximal percentage for deviation of the duration of consecutive beats). Parameters governing these artefact detections can be modified in the main menu by selecting *Edit* → *Settings* → *Respiration scoring*.

NOTE CAREFULLY: After changing the settings, the respiration signal and RSA are recalculated on the original signal. This means that manually rejected fragments will be restored, so first make sure you have chosen the optimal settings before manually rejecting fragments of the recording. It will warn you before recalculation.





Relative threshold [0...1] : 0.33 (default)

Purpose: The purpose of this parameter is to alter the sensitivity for the detection of breaths. A breath is defined by two zero crossings (a peak and a valley) in the first derivative of the filtered impedance signal that are separated by a minimum amplitude. The *Respiration Scoring* tab calculates a running average over the 20 seconds preceding the current selected breath cycle of the difference in amplitude at peaks and valleys in the dZ signal. The relative threshold defines the percentage of this average that is used as the minimum amplitude for the ‘tidal volume’ in a respiratory cycle.

Adjustment: A higher threshold decreases the sensitivity (less of the consecutive peak-valley pairs in the filtered impedance will be counted as true breaths – use when too many small wobbles are counted as breaths), and a lower threshold value increases the sensitivity for amplitude differences (more of the consecutive peak/valley pairs will be counted as true breaths – use when the amplitude of the actual breaths becomes low, for instance in nighttime belly breathing).

dZ-HR Phase shift (in msec) :1000 (default)

Purpose: This defines the delay added to the inspiratory and expiratory phases in which the *Respiration Scoring* tab is allowed to search in the IBI series for a shortest

IBI in inspiration or longest IBI in expiration, respectively. Increasing the dZ-HR Phase shift can increase the number of valid RSA values in subjects with low respiration rates whereas at high respiration rates, the default 1000 msec interval may lead to erroneously used IBIs from the next respiratory cycle.

Adjustment: Increasing the phase-shift increases the time-delay.

Automatic respiration rate artefact detection : is “on” when ticked

Purpose: The purpose of this option is to automatically reject breaths with an unusually small or unusually high respiration rate as compared to the running average of the 20 preceding breaths. For participants with irregular breathing, the maximum allowed deviation might need to be increased in order to prevent false rejects.

Adjustment: The ‘maximum allowed deviation’ (default 50%) enables the scorer to specify how much the respiration rate of a breath needs to deviate from the running average in order to be excluded by the automatic scoring program. Increasing the percentage means allowing for larger deviations from the running average.

Automatic impedance range check

Purpose: The purpose of this option is to automatically reject clipping (i.e. where the raw respiration signal turns into a flat line at $dZ = 1$ ohm or $dZ = -1$ ohm).

Adjustment: Although the default values generally seem to work well, some recordings may require an automatic impedance range check that is a fraction more or a fraction less strict.

Automatic IBI artefact detection

Purpose: The purpose of this option is to automatically reject spikes in the IBI time series, that represent extrasystolic beats or very prolonged beats. Note that these beats do not represent an error in R-peak placement by the DAMS program (which should have been dealt with earlier during manual inspection and correction). They do result in IBIs that are twice the length or half the length of most of the other IBIs. This inflates the RSA value for the breaths in which they occur very strongly. When the irregular IBI check is ‘on’ these beats are removed from the set of IBIs that are considered when selecting the shortest IBI and longest IBI to compute the RSA.

Adjustment: The allowed magnitude of the difference between consecutive IBIs can be adjusted by changing the ‘maximum allowed deviation’ (default 50%).

2.6.4 Exporting raw breath to breath data

You have the option to export breath to breath results to a tab delimited text output file using the button “Export To RSR File”. These *.rsr* files give the following information on each respiratory cycle on a single line:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1105016	16	11-05-2011	09:04:13	1800	1800	754	755	16.67	1	768.5	-34.16	114.64	148.81	A	10
1105016	17	11-05-2011	09:04:16	1700	1200	748	-1	20.69	-2	751.67	-99.87	-1.6	98.27	A	10
1105016	18	11-05-2011	09:04:19	2000	3200	716	812	11.54	96	742.17	-35.45	149.61	185.06	A	10
1105016	19	11-05-2011	09:04:24	1900	1200	695	-1	19.35	-2	737.33	-137.62	56.78	194.4	A	10
1105016	20	11-05-2011	09:04:27	2600	1900	683	748	13.33	65	717.2	19.24	74.63	55.39	A	10

column 1 : Subject ID

column 2 : Respiratory cycle number

column 3 : Date (dd-mm-yy)

column 4 : Start of respiratory cycle (hh:mm:ss)

column 5 : Inspiration time [msec]

column 6 : Expiration time [msec]

column 7 : Shortest accelerating IBI in inspiration [msec]

column 8 : Longest decelerating IBI in expiration [msec]

column 9: RR [breath per min]

column 10: RSA [msec]

column 11: Mean IBI across the cycle [msec]

column 12: Amplitude dZ at start inspiration [milliOhm/sec]

column 13: Amplitude dZ at start expiration [milliOhm/sec]

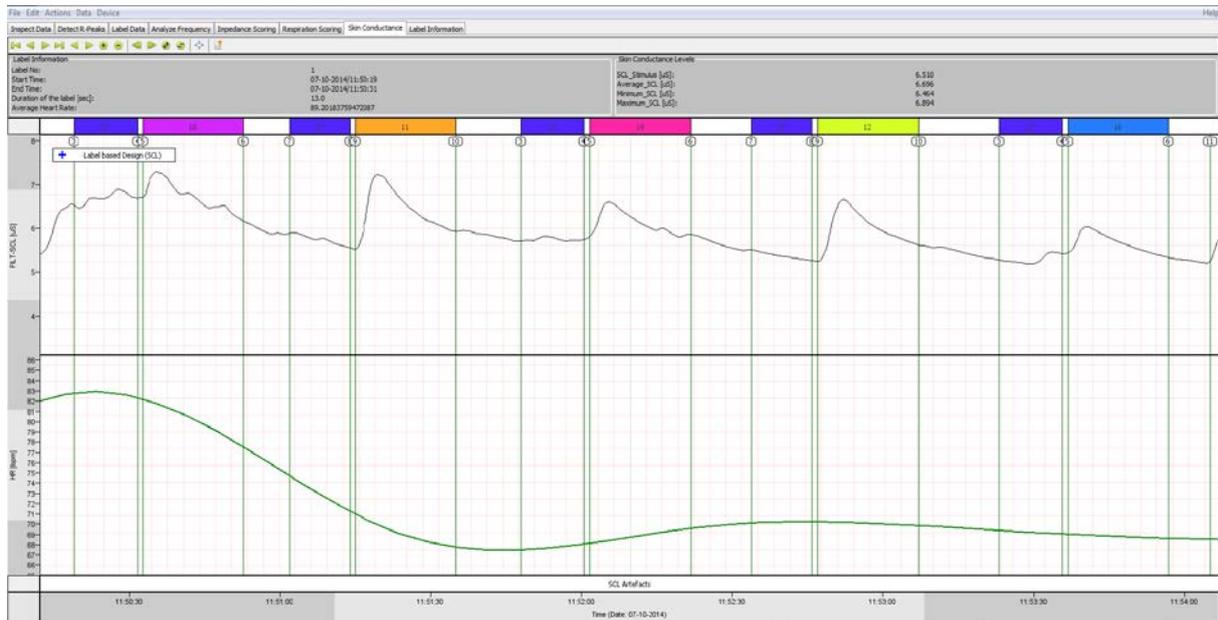
column 14: Tidal volume [milliOhm/sec] - calibration is needed to translate this to ml

column 15: Rejected (R) as artefact or accepted (A)

column 16+: Labels (-9999 = not available)

You can import this text file in e.g. SPSS for more fine grained analyses that use breath-to-breath information rather than the averaged values per label that are typically produced under the *Label information* tab. Please note that amplitude is in milliOhms/sec and needs calibration before volumes have physiological meaning. Careful outlier detection is needed before you do further statistical analysis on these breath-to-breath data. In view of the huge number of breath cycles to be quality controlled in 24-hour ambulatory monitoring, some automation of these checks is desirable, for instance by scripting in MATLAB, R or even SPSS.

2.7 Skin Conductance Tab

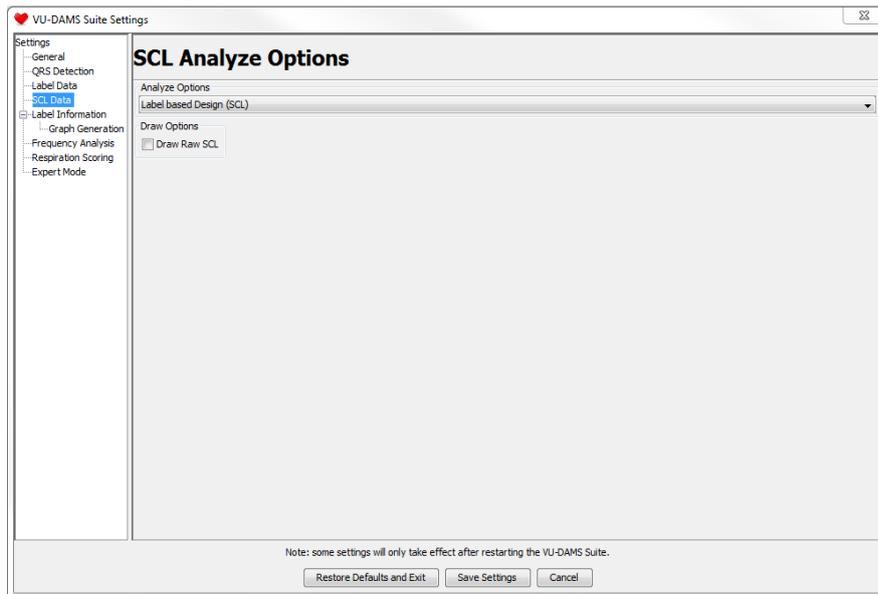


NOTE: While skin conductance recording on the VU-AMS is reliable and fully supported, the analysis options for electrodermal activity in VU-DAMS are still in beta. For anything other than visual inspection of the data it is currently recommended to export your raw SCL signal to ASCII and process it in an external package.

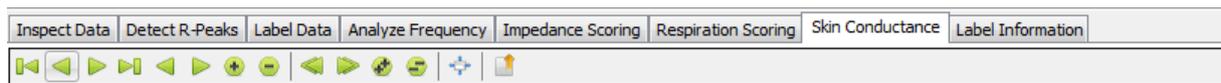
Change Settings

Depending on the type of experiment conducted, the skin conductance analysis method can be chosen from the main menu by clicking *Edit* → *Settings* → *SCL Data* → *Analyze Options*. The default setting for the analyzing method is the Label based Design (SCL);

When analyzing ambulatory recordings of several hours in length, it is recommended to turn on the “Draw Raw SCL” option. This will display the unfiltered signal and is currently the only method to display more than an hour of data at the same time.

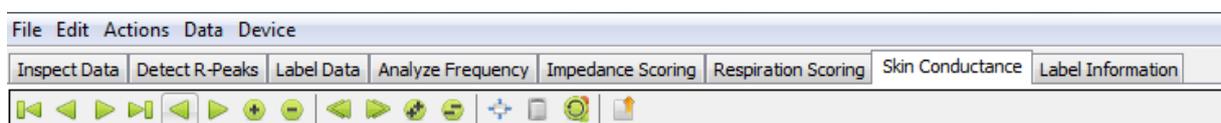


All actions for *the Skin Conductance* tab for **Label Based Design (SCL)** are presented in the form of buttons:



Actions	Data	Device
First Label		M
Previous Label		Comma
Next Label		Period
Last Label		Slash
Move Left ¼ Screen		Left
Move Right ¼ Screen		Right
Zoom In 2X		Up
Zoom Out 2X		Down
Move Left 1 Screen		Page Down
Move Right 1 Screen		Page Up
Zoom In 4X		NumPad +
Zoom Out 4X		NumPad -
Autoscale All		F5
Export SCLData To Text File		Ctrl+E

Likewise all actions for the *Skin Conductance* tab for **Event Based Design (SCR)** are presented in the form of buttons:



Actions	Data	Device
First Event		M
Previous Event		Comma
Next Event		Period
Last Event		Slash
Move Left ¼ Screen		Left
Move Right ¼ Screen		Right
Zoom In 2X		Up
Zoom Out 2X		Down
Move Left 1 Screen		Page Down
Move Right 1 Screen		Page Up
Zoom In 4X		NumPad +
Zoom Out 4X		NumPad -
Autoscale All		F5
Delete SCL Cycles Under Artefacts		Ctrl+D
ReCalculate SCL Cycles		Ctrl+A
Export SCLData To Text File		Ctrl+E

2.7.1 Skin Conductance Explained

Skin Conductance Level (SCL) is a measure of the electrodermal activity of the skin regulated by the sweat glands of the body. SCL can be used as an indication of psychological or physiological arousal since sweat glands are only innervated by the sympathetic nervous system.

The SCL signal is measured using direct current (DC) utilizing a 16 bit A/D converter. The sampling rate is 10 Hz with a signal range of 0-95 micro Siemens (μS).

2.7.2 Signal Pre-processing

The SCL signal is pre-processed to remove the noise and power line interference (if any) in the signal. A low pass filter with cut-off frequency of 2 Hz is used to filter the signal. In order to avoid shifting of peaks, filtering is done both in forward and reverse directions.

2.7.3 Detecting Artefacts

Automatic Artefact Detection

In the SCL Artefacts bar, clipping of SCL is automatically detected and marked as an artefact. These artefacts are labeled by a red bar.

User Supplied Artefacts

Manual selection of bad skin conductance signal and marking it as an artefact can be done by placing a label in the artefact bar (currently only available in event based design mode).

2.7.4 Skin Conductance Analysis

Skin conductance measurement can be characterized into two types namely tonic and phasic components.

Tonic Component: Tonic skin conductance is considered as the level of skin conductance obtained over longer periods of minutes to hours. It is a slow changing signal and it is often referred as Skin Conductance Level (SCL). It is important to note that SCL does not exclusively measure the person's arousal state. It is very sensitive to the environmental temperature and can change over time due to changes in the skin-electrode interface.

Phasic Component: Phasic skin conductance are considered as short term events and they are usually accompanied by rapid change in skin conductance, commonly called as 'Skin Conductance Responses (SCRs)'. These changes occur:

- in the presence of discrete external stimuli which can be sound, cognitive processes, decision making, shock, etc.
- spontaneously, without a clear relation to discrete external stimuli, and are then called non-specific SCR's (ns-SCRs).

Skin conductance analysis is performed based on the design of the experiment. The experiments can be broadly divided into two categories namely Event based Design and Label based Design.

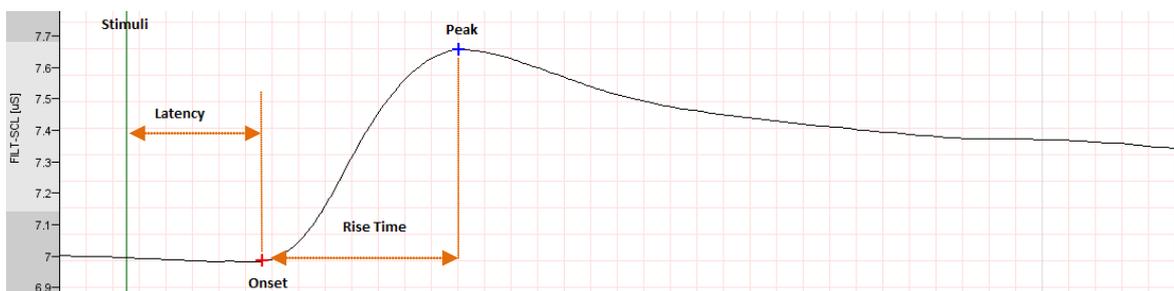
2.7.5 Event based Design – Capturing SCR's

Event based design are experiments looking at shorter time periods and are interested in phasic change in skin conductance. Instead of measuring the skin conductance level (SCL) over a period, these experiments focus on the short modulations in the signal followed by a peak. This individual peak representing a discrete stimuli is called Skin Conductance Response (SCR). Some of the examples of event-based design experiments are risky decision-making, providing feedbacks after each answer, stressful tasks, etc.

An experiment can be classified as "Event Based Design" when the events are clearly defined by discrete stimuli which may evoke an individual skin conductance response. These responses usually lasts for few seconds and they follow a specific pattern of Steep Rise- Sharp Peak – Slower return to Baseline. There are two main aspects taken into account while designing event based experiments:

- Clear events
- Sufficient Inter- Event time

The inter-event time should be sufficient enough to make sure that the skin conductance is back to baseline before the start of a new event. In general, the onset might be noticed within 4 seconds upon application of a stimulus. The skin conductance response (SCR) can take 4-6 seconds to complete. So, the inter-event time assumed while designing these type of experiments is at least 8 seconds.



The immediate first peak occurring after the specific stimuli is the point of interest. In these experiments, it is uncommon to see second or late responses due to habituation. This is because of sufficient inter-event time between the events. The following information can be derived from the skin conductance signal.

Event Information		Event based Skin Conductance Response	
No:	7 of 34	SCR:	true
Event Time:	07-10-2014/11:50:32.751	Onset_Time:	07-10-2014/11:50:32.751
Event Code:	5	SCL_Onset [uS]:	6.726
Heart Rate:	90	Latency [sec]:	0.000
SCL_EventTime [uS]:	6.726	Peak_Time:	07-10-2014/11:50:35.151
Baseline_SCL [uS]:	6.707	SCL_Peak [uS]:	7.294
		Rise_Time [sec]:	2.400
		Rise_SCL [uS]:	0.588

Calculated Parameters:

1. Baseline_SCL [uS] – is the average SCL in a window of 1 sec before the stimulus.
2. SCL_EventTime [uS] – is the SCL measured when stimulus is applied.
3. Onset_Time (SCR). – is the start time of a skin conductance response
4. SCL_Onset [uS] – is the skin conductance value measured at onset time.

5. Latency [sec] – is the time between the stimulus time and the onset time. It is usually between 1-4 seconds.
6. Peak_Time – is the time at which a max SCR is recorded within 7 seconds upon application of stimulus.
7. SCR_Peak [uS] – is the maximum SCR measured after a stimulus.
8. Rise time [sec] – is the time between the onset time and the time at which a peak is found. It is usually between 2- 4 seconds.
9. Rise_SCL [uS] – is the amplitude difference between the SCL baseline and the SCL measured at peak.

2.7.6 Label Based Design – Capturing Baseline SCL

Label based design are experiments looking at longer time intervals and are interested in measuring overall skin conductance level (SCL) over a period instead of looking at individual elevated peaks if present. In other words, these experiments may or may not be directly linked to a stimulus. The SCL measured is an indication of the general level of arousal. Some of the examples for Label based design experiments are listening to music, reading instructions, questions without feedback, etc.

Calculated Parameters:

1. Baseline SCL – The baseline skin conductance level is the electrical conductivity of the skin measured before presenting any task, more likely to be in the instruction phase.
2. Average SCL over a label – An average is taken over all the skin conductance levels measured during the task phase of the experiment.
3. Rise in SCL – Average SCL Over a label – Baseline SCL
4. Maximum SCL over a label – This is the maximum SCL reached during the task phase of the experiment.
5. Minimum SCL over a label – This is the minimum SCL value during the task phase of the experiment.

2.7.7 Export SCL data to a text file

You have the option to export SCL data (label based or marker based) results to a tab delimited text output file using the button “Export SCL Data to text file”. These

.scl files give the following information on each SCL cycle. The output columns of the marker based .scl file is given below:

```

Skin Conductance Response Per Event
C43_SCR.scl 07-01-2015/09:19:53 07-01-2015/12:01:02
No Event date/time EventCode HeartRate SCL_EventTime[uS] Baseline_SCL[uS] SCR_Present Onset_Time SCL_Onset[uS] Latency[sec] Peak_Time SCL_Peak[uS] Rise_Time[sec] Rise_SCL[uS]

```

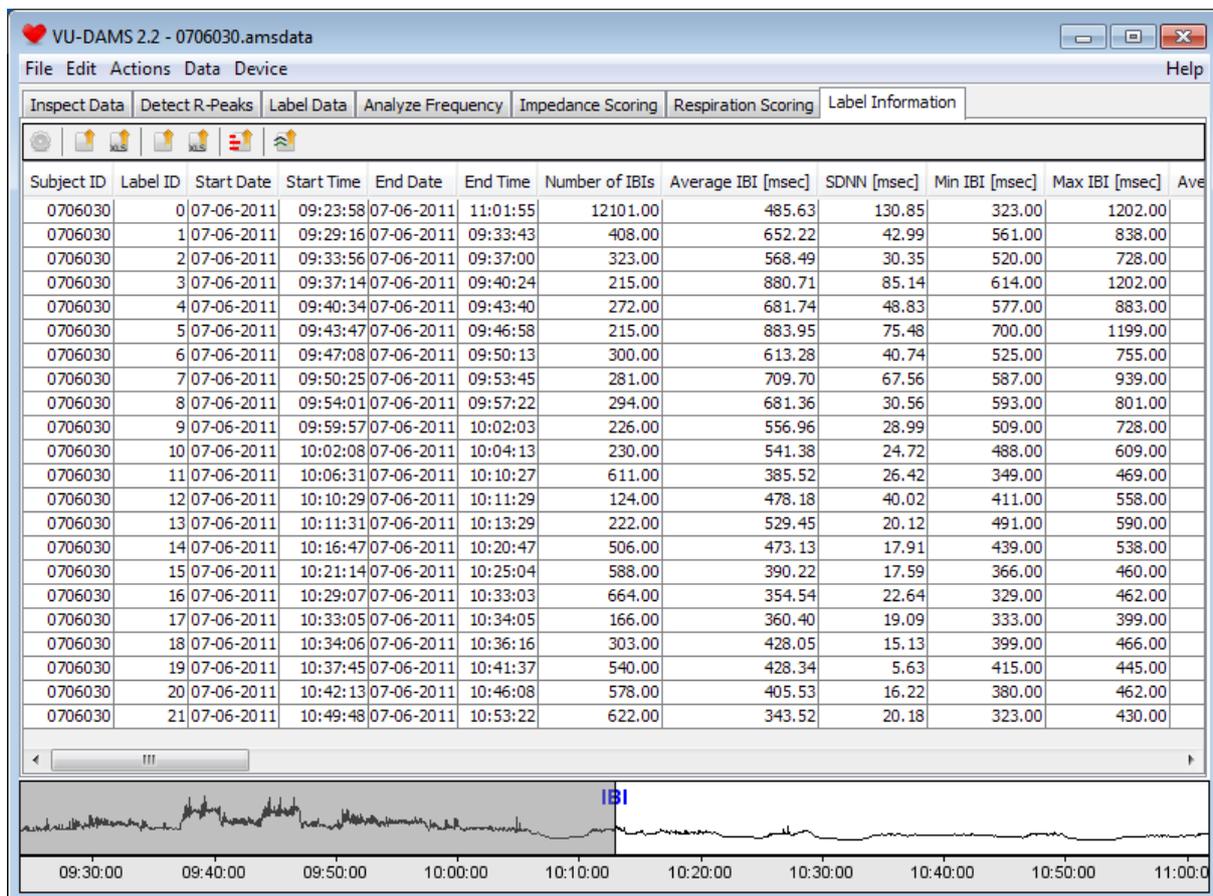
The output columns of the label based .scl file is given below:

```

Skin Conductance Response Per Label
C43_SCR.scl 07-01-2015/09:19:53 07-01-2015/12:01:02
Begin date/time End date/time Labelcode Label_Duration Average_HR SCL_LabelStart Average_SCL MinumumSCL MaximumSCL

```

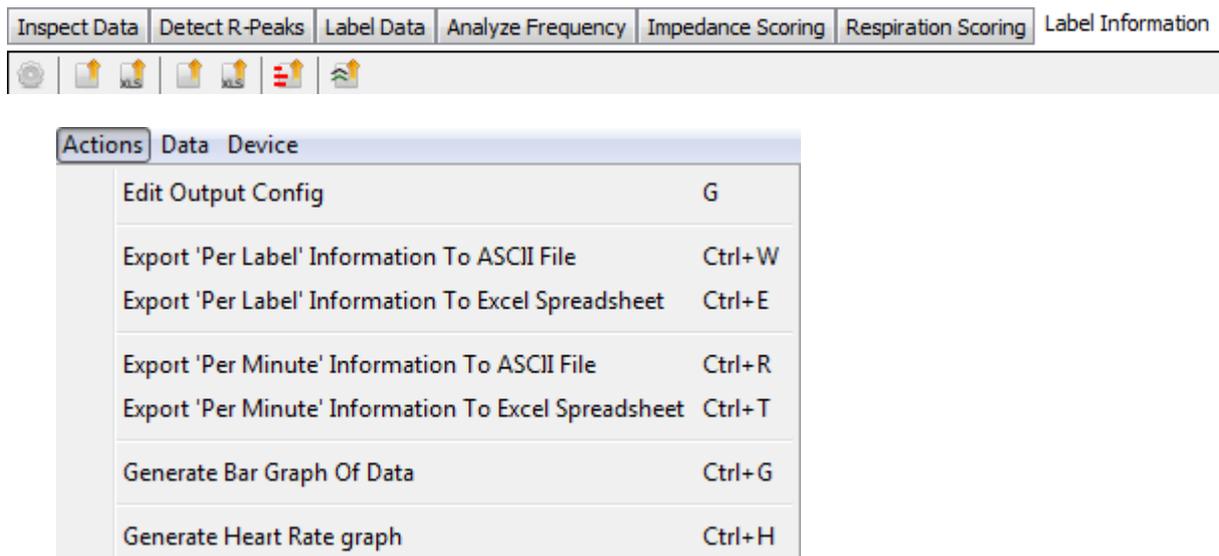
2.8 Label Information/ Exporting results



After clicking on the *Label Information* tab wait until all cells are finished calculating. The first column in the *Label Information* tab is the subject name, which is the ID that we gave when programming the device for recording. Each row represents a single labeled experimental/ambulatory condition and each consecutive labeled

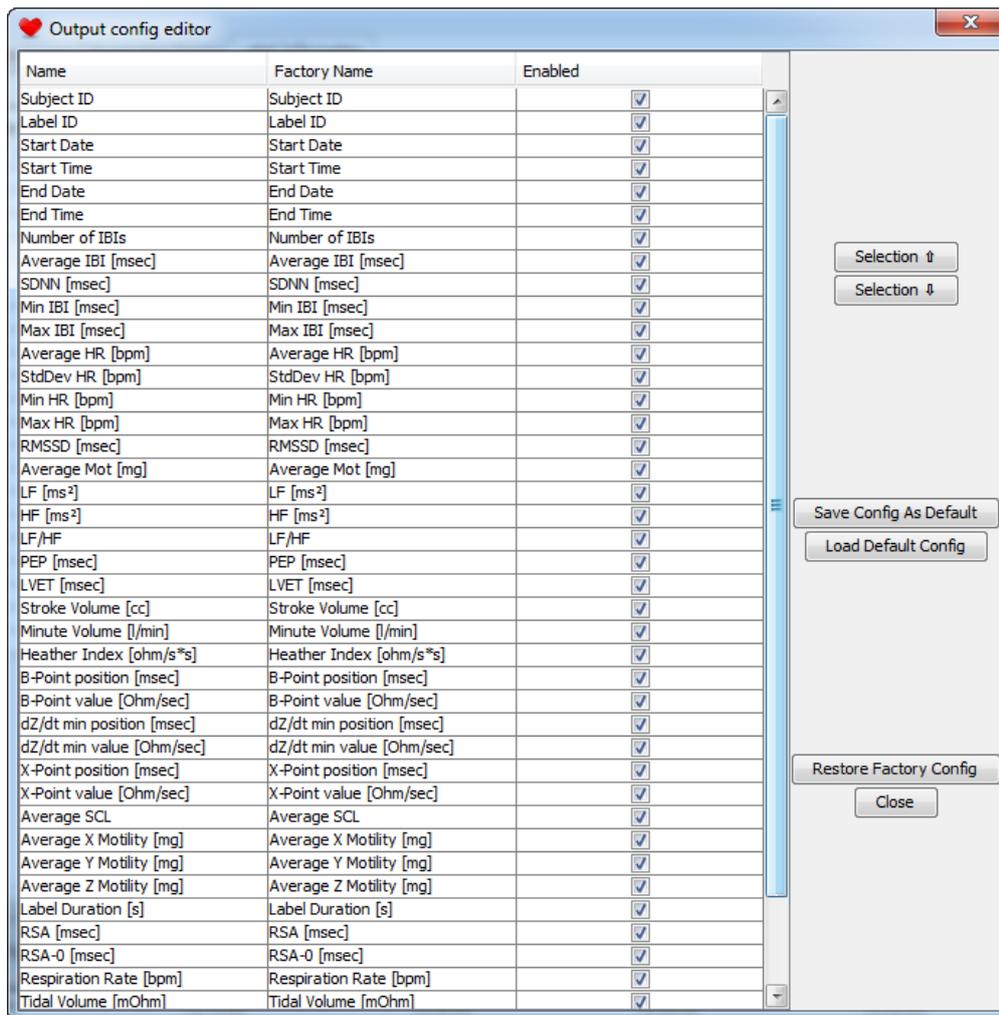
condition is rank-ordered by the *Label ID* field. Clicking a *Label ID* will take you directly to that label in the *Label Data* tab. The rest of the columns contain values for a large number of physiological variables. ICG-based variables only have a value when the scoring under the *Impedance Scoring* tab has been done (e.g. PEP) and the LF and HF power values from spectral analyses on the IBI time series are only present for labels with a minimum length of 4 minutes.

All actions for the *Label Information* tab are presented in the form of buttons:



2.8.1 Output configuration editor

Click the *Label Data* tab → *Actions* → *Edit Output Config* to adjust variable names, order or omit names. A menu with all variables will appear.



To change variable names click in the left column and type in the new name. The second column will show the factory configured name of that particular variable. To restore the output configuration to the factory configuration, click on *Restore Factory Config*.

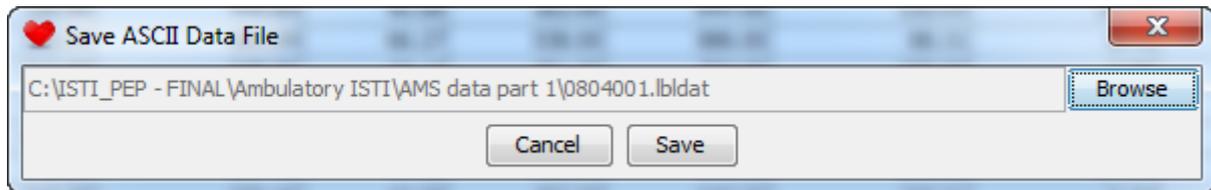
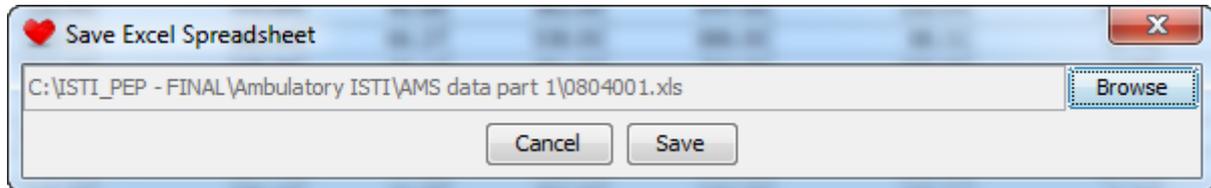
To omit variables simply uncheck the box behind the variable.

To change the order of variables in the output, use *Selection up* and *Selection down* buttons. To restore the output order to the factory configuration, click on *Restore Factory Config*.

After changing the output configuration, you can *Save Config As Default*. This output configuration will then be applied to all .amsdata files that are opened / processed with this DAMS version by this user on this particular computer. You can switch between factory configuration and default configuration by using *Load Default Config* and *Restore Factory Config*.

2.8.2 Export per label

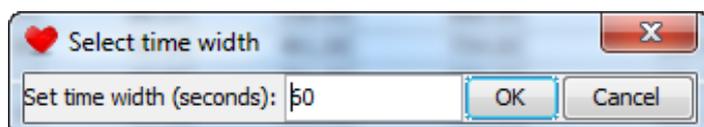
You can either export your data to an excel file (with the extension .xls) or a text file (with the extension .lbdatt). Click on the export button in the menu and you will be prompted to enter the location to the output file.



*Be aware that there is a *label_ID* with the number **0** by default. This label is the average of the entire recording and not the average of all the labels. If you do not want this in your output you can permanently make sure the program does not show the *label_ID* with the number **0** in the *Label information* tab. To do so select in the main *Edit* → *Settings* → *Label information*. Then deselect: *Include label 0 for entire data recording* and save the new settings.

2.8.3 Export for fixed time based labels

By default the exported data will reflect the averaged values across the labels that were generated during *Labeling of your data*, using experimental condition or diary information to define labeled time periods. However there is also the option to export across fixed periods of time. Click on either the *Export 'Per Minute' Information to ASCII File* or the *Export 'Per Minute' Information to Excel Spreadsheet* button. You will be prompted to enter the duration of the fixed time periods. The output will give averages across consecutive periods of this length in the chronological order of recording. The start and stop times of the fixed time period 'labels' will help you link the generated data to the real time of the experiment.

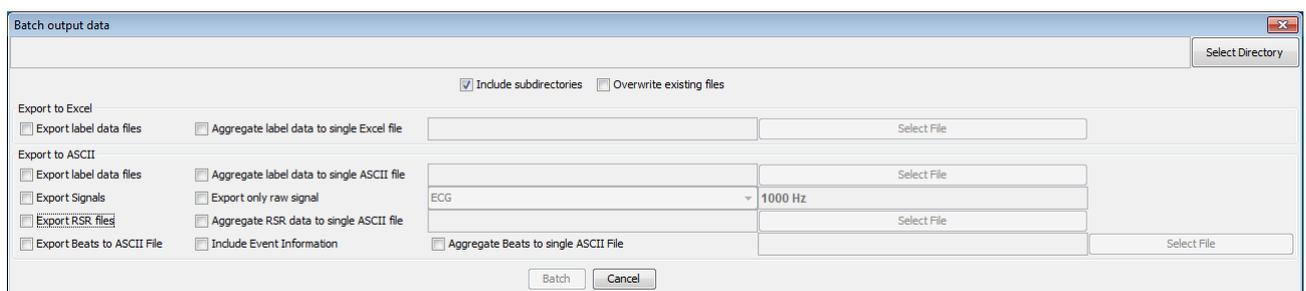


**NOTE 1: The PEP etc. will be set to missing (-9999 by default), as the ensemble averaged impedance complexes always need manual scoring before values for ICG-derived variables are generated. You need to use Add Time-Based Labels during labeling if you want to produce e.g. one-minute average ensemble PEPs.*

**NOTE 2: Spectral analysis will only output values for LF and HF labels if the fixed periods are chosen longer than 4 minutes.*

2.8.4 Batch export

You can export text files in batch mode. This function will generate output files per subject or a merged output file of many subjects from single .amsdata files as long as they are placed in the same directory (or a subdirectory in that directory). So place all files that need to be exported for a certain project in one directory and click on *Batch export data* under *File* in the menu bar.



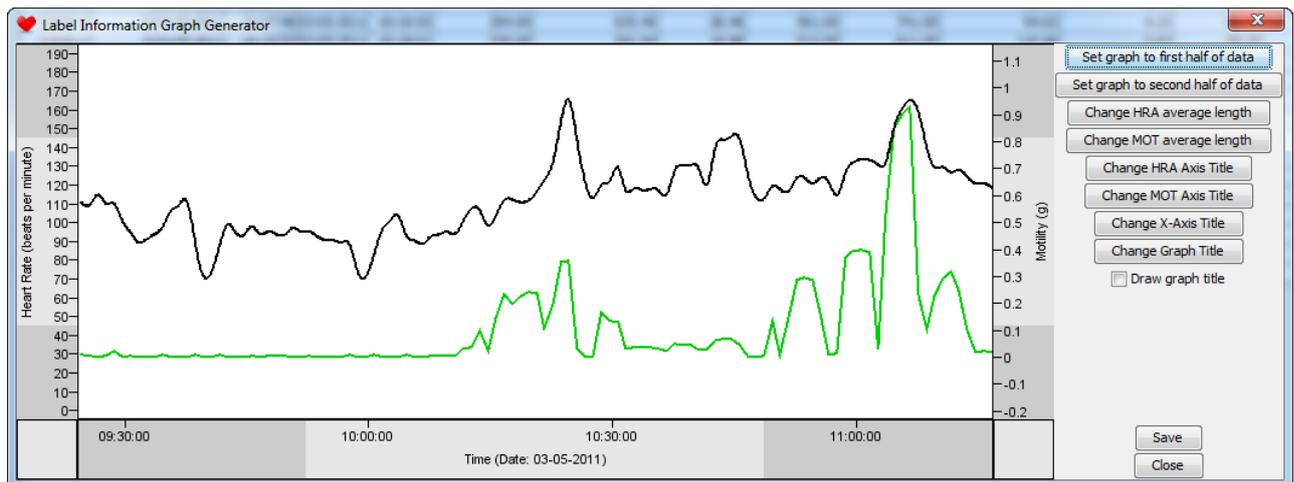
Simply select to export to XLS or to ASCII in single mode or merged mode. Then select the output directory and name the output file.

2.9 Generate reports for the participant

There is an option to generate feedback reports for participants in the forms of heart rate graphs and bar graphs.

2.9.1 Heart rate graph

Click on the *Generate Heart Rate graph* button. You will see the following screen.



The graph will; show the heart rate and motility signal of the entire recording. You can change names of the x-axis, y-axis of the HR and the y-axis of the motility as well as the graph title itself (or hide it by unchecking the *'Draw graph title'* box).

You can adjust the degree of smoothing of the signals by *Change HRA average length* or *Change MOT average length*. Increasing the length will give a more smooth signal.

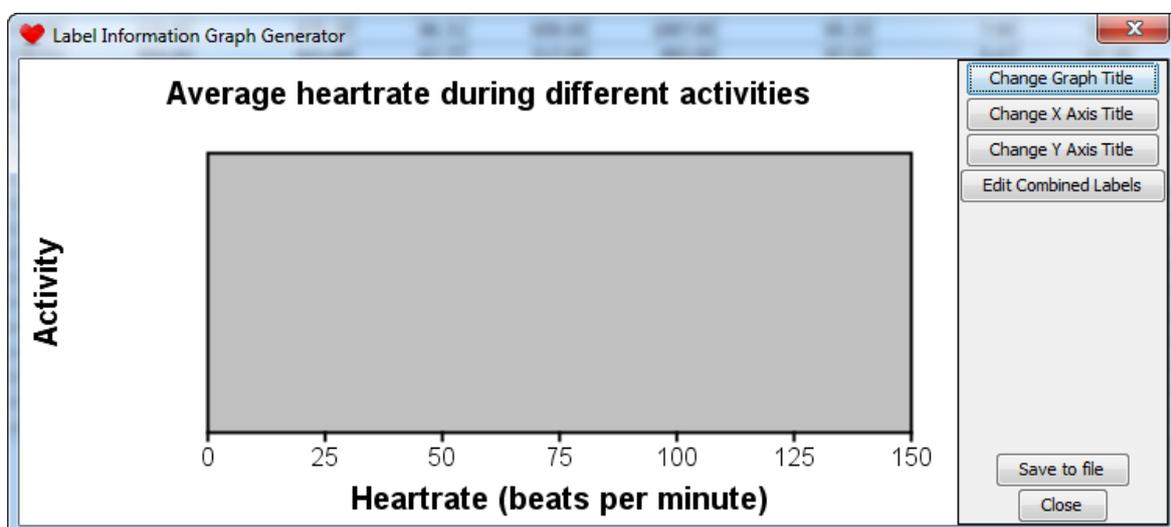
For long recordings (e.g. > 24H) you have the option to display the first or second half of the data by using the buttons of the heart rate graph menu.

When finished, you can save the graph to a .png file by clicking on *Save*.

2.9.2 Generate bar graph

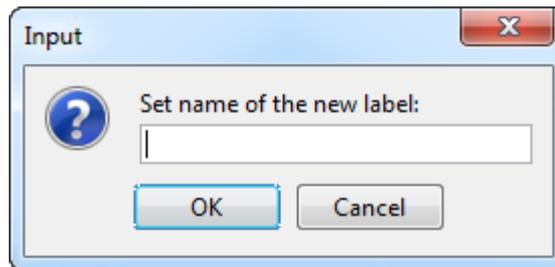
With the heart rate graph it is possible to display the average heart rate across single activities or sets of combined activities. Select or combine various labels into a single bar. Click on the *Generate Bar Graph Of Data* button. You will see the following screen:

Now click on *Edit Combined Labels*, you will see the following screen:

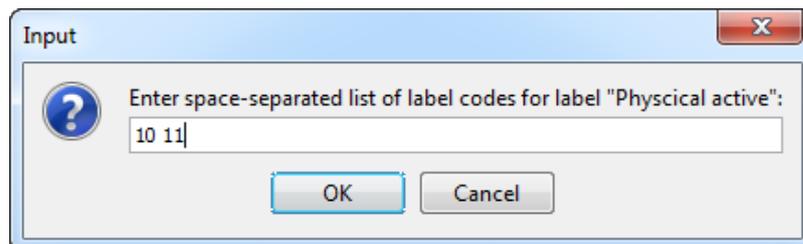


To add bars to the bar graph you need to define what activities should be averaged into a single bar. You can either choose to have a bar represent a single level of a labeling category for example Cycling, or you can combine multiple levels of a category, i.e. cycling and walking into one bar that represents 'physical active' periods.

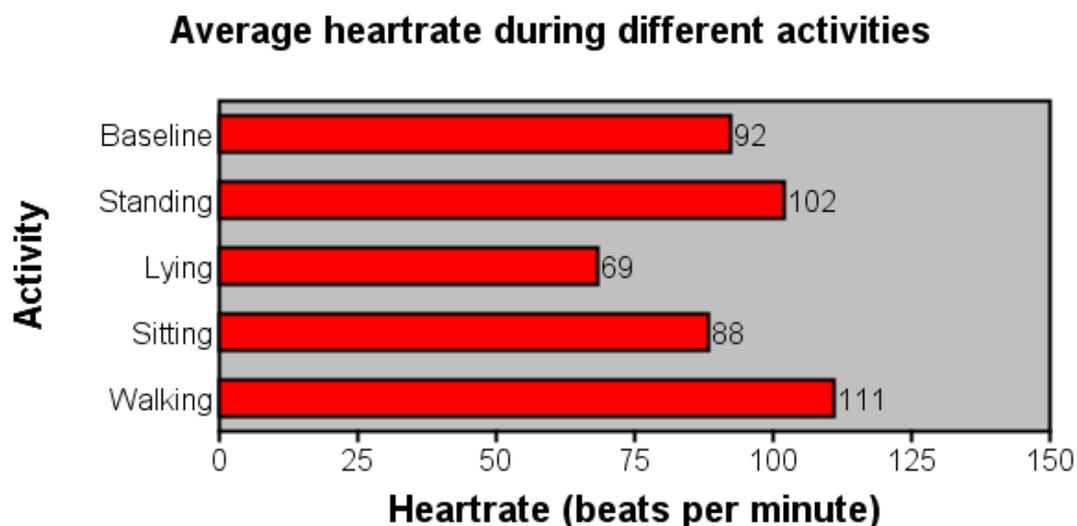
To do this click on *Add New Label* and enter the category name you want to give to this specific bar (e.g. physical active).



Click *OK*. Then enter the space separate list of level codes that need to be averaged for this bar. e.g. 10 for cycling and 11 for walking would be entered like this:



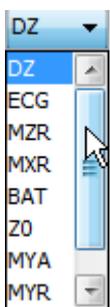
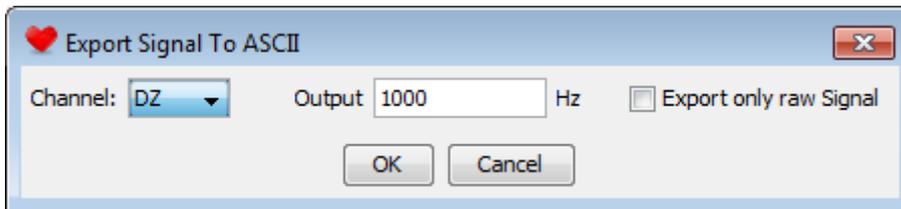
When you have entered all desired bars, you can save the bar graph setting as default. You can change the name of the X-axis, Y-axis and Graph by clicking on the *Change ... Title* buttons of the bar graph menu. The end result might look like this:



2.10 Export VU-AMS signals

A raw data dump can be obtained from each recorded signal into a text file.

Click on *Data* in the main menu and select to *Export Signal To ASCII*. You can choose to export any signal to an ASCII file and choose the resolution of the output.

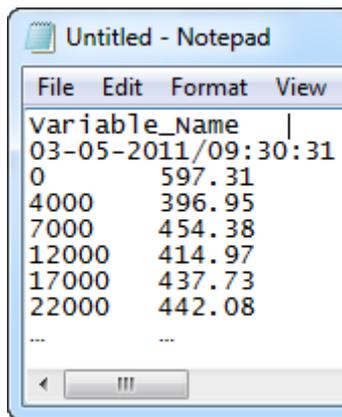


The file has a fixed format that includes the raw signal but also the cumulative time index and the label codes. Each line represents a single sample from the raw data, with samples spaced in time by the specified resolution. N.B.: This can generate very large data files in 24-hour recordings!

2.11 Import external signals

Click on *Data* in the menu and select to (re)import a raw signal dump from a text file. This option allows you to use downsampled data or to import an entirely different signal (as long as the format complies with the DAMS raw data dump format).

Click on *Data* in the menu and select *Load external signal*. In the pop-up screen select the ASCII file containing the external signal. This ASCII file should be structured as follows:



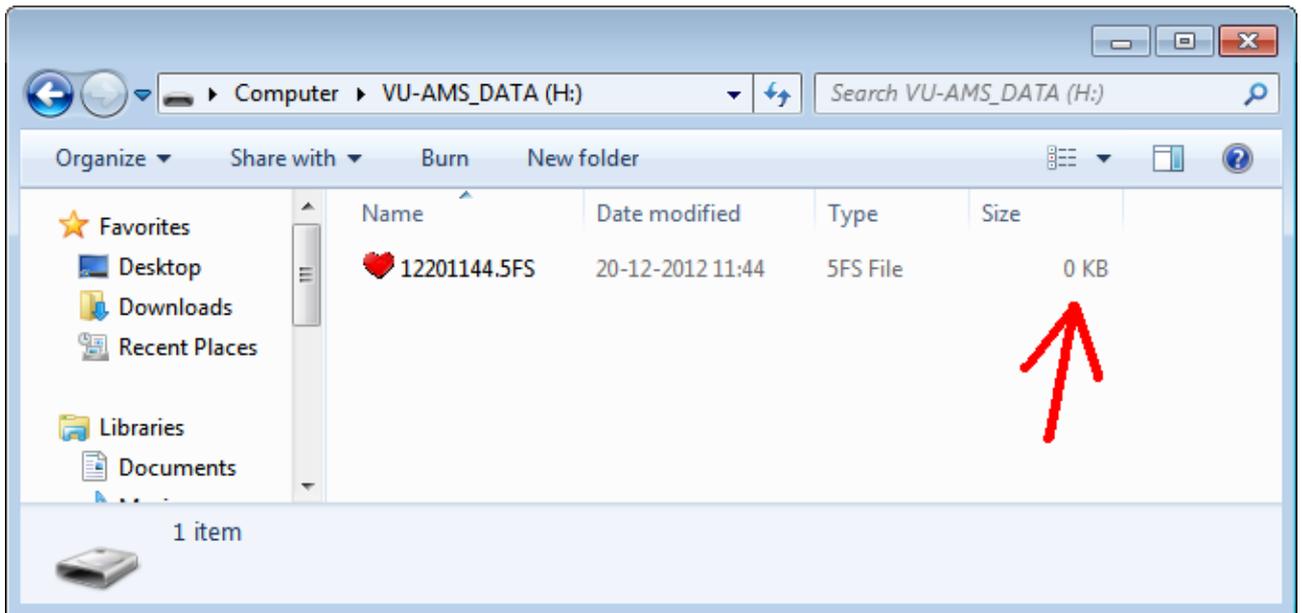
Variable_Name → Name of the external signal
 03-05-2011/09:30:31 → Start date and start time of the recording
 0 597.31 → The first column is the time in msec (starting at zero) and the second
 4000 396.95 column is the corresponding value of the external signal
 7000 454.38
 12000 414.97
 17000 437.73
 22000 442.08

The external signal will appear above the whole IBI recording panel. The mean value of the external signal over each condition will appear in the Label Information tab under 'External Signal Average'. A maximum of three signals can be imported into VU-DAMS.

Click on *Data* in the menu and select *Clear external signal* to remove the external signal.

3. Troubleshooting

3.1 VU-AMS file has zero bytes.



Cause: the VU-AMS has made a recording and probably all data are there but an end-of-file summary has not been placed and the FAT table isn't updated.

Solution: This can be repaired by closely following the instructions on www.vu-ams.nl > Support > Tutorials > Troubleshooting > [Video manual: How to repair a 0KB file recorded with the VU-AMS5fs](#).

3.2 Deviant flashing

When on standby (meaning batteries inserted but not recording), the VU-AMS device flashes once every 10 seconds, when recording the VU-AMS device flashes once every 3 seconds. Faster flashing signals problems:

- The green light is flashing very rapidly
Cause: The Compact Flash card is not (properly) installed.
Solution: Install the Compact Flash card in the proper way.

- The green light is flashing rapidly
Cause: The battery lid is not (properly) fastened.
Solution: Fasten the battery lid in the proper way.

3.3 Warning beeps

When the VU-AMS detects that something is amiss it can generate various warning beeps:

- You hear a double beep (the 'alert beep'), which is repeated after increasingly shorter intervals (from 30 to 10 seconds).
Cause: The battery voltage is becoming low.
Solution: Replace the batteries with fresh ones.
- You hear a triple beep (the 'warning beep').
Cause: An electrode comes off, a lead wire gets detached, or the lead wire connector is pulled out by accident.
Solution: No worries. Just attach the electrode again (use a spare one if necessary), reattach the lead wire, or plug the connector back into the socket.

3.4 Frequently asked questions.

See <http://forum.vu-ams.nl>

and

www.vu-ams.nl/support/tutorials