

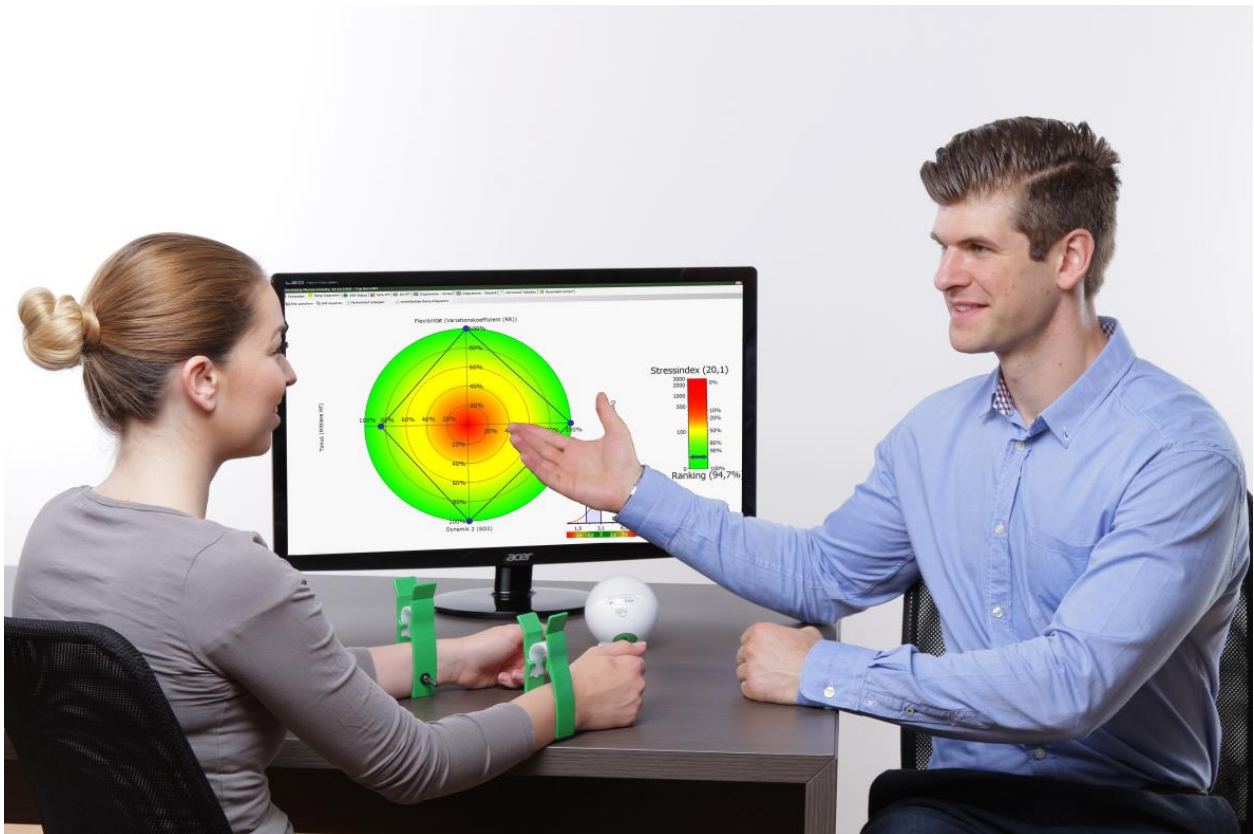
Documentation

for



Part 2:

**Valsalva-Test, Long Term HRV/24h HRV,
Templates, Summary Report,
Possibilities of data import**



BioSign
SCIENCE FOR A BETTER LIFE

BioSign GmbH
Brunnenstr. 21
D-85570 Ottenhofen
www.biosign.de
info@biosign.de

Content

The Valsalva Test (Valsalva maneuver)	3
Additional HRV tests	6
HRV supine/standing.....	6
Long term measurements.....	7
Long-term Analysis - Step 1 - Diagrams.....	7
Long-term Analysis - Step 1 - View.....	8
Long-term Analysis - Step 1 - Filter	10
Long-term Analysis - Step 1 - Tables	12
Long-term Analysis - Step 1 - Protocol.....	13
Creating an activity protocol using the smartphone app.....	13
Import data from an XML protocol file created with the smartphone app	18
Long-term Analysis - Step 2	19
Long-term Analysis - Step 2 - HRV Progress	20
Extended 24h analysis	21
Detailed assessment of measurement quality.....	21
Abnormalities in the HRV.....	24
Spiderweb charts with normative percentiles	25
Assessment of nocturnal recovery	27
Heart beats in 24 h, heart rate and nocturnal lowering.....	28
Specific performance indexes for the sympathetic and parasympathetic nervous system	29
Fluctuation-Index: The Variability of the Variability.....	30
„Functional HRV Age“ and „Premature Aging (PMA)“	31
Functional HRV age as a risk.....	34
Sleep	35
Working with templates in the HRV-Scanner	38
Creating Templates.....	38
Analysis with Templates	39
Summary Report	42
Creating a Summary Reports	42
Result	44
Definition of the scoring algorithm of a summary report	45
Step 1: Selection of the individual parameters	45
Step 2: Defining the evaluation criteria for each parameter (defining scores).....	45
Step 3: Evaluation criteria for a single test	46
Step 4: Evaluation of the complete functional analysis	46
Import Options	47
ASCII.....	47
ASCII biosignals.....	47
EDF - European Data Format	47
eMotion HRV	47
Polar.....	47
Suunto.....	47
SRM long term measurement.....	47
Technical Manual HRV-Scanner Hardware plus	48
Prepare the Breathing Sensor	48

The Valsalva Test (Valsalva maneuver)

The Valsalva test is an additional stimulation test for the functional testing of the autonomic nervous system. Since it is one of the few functional tests that also tests the adrenergic reflex arcs, it is especially indicated when a possible impairment of the sympathetic nervous system is to be investigated.

Patient preparation

The Valsalva test requires a very good derivation of the ECG signal and the pulse signal. If too many artifacts occur during the test, e.g. by arm movements during pressing, adhesive electrodes on the chest might be a better alternative.

Contraindications and warnings

Basically, the Valsalva is considered a safe function test. However, due to potential blood pressure peaks, the Valsalva test should not be performed on people who need to avoid peak blood pressure. These include, for example, patients with retinal hemorrhages in the past or known brain neureurysms.

Test procedure

During the Valsalva test the patient blows into a mouthpiece with a pressure transducer attached, maintaining a pressure of approximately 40 mmHg for 15 seconds. The pressure transducer should have a leak to ensure a continuously opened glottis.

Physiology

The Valsalva maneuver (VM) is a very potent circulatory stimulus that induces a pronounced transient drop in blood pressure. The reduction of the parasympathetic alone is not sufficient to counteract the drop in blood pressure. There is therefore an activation of the adrenergic sympathetic system with a pronounced vasoconstriction, which lasts for a few seconds due to the inertia of the sympathetic nerve even after the end of the VM.

Die neurovegetative Regulation des VM lässt sich in vier Phasen gliedern:

The initial intrathoracic pressure increase due to the active pressing initially causes a transient increase in blood pressure (Phase I). The intrathoracic pressure increase affects the venous return to the heart, causing heart rate and blood pressure to steadily decrease (Phase IIa). Reflectively, there is a counter regulation, which is characterized by an initially vagus inhibition and an increase of the sympathetic activity, especially on the resistance vessels (phase IIb, vasoconstriction). At the end of the pressure maneuver the intrathoracic pressure drops suddenly. This leads to a brief physical drop in blood pressure (Phase III). Due to the reintroduced strong venous influx, the stroke volume increases significantly with concurrent vasoconstriction. This leads to a rise in blood pressure which is generally significantly higher than the baseline value (phase IV). This sudden increase in blood pressure causes a rapid vagal counter-regulation, which is expressed in a significant drop in heart rate. From this drop in heart rate, the Valsalva Ratio can be calculated: Ratio of the maximum RR interval after the maneuver to the shortest RR interval during or shortly after the end of the maneuver. In general, the Valsalva ratio is a parasympathetic parameter.

Based on the envelope and the amplitude of the pulse signal (yellow curve) and the pulse wave transit time (PTT, red curve), the course of the systolic blood pressure in the Valsalva maneuver can be estimated well. The PTT behaves inversely to the systolic blood pressure: the lower the systolic blood pressure, the higher the PTT.

An intact sympathetic system leads to a marked vasoconstriction, triggered by the drop in blood pressure during pressing. Due to the longer reaction times of the sympathetic nerve compared to the parasympathetic nervous system, vasoconstriction is delayed and continues beyond the end of the VM.

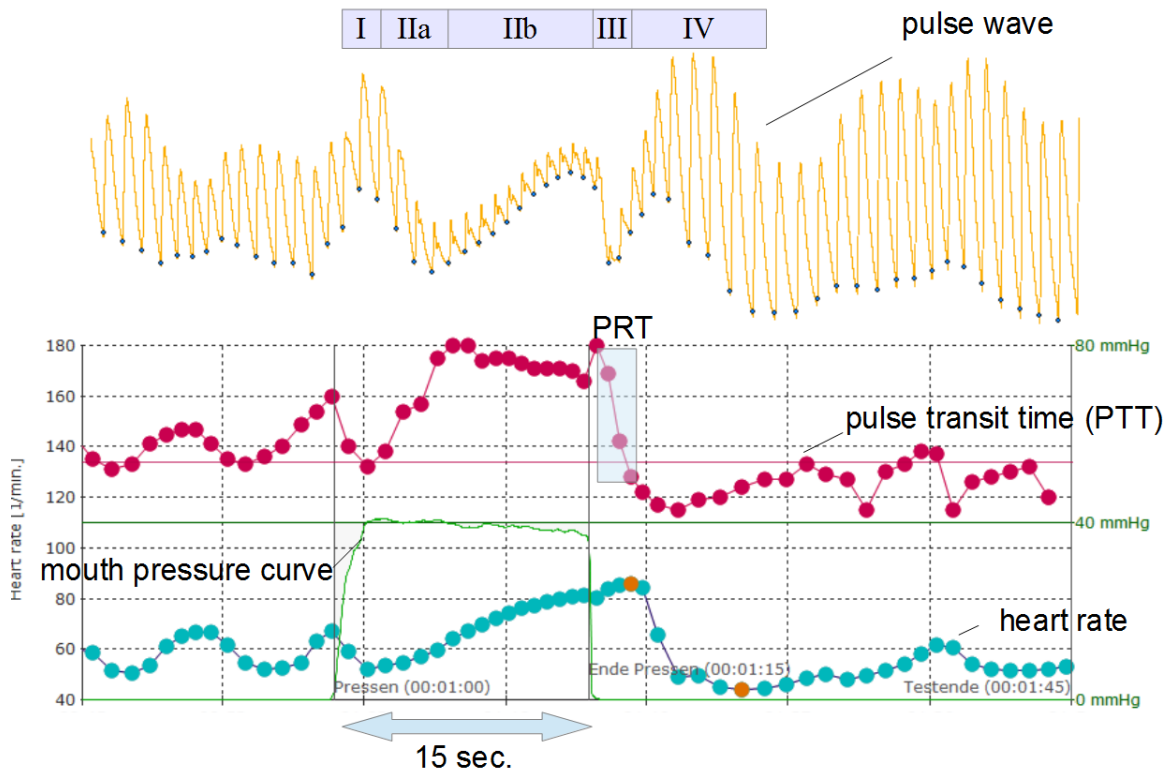


Figure 1: Valsalva test of a healthy volunteer. Based on the red PTT curve, the blood pressure profile during the VM can be understood very well: In phase IIa there is a pressure drop (increase in PTT). Increased vasoconstriction, combined with an increase in heart rate, stops and minimizes pressure drop (small but continuous decreasing of the PTT in Phase IIb). At the end of the press, there is an excessive increase in blood pressure (Phase IV) due to the existing vasoconstriction, high heart rate, and rapidly increasing stroke volume, as indicated by a fall in PTT below baseline (red horizontal line). The Blood Pressure Recovery Time (PRT) indicates the time from the beginning of Phase IV until the recovery of baseline blood pressure.

Indications for adrenergic dysfunction

A possible adrenergic dysfunction is in general visible in a different course of the blood pressure curve. For this reason, the Valsalva test has so far been performed only in specialized facilities where a continuous measuring blood pressure monitor is available that allows a quantitative beat-to-beat analysis of blood pressure. However, these systems are hardly used due to their high price (> 20.000 €).

In order to still allow an assessment of the blood pressure profile in the VM, the HRV scanner calculates the pulse transit time (PTT), which is known from many studies that it correlates very well with the systolic blood pressure for short periods. The PTT allows only a qualitative assessment of blood pressure changes, a quantitative analysis in mmHg is therefore not possible. However, a severe adrenergic insufficiency leads to a typical pattern of blood pressure, which is also clearly recognizable in PTT: Due to the lack of vasoconstriction in phase IIa, the blood pressure cannot be stabilized and continues to fall. In Phase IV, the time to recovery of the baseline blood pressure ("PRT") increases. The result is a "V" -shaped pattern of blood pressure history. The PRT is usually less than 5 seconds and can be prolonged up to 40 seconds in severe adrenergic weakness.

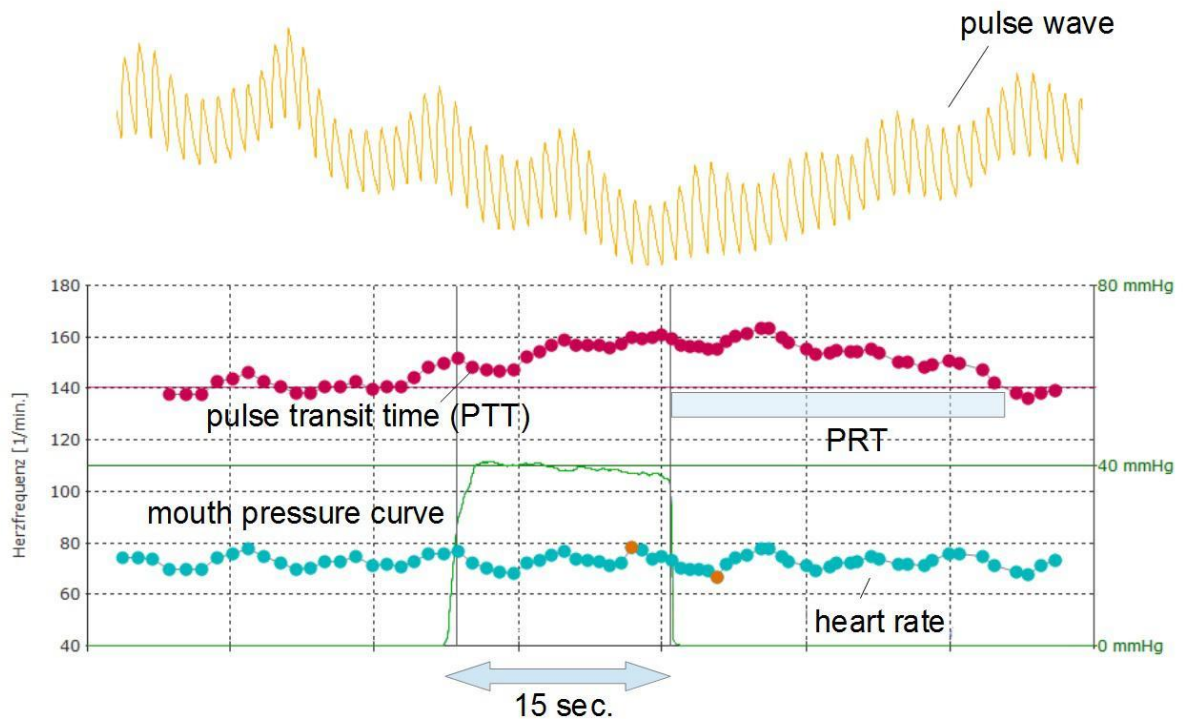


Figure 2: Schematic course of a pronounced lack of regulation. The blood pressure drops continuously during the pressing. The "Blood Pressor Recovery Time (PRT)" is significantly extended.

There are vegetative dysfunctions such as the postural tachycardia syndrome (POTS), which differ significantly in the VM from normal findings and a pure sympathetic insufficiency (Fig. 2). POTS patients and patients with chronic fatigue syndrome (CFS) often show overlapping symptoms that clinically translate into fatigue and fatigue. In the VM, POTS patients have a hyperadrenergic reaction pattern with a pronounced and prolonged overshoot of blood pressure in Phase IV (Figure 3). The vagal function tests are usually within the normal range.

Therefore, in patients with symptoms of prolonged fatigue and fatigue and, of course, symptoms of orthostatic intolerance, we recommend not only performing primary vagal function tests, but also testing the sympathetic portion of the autonomic nervous system using VM and orthostasis.

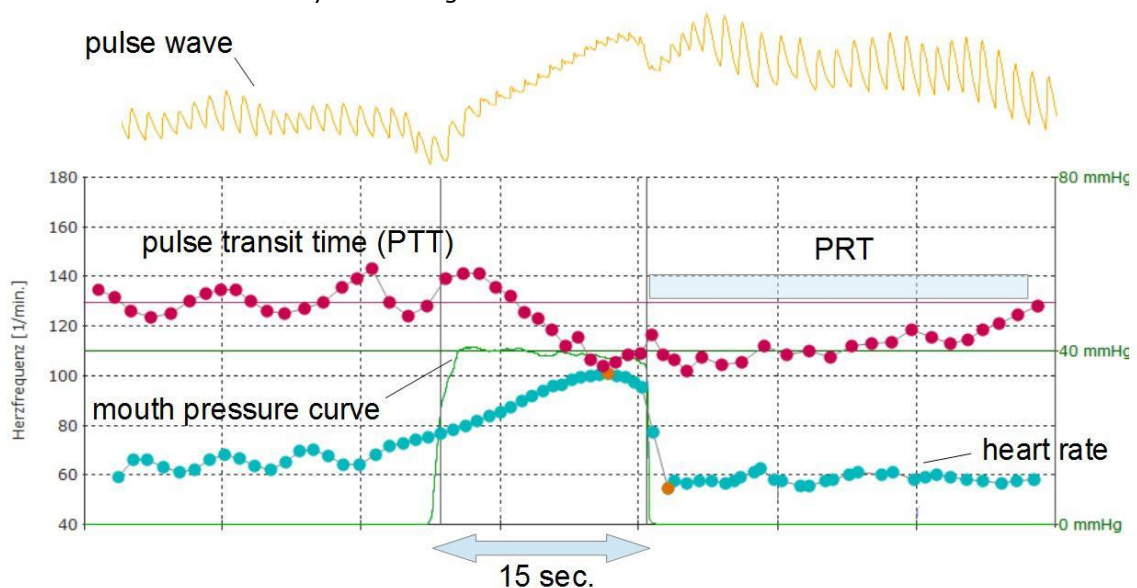


Figure 3: Schematic course of a hyperadrenergic reaction in the VM in a patient with postural tachycardia syndrome (POTS). In phase IV, the blood pressure rises excessively and drops back to the original baseline value only very slowly.

Additional HRV tests

HRV supine/standing

HRV supine/standing measurement with or without blood pressure determination. Standard 5 minutes of supine/standing up/5 minutes standing, or freely configurable.

This test examines the physiological responses when changing the body position from lying to standing. Because there is a 5 minute phase of laying before standing up, the Short-Term HRV can also be carried out in this test. As a result, a separate determination of the Short-Term HRV can be committed and measurement time can be saved.

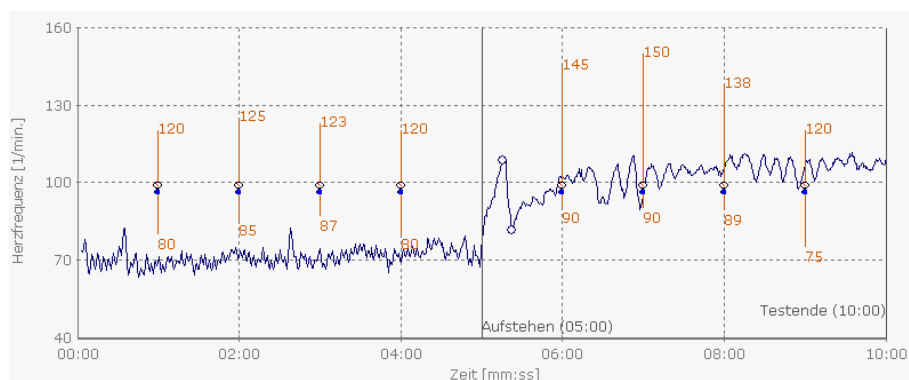
Immediately after standing up, the heart rate increases until it slows down significantly after about 20 seconds. The rapid increase in the heart rate is caused by a reduction in the parasympathetic activity, while the subsequent bradycardia is mediated by the baroreflex. The aim of the whole regulation is to ensure a sufficient blood pressure, because in the orthostatic the sudden shedding of more than half a litre of blood in the legs must be balanced. Therefore, in addition to the adaptation of the heart beat, there is also an increase in the sympathetic activity of the vascular system, combined with an engorgement of the vessels. In healthy persons, the orthostatic regulation is completed on average after approximately 20 seconds.

Age, sex, and exercise can affect the regulatory behaviour as well as metabolic factors, e.g. food intake, alcohol or nicotine.

A normal, physiological blood pressure regulation is reflected in a slight decrease in systolic blood pressure by 5-10 mmHg, an increase in diastolic blood pressure by 2-5 mmHg and an increase in heart rate between 5-20 beats/min.

The blood pressure should decrease systolic not more than 20 mmHg and diastolic not more than 10 mmHg. A more severe reduction in blood pressure is also called orthostatic hypotonic. Another misregulation is an excessive increase in heart rate while standing. The heart rate should not rise more than 30 beats per minute, compared to the lying level, or not exceed a value of more than 120 beats/min.

Example of an orthostatic measurement. Significant Ewing response (rapid increase in heart rate, followed by a marked drop in heart rate). Remarkable is the strong increase of heart rate while standing (> 30 beats/min).

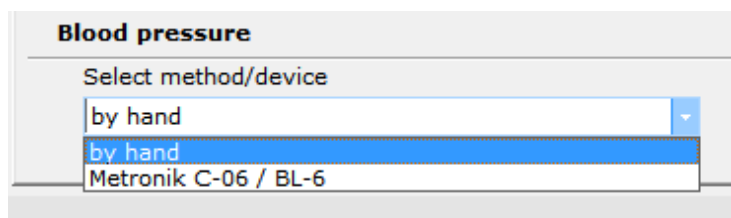


Note on implementation:

Be careful not to inform the subject too early about the time of standing up, because this creates an expectation that is associated with an increased sympathetic tone and can distort the result. The subject should stand still immediately after getting up without activating the leg musculature more than necessary, because the muscular pump is arbitrarily interfered with in the regulation of blood pressure and heart rate and thus the control power of the vegetative nervous system is no longer assessable.

Danger:

When performing the Ewing test, some people may experience syncope. The appropriate design of the test sequence must ensure that the test person does not suffer any damage during the occurrence of the syncope. (No sharp or sharp-edged objects in the vicinity of the volunteer, assistant staff in the immediate vicinity of the subject when standing up, which is able to absorb a sudden fall or to mitigate.)



Note: The blood pressure can be measured manually or using the Metronik C-06/BL-6 blood pressure monitor. Specify in the system settings which method should be used.

Long term measurements

Long-term HRV measurements can provide valuable insights regarding HRV during the day. The measurement is usually carried out with holter systems. We recommend using the Faros 180 waterproof from Bittium. This device records the ECG and has acceleration sensors in the three axes.

The first step of the analysis involves the production of a heart rate graph as good as possible through processing the ECG. All other parameters and curves will be created on the basis of this in the second step.

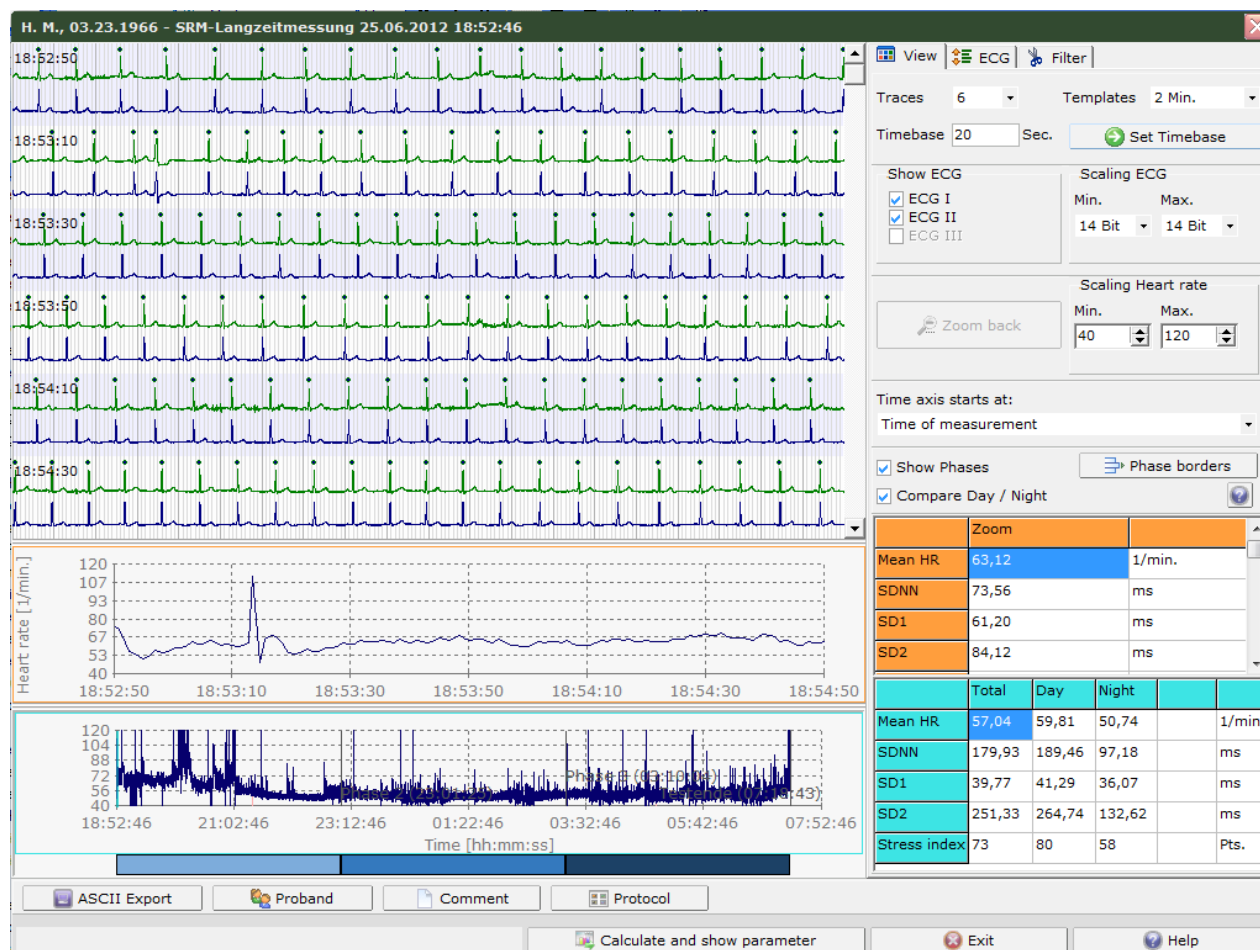


Fig.: Structure of the analysis window

Long-term Analysis - Step 1 - Diagrams

In the left part of the window you will see three diagrams and the phase bar, which displays the length of the individual phases of a measurement. The upper diagram shows the ECG, the two lower diagrams show the heart rate graph. The upper heart rate diagram represents the heart rate graph derived from the ECG above. The lower heart rate diagram shows the heart rate graph for the entire test.

Note:

You can alter the sizes of the diagrams by dragging the two "splitters" (separation lines between the ECG and heart rate diagrams and between the two heart rate diagrams).

To scroll through the measurement click the scroll bar on the right next to the ECG diagram. You can also zoom in on any area in either of the diagrams by using the left mouse button. By clicking the undo button in the "display" tab the zoom can be undone. You can also achieve the same effect by pressing the right hand mouse button.

You will see the phase bar beneath the heart rate diagram. By dragging the mouse with the left mouse button held down you can split the measurement into three different phases each of which will be analysed separately.

Long-term Analysis - Step 1 - View

Here you can configure the diagrams

The screenshot shows the 'View' tab of the HRV-Scanner configuration window. It includes settings for Traces (6), Templates (2 Min.), Timebase (20 Sec.), and a 'Set Timebase' button. There are checkboxes for 'Show ECG' (ECG I, ECG II, ECG III) and 'Scaling ECG' (Min. 14 Bit, Max. 14 Bit). A 'Zoom back' button is also present. The 'Scaling Heart rate' section has Min. 40 and Max. 120 settings. The 'Time axis starts at:' dropdown is set to 'Time of measurement'. There are checkboxes for 'Show Phases' and 'Compare Day / Night'. At the bottom, there are two tables showing measurement data.

	Zoom	
Mean HR	63,12	1/min.
SDNN	73,56	ms
SD1	61,20	ms
SD2	84,12	ms

	Total	Phase 1	Phase 2	Phase 3	
Mean HR	57,04	65,02	50,74	53,68	1/min.
SDNN	179,93	194,27	97,18	134,58	ms
SD1	39,77	44,54	36,07	37,12	ms
SD2	251,33	271,10	132,62	186,67	ms
Stress index	73	118	58	43	Pts.

Number of lines in ECG diagram

Time base

Length of the ECG displayed in a given track in seconds. To accept the setting please click on "set Time base".

Templates

Templates display an excerpt from the measurement with a predefined length, whereby the number of tracks and the time base will be set such as to produce an optimised display.

Scaling ECG

The ECG is saved in the HRV-Scanner in a 16-bit Format with plus/minus signs, i.e. from +32767 to -32767. This corresponds to a number range from +15 bits to -15 bits, whereby often only a small part of the number range will be used, depending upon the ECG amplification, so that it will be necessary to configure a correspondingly smaller number range in order to be able to see the ECG.

Note: Please note that changing the scale here is only relevant to the display and not to the recognition of the R-waves in the "ECG" tab.

Scaling Heart rate

Here you can set the Y-axis of the heart rate diagram.

Time Axis starts at

Here you can decide, whether the time axis should begin with $t = 0$ or with the actual time of the measurement.

Show Phases

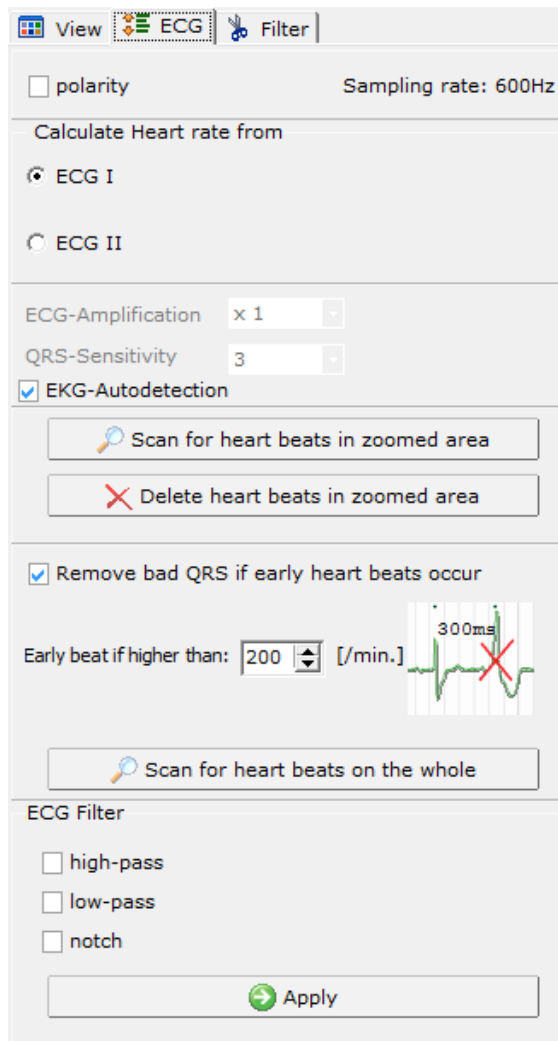
Here you can decide, whether the measurement should be subdivided into three phases, and/or whether the division should be displayed and taken into account in the analysis.

Phase borders

Here you can set the phase limits (start and finish). The window for editing the phase limits will appear. The phase limits are entered in this window depending upon the configuration of the time axis. If you have selected ($t = 0$) then the time entered will relate to the interval from the start of the measurement, otherwise please

enter the actual times for the phase limits. By clicking "accept" the phase limits will be included in the measurement and the display.

Long-term Analysis - Step 1 - ECG



Polarity

Reverses the polarity of the ECG. This is useful if, for example, the electrodes have been applied the wrong way round. After reversing the polarity the QRS analysis to determine the R-waves should be repeated.

Calculate Heart rate from ...

If several ECG tracks are recorded then this is where you can select which track should be used to determine the heart rate.

ECG Amplification and QRS Sensitivity

This affects the settings for the QRS analysis. The greater the configured values the more sensitive will be the QRS analysis. This also increases the likelihood that minor artefacts will be falsely identified as R-waves.

ECG-Auto detection

The settings for the QRS analysis will be set automatically.

Scan for heartbeats in zoomed area

Searches for R-waves within the ECG diagram. Sections of the analysis outside the ECG diagram will not be analysed.

Delete heartbeats in zoomed area

Deletes all R-wave markers within the ECG diagram. Does not affect sections of the analysis outside the ECG diagram.

Remove bad QRS if early heartbeats occur (only available with actual ECG, not available for measurements from RR intervals and artificially created ECGs)

Sometimes two identified R-waves are so close together than it is unlikely that both R-waves are the result of a physiological sinus rhythm. This is often the result of an extra beat or an artefact in the vicinity of a normal heartbeat. If the "remove premature QRS" function is activated then after clicking on "Find All QRSs" the form of R-waves in close proximity will be analysed and compared to the rest of the R-waves. The R-wave whose form comes closest to that of the majority will be retained and the other will be rejected as an artefact. Using the entry field you can specify the point as of which two R-waves will be regarded as premature and checked for form similarity.

Scan for heartbeats on the whole

Starts a search for R-waves throughout the entire ECG, whereby existing markers will be deleted.

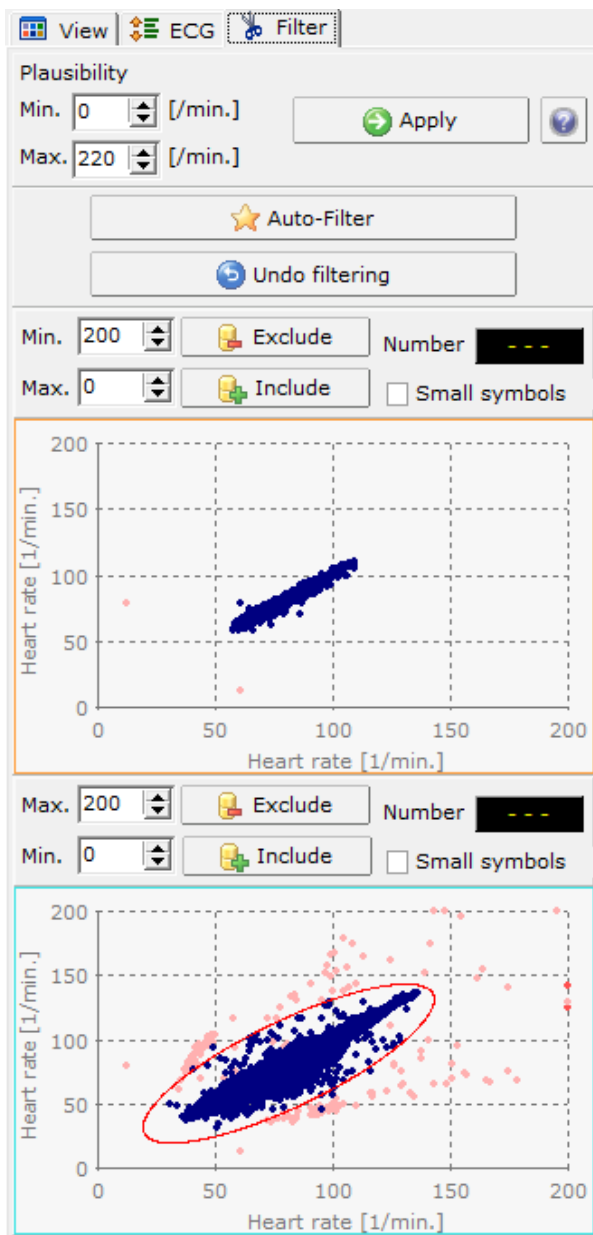
ECG Filter (only available with actual ECG, not available for measurements from RR intervals and artificially created ECGs)

Using this function you apply various different filters to the ECG. The high-pass filter removes slow signal element, e.g. base line fluctuations. The low-pass filter can remove high frequency interference. The notch filter is used to reduce any network hum.

Note: Measurements generated through the import of RR lists are given an artificially generated ECG. In this case the filters are not available as there can be no faults in the signal.

Long-term Analysis - Step 1 - Filter

Use the various filters to remove as many artefacts as possible. Only in this way can a valid analysis of the measurement be produced.



Plausibility

A normal heart rate graph (sinus rhythm) is unlikely to contain extremely high or low heartbeat frequencies. Usually any such exceptions are the result of artefacts or extra beats. Set the upper and lower limits in order to exclude such artefacts right from the start.

Undo filtering

Reverses the last Poincaré filter.

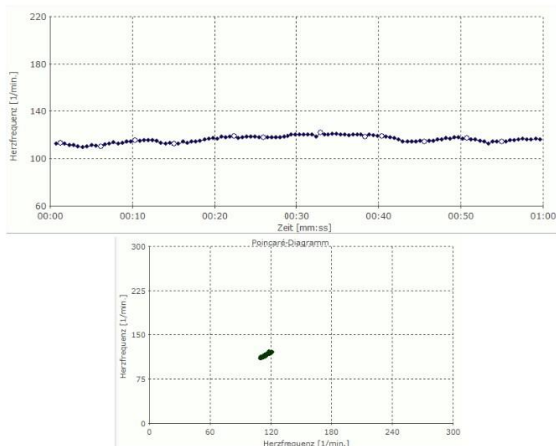
Poincaré-Filter

see below

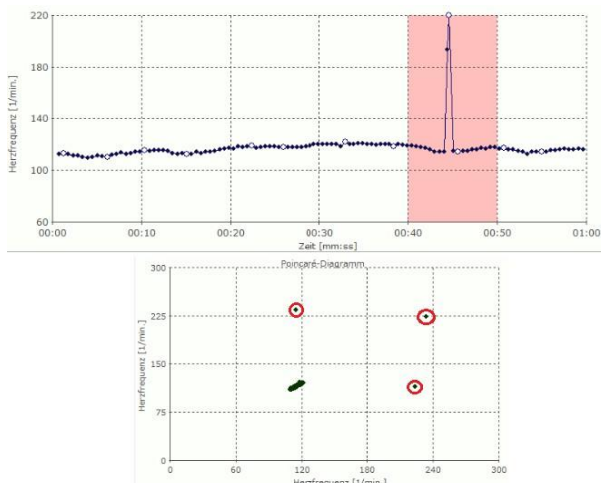
Poincaré-Filter

There are two graphic filters available based on so-called Poincaré plots. Poincaré diagrams are particularly well suited for identifying outliers in the heart rate graph.

The following example shows an artefact-free heart rate graph and below it the corresponding Poincaré diagram.

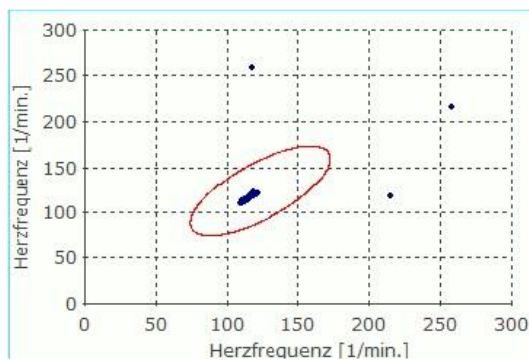


Now the same heart rate graph with several artefacts:



The exceptions can be clearly identified in the Poincaré diagram as points outside of the point cloud (marked with a red circle) and can now be easily filtered out:

to do so simple hold down the left mouse button and drag an ellipse around the point cloud formed by the real heartbeats (see image).



Now click the "exclude" button in order to remove the artefacts. If you accidentally remove too many heartbeats you can reverse the last filter by clicking on the relevant button. Alternatively you can create a new ellipse and then click "include" to include all heartbeats within the ellipse.

Long-term Analysis - Step 1 - Tables

Two tables show you the most important HRV parameters for orientation.

	Zoom		
Mean HR	81,30	1/min.	
SDNN	106,45	ms	
SD1	20,75	ms	
SD2	149,10	ms	
	Total	Phase 1	Phase 2
Mean HR	71,17	- - -	- - -
SDNN	178,74	- - -	- - -
SD1	24,90	- - -	- - -
SD2	251,55	- - -	- - -
Stress index	81	- - -	- - -

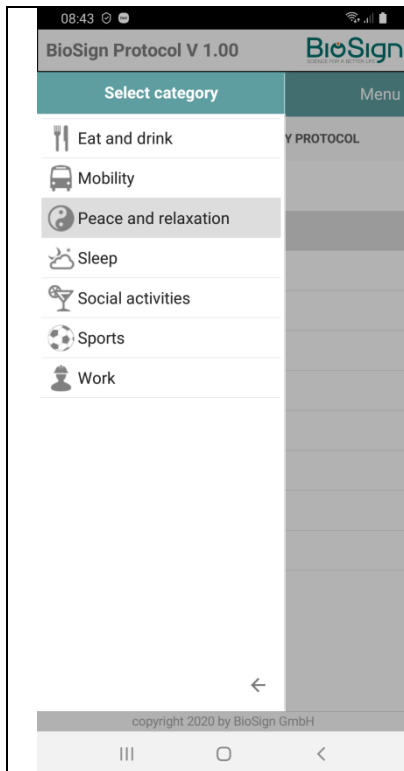
The upper table shows the calculated HRV parameters of the upper heart rate diagram (measurement excerpt), the table below shows the HRV parameters of the lower heart rate diagram (entire measurement), divided into phases. The tables are updated every time changes are made to the heart rate curves, e.g. through the application of filters

Long-term Analysis - Step 1 - Protocol

With the help of the protocol function, the long-term measurement can be commented for a better interpretation.

Creating an activity protocol using the smartphone app

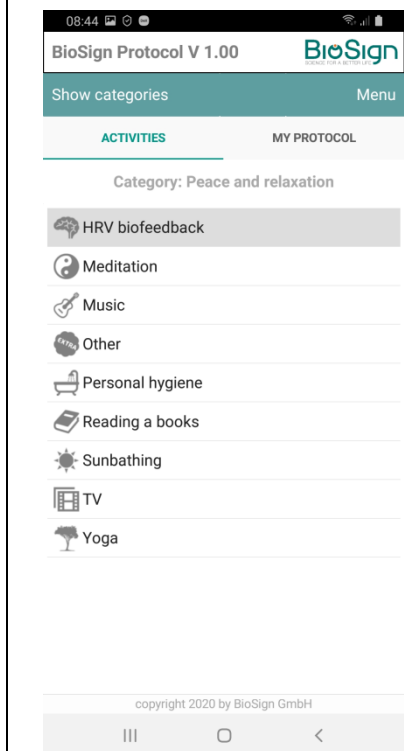
Our smartphone app is available in the Google Play Store and the Apple App Store as "BioSign Protokoll".



Main window and category selection

In the main window of the app you will see a list with categories. Each category contains a few templates for activities to insert in you protocol. This category list can be shown at any time by clicking on "Show categories" in the top left.

Selecting a category entry activates the list with the subentries from the selected category.



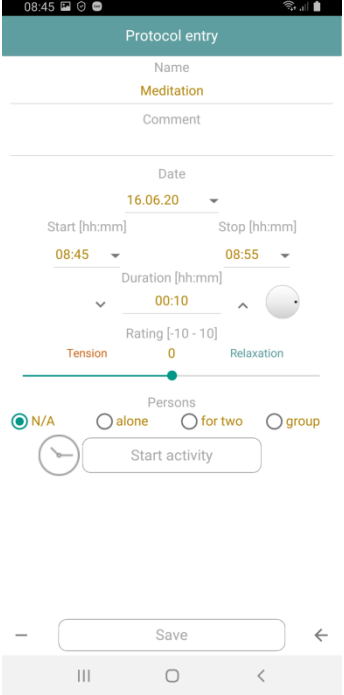
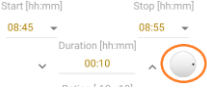
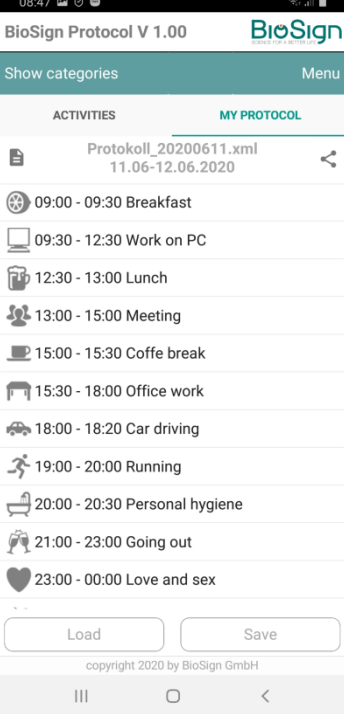
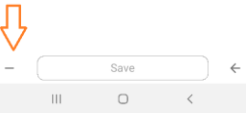
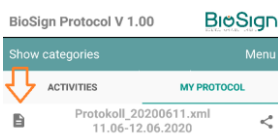
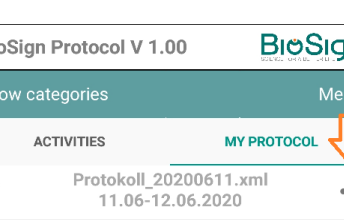

Selection window for templates of activities to be inserted in the protocol

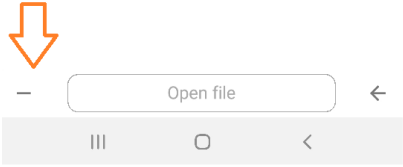
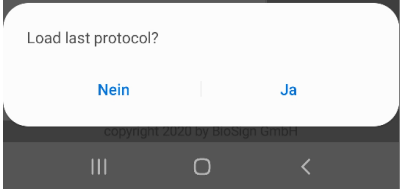
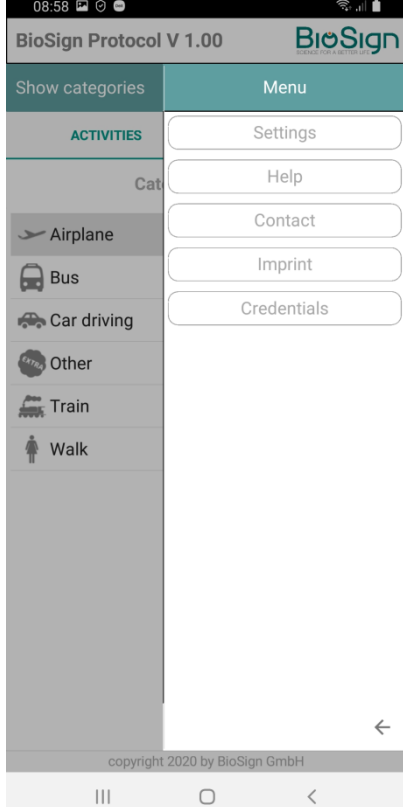
Select from the list which template for an activity should be inserted in the current protocol.

Each category contains an "Other" entry. If this entry is inserted in the protocol, you can individually determine which activity it is. Please note that in this case a name must be entered in the properties of a protocol entry.

Selecting an entry activates the window for the further properties of an entry:

- Start time, stop time or duration
- Name if "Other" is selected
- Comment
- Rating (regarding tension and relaxation)
- Indication of whether the activity was accompanied by other persons or done alone

	<p>Activity properties window</p> <p>Enter here when the activity started and when it ended. This can be done by entering two times (start / stop) or by entering the start time and duration.</p>  <p>The duration can be changed quickly using the wheel symbol.</p> <p>It is also possible to start an activity in the app directly and to end it when the activity has been completed. A timer records the elapsed time and overtakes it in the properties.</p> <p>Further properties for the activity (comment, rating, persons) can also be entered here.</p> <p>Please note that if you select the "Other" template, you must enter a description. Press finally the "Save"-button in order to overtake the new activity into the protocol.</p>
	<p>"My Protocol" window</p> <p>After an activity has been inserted into the protocol by using "Save", the new activity appears in your current protocol. You can edit the entries later by selecting them here.</p>  <p>In order to remove an entry open its property window and press the delete button "-" (on the left side of the "Save"-button).</p> <p>To forward the activity protocol to your therapist, you should save the activity protocol in an XML file. This file can also be loaded back into the app later, e.g. if corrections are necessary or individual entries should be deleted.</p>  <p>You can create a new empty protocol with the button at the top left.</p>
	<p>Forwarding of the protocol data as an XML file</p> <p>You can send the XML protocol file to your therapist by e-mail using the share button at the top right. You will also find all XML protocol files in the "Documents" -> "Documents" folder and can share them from there using many smartphone applications (WhatsApp, Threema, Mail, ...). All information in the XML files is secured by a 256-bit AES encryption.</p>
	<p>Load protocol files</p> <p>Saved protocol files can be reloaded into the app in the "My protocol" window. Select the desired xml-file from the list in the selection window and press "Load".</p>

	<p>Delete protocol files</p> <p>In the selection window of the saved XML protocol files, you also have the option of deleting files that are no longer needed on your smartphone.</p>
	<p>Load the last protocol file at startup</p> <p>When starting the app, you can choose whether the last protocol should be loaded or not.</p> <p>Note: Even if the active protocol file has not been saved as XML, the active protocol of the previous session is available for loading when the program is started. If the app e.g. crashes or has been terminated unintentionally, the last protocol can still be restored from a backup.</p>
	<p>More features</p> <p><i>Settings</i> Select your language</p> <p><i>Help</i> Help function for the app</p> <p><i>Contact</i> Contact form</p> <p><i>Imprint</i> Legally required information about the app</p> <p><i>Credentials</i> Credentials about elements used in the app</p>

Creating an activity protocol in the HRV scanner

You can open the protocol window by clicking the "Protocol" button in the below area of the biosignal window:

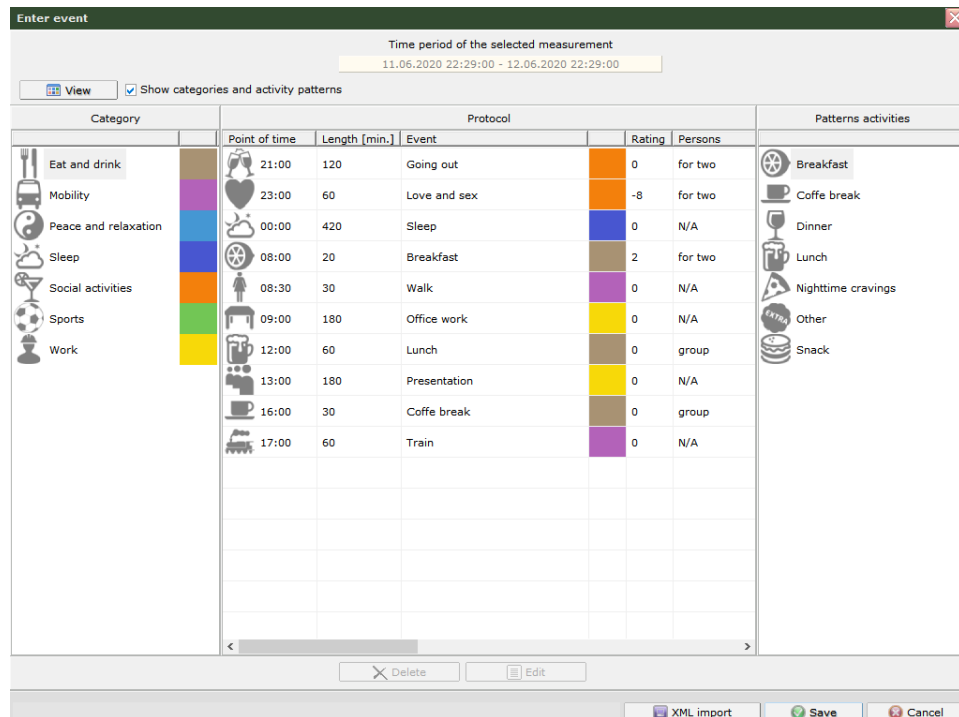
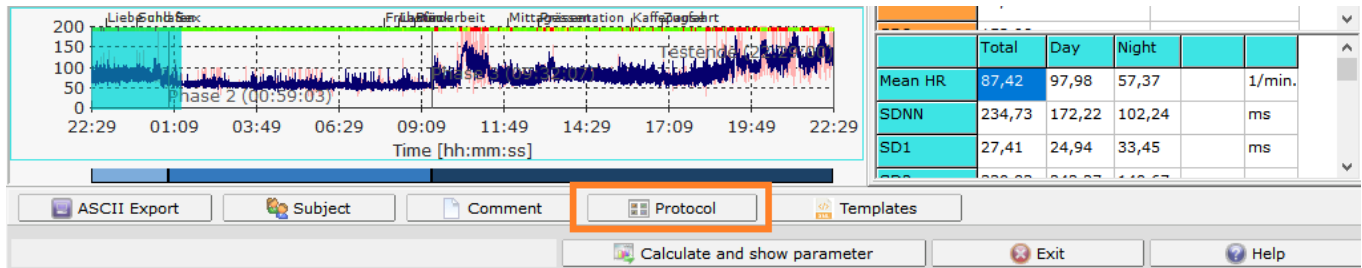


Fig.: Window for editing an activity protocol

On the right side you can see the list with the categories of the activity patterns. Select an entry with the mouse in order to display its related activities. If you want to add one of those activities to the protocol, simply drag it into the middle protocol list with the left mouse button pressed. If there are already entries, you can also place the new entry on an existing entry in order to insert it behind the existing one.

Each category contains an "Other" pattern entry. If this entry is inserted in the protocol, the activity must be described individually via the field "Name".

Dragging an entry with the mouse into the protocol list activates the window for the further properties of an activity:

- Start time, stop time or duration
- Name if "Other" is selected
- Comment
- Rating (regarding tension and relaxation)
- Indication of whether the activity was done in accompaniment or alone

Fig.: Properties of a protocol entry

To add an event to the list, enter a time in the format "hh: mm" (two-digit hour, two-digit minute). Whether you have to enter the actual time or the time after the start of the measurement depends on the type of display you have selected in the biosignal window under "View" ("t = 0" or "Time of measurement"). Enter the duration of the event and, if necessary (if you have selected the "Other" template) a description. With "Apply" you add the event to the list.

In the protocol list it is also possible to edit existing events. Therefore doubleclick on an entry or select the entry and press "Edit".

The events are shown in the analysis in the heart rate diagrams and in the HRV history.

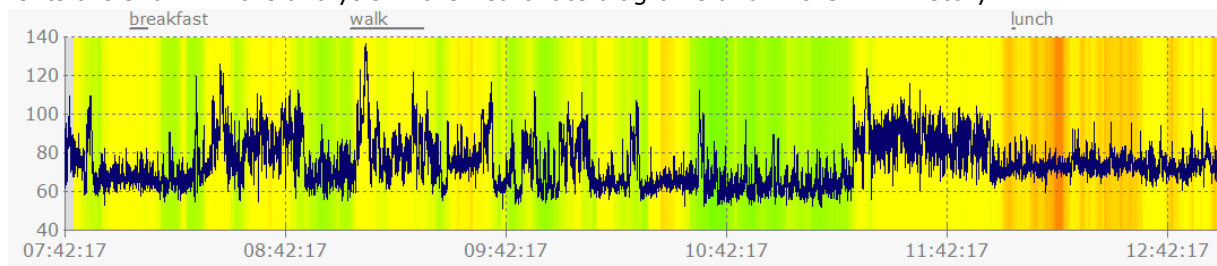


Fig.: Entries from the protocol list in the HRV graph

For a better overview in the input window for the activity protocol, you can change the view (small or large symbols) and hide the list of categories and activity templates.

Entries can be removed from the protocol with "Delete".

Import data from an XML protocol file created with the smartphone app

Your patients can provide you with their recorded activities as an XML file, for example by email. You can import this via "XML import" in the input window for the activity log.



The screenshot shows a window titled "XML import from app protocol" with a table of activities. The table has columns: Event description, Category, Start, Stop, Rating, Persons, and Comment. Activities are color-coded: green for those within the selected time period and gray for those outside. Below the table, there is a section for the "Time period of the selected measurement" showing the dates 11.06.2020 22:29:00 - 12.06.2020 22:29:00, an "Open file" button, and a file path. At the bottom, there is a note about green and gray entries and three buttons: View, Apply, and Cancel.

Event description	Category	Start	Stop	Rating	Persons	Comment
Breakfast	Eat and drink	11.06.2020 09:00	11.06.2020 09:30	4	for two	
Work on PC	Work	11.06.2020 09:30	11.06.2020 12:30	-5	alone	
Lunch	Eat and drink	11.06.2020 12:30	11.06.2020 13:00	5	group	
Meeting	Work	11.06.2020 13:00	11.06.2020 15:00	-5	group	
Coffe break	Eat and drink	11.06.2020 15:00	11.06.2020 15:30	4	alone	
Office work	Work	11.06.2020 15:30	11.06.2020 18:00	0	N/A	
Car driving	Mobility	11.06.2020 18:00	11.06.2020 18:20	0	N/A	
Running	Sports	11.06.2020 19:00	11.06.2020 20:00	0	N/A	
Personal hygiene	Peace and relaxation	11.06.2020 20:00	11.06.2020 20:30	0	N/A	
Going out	Social activities	11.06.2020 21:00	11.06.2020 23:00	0	for two	
Love and sex	Social activities	11.06.2020 23:00	12.06.2020 00:00	-8	for two	
Sleep	Sleep	12.06.2020 00:00	12.06.2020 07:00	0	N/A	
Breakfast	Eat and drink	12.06.2020 08:00	12.06.2020 08:20	2	for two	
Walk	Mobility	12.06.2020 08:30	12.06.2020 09:00	0	N/A	
Office work	Work	12.06.2020 09:00	12.06.2020 12:00	0	N/A	
Lunch	Eat and drink	12.06.2020 12:00	12.06.2020 13:00	0	group	
Presentation	Work	12.06.2020 13:00	12.06.2020 16:00	0	N/A	

Time period of the selected measurement
11.06.2020 22:29:00 - 12.06.2020 22:29:00

Open file

\\...\\Protokoll_20200611.xml

* entries marked in green are completely or partially within the period of the current measurement, those marked in gray are outside

View Apply Cancel

Fig.: Content of a XML protocol file

Only entries can be accepted that are wholly or at least partially within the period of the selected measurement. These are marked green in the window. With "Apply" you can apply the entries from the opened XML file to the protocol.

Entries that are already in the protocol are not accepted again.

Long-term Analysis - Step 2

In addition to the usual depiction of the analysis in the HRV-Scanner (parameter list, bar chart, heart rate graph, Poincaré diagram, spectral analysis for the entire measurement and up to 3 freely configurable phases, colour FFT, 3D FFT) the new long-term analysis module includes a colour shaded HRV graph.

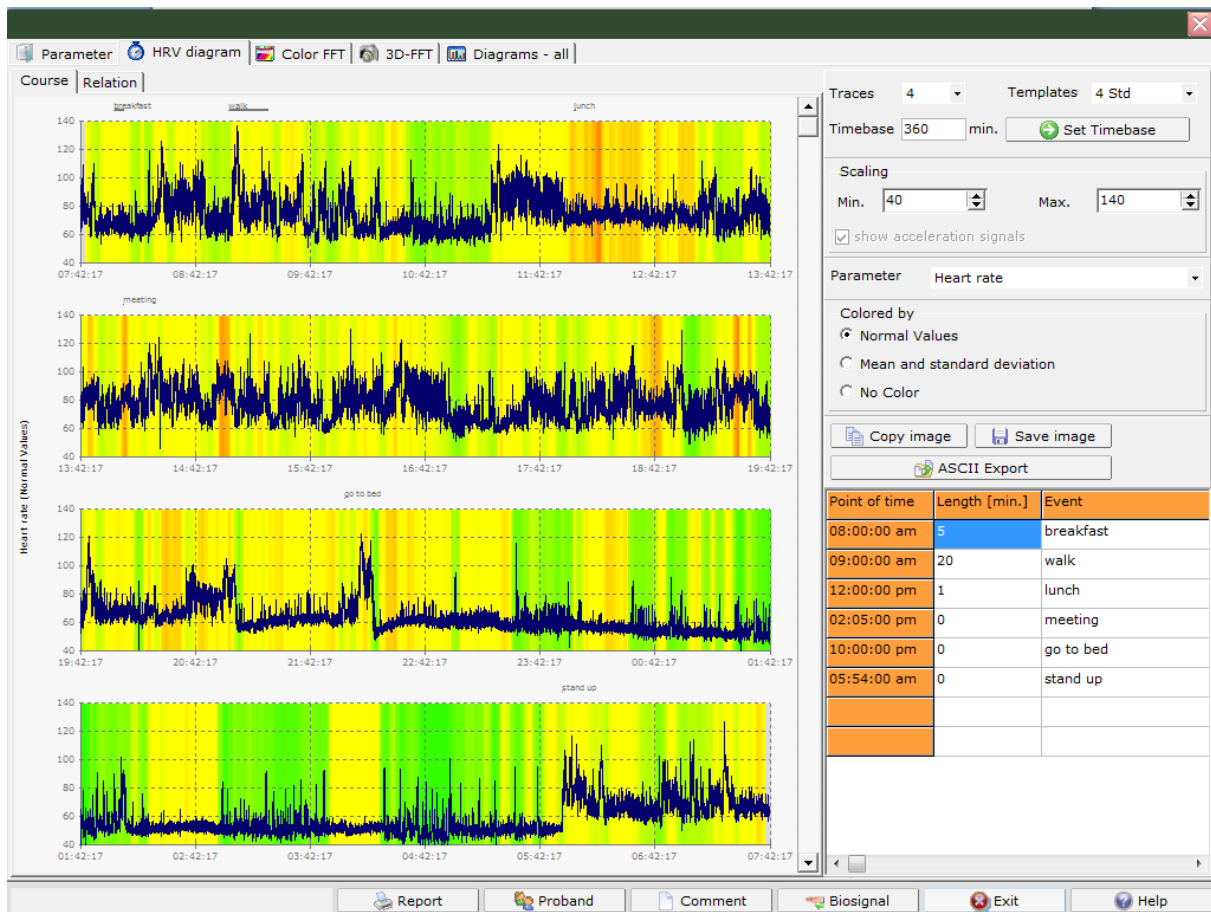


Abb.: Fig.:

Analysis window overview - Step 2

Long-term Analysis - Step 2 - HRV Progress

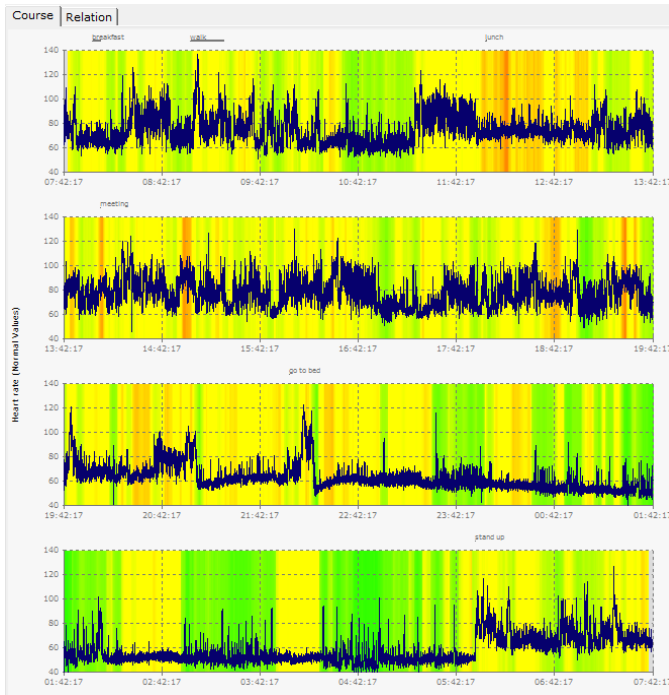


Abb.: HRV progression

In comparison, the percentage distribution of the recorded sections for the adjusted parameter is shown in the comparison total/phase 1 - 3 or in the day/night comparison.

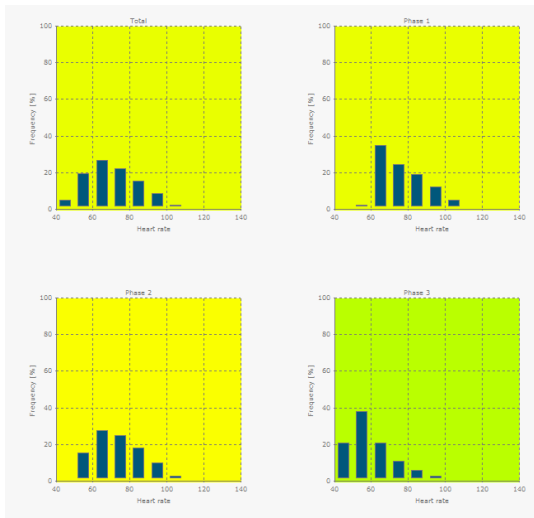


Fig.: Comparison overall/phases (1-3)

The colours displayed in the HRV graph are determined by the ranking of the age correlation of the Short-Term HRV measurement as a percentage. To this end the long-term measurement is divided into a number of short-term measurements (5 minutes each) and the ranking of the age correlation is calculated as a percentage for each section.

Alternatively the colour can be calculated on the basis of "average value and standard deviation". It is also possible to display graphs without colour shading.

The following parameters can be selected for the HRV graph display:

heart rate, average HF, St. Dev., SD1, SD2, stress index, in (stress index), power HF, power LF, power total, in (power HF), in (power LF), in (power total), LF/HF Ratio, percent ranking (short-term HRV), degree of rhythmisation.

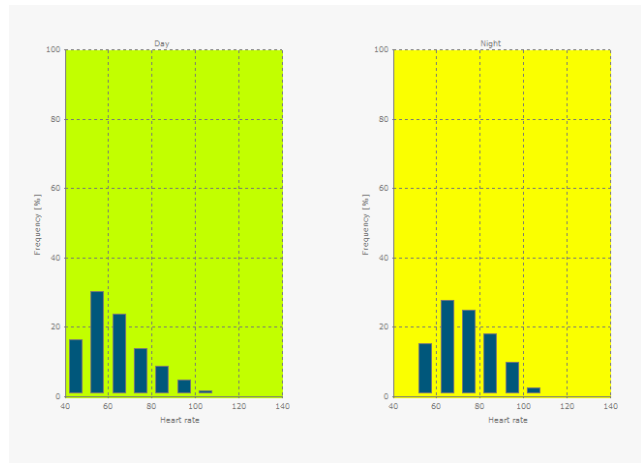


Fig.: Comparison day/night

Extended 24h analysis

Introduction:

With the advanced 24h analysis, there are several new features available that allow an even more accurate assessment of the 24 hour HRV:

- Detailed assessment of measurement quality in the 24-hour process.
- Analysis of abnormalities in HRV (percentage HRV parameters beyond 1% and 99% percentiles respectively) for day and night.
- Spiderweb plots with normative percentiles for many parameters for day and night.
- Assessment of nocturnal recovery (day / night shift HRV).
- Heart beats in 24 h, heart rate and nocturnal lowering
- Specific performance indexes for the sympathetic and parasympathetic, each for day and night.
- "Functional HRV Age": calculation of a functional HRV age as the biological age of the autonomous nervous system. A high functional HRV age may indicate an increased cardiovascular risk.
- Sleep: Scan for Obstructive Sleep Apnea (OSA) with calculation of the probability that OSA is actually present (Post-Test Probability).

Click on the "Extended 24h analysis" button in order to start the extended 24h analysis. Please note that you can move this evaluation window on the desktop independently of the actual HRV scanner window, so that you can view the additional evaluations in parallel to previous diagrams.

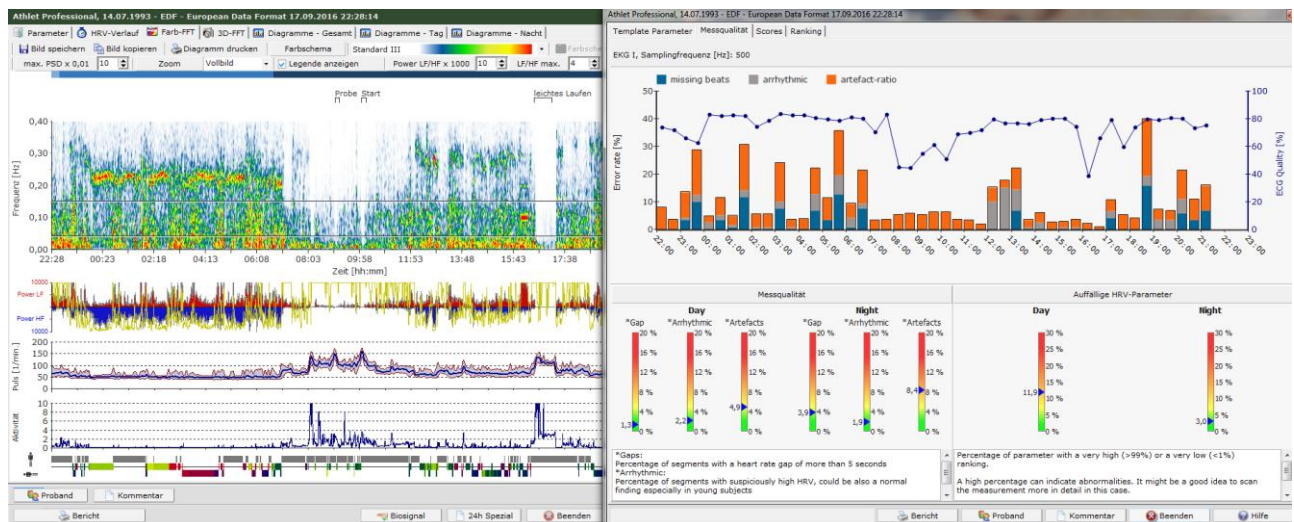


Image: Arrangement of the 24h analysis window next to the main window is possible

Detailed assessment of measurement quality

The basis of every HRV measurement is an artifact-free registration of the ECG curve. Motion artifacts, poor electrode contact, or other sources of interference, such as electrical noise, can lead to a poor quality ECG. This makes the recognition of the heartbeat difficult or it may result in errors in the calculation of the heart rate curve.

In order to assess the validity of an HRV measurement, it is therefore always necessary to consider the quality of the measurement. There are two new charts in the HRV scanner:

- Measurement quality broken down over time
- Measurement quality added up for the day the night

The following sources of interference are recorded:

Gaps

Specifies the percentage of segments containing gaps in the heart rate curve longer than 5 seconds. Gaps occur when, for example, an unfavorable ECG lead has been selected and the R-waves are very small and are not reliably detected by the QRS analysis. But gaps also arise when, for example, a severely blurred ECG (muscle and motion artifacts) leads to many false-positive detected R-waves, which are then filtered out in the second step.

Arrhythmia

Specifies the percentage of segments with conspicuously high HRV. In particular, rapid heart rate changes, as typical of arrhythmias or artifacts, are weighted. However, high arrhythmia levels are not proof of a possible arrhythmia, as children and athletic young adults sometimes have a very high HRV, but this is physiological. In our experience, falsely high arrhythmia levels no longer occur in subjects with sinus rhythm older than 30 years. In case of doubt, it is advisable to take a closer look at the ECG and the heart rate curve. Often, the artifacts are not sufficiently eliminated, or the heart rate curve has not yet been filtered.

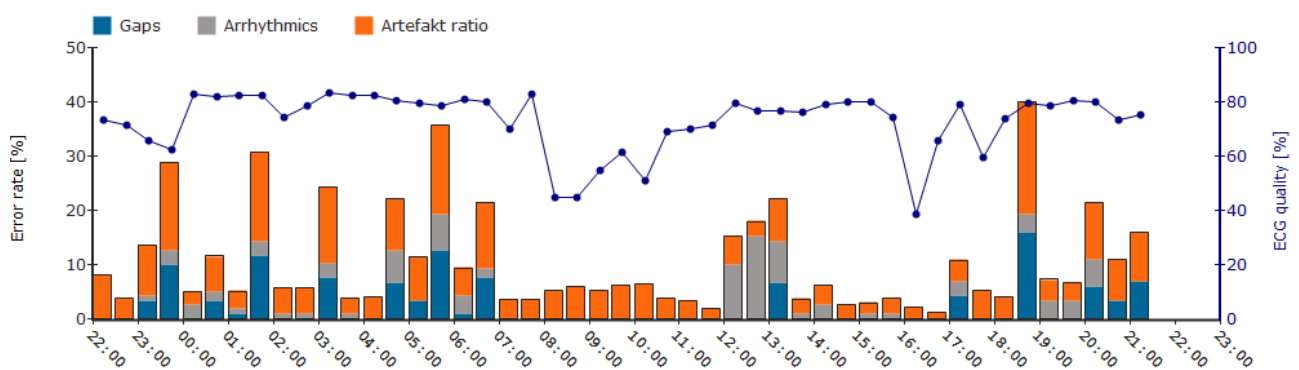
Artifact Ratio

The Artifact Ratio indicates the percentage of how many heartbeats were removed by filtering. The higher the ratio, the more heart beats were recognized, but classified by the user as not to the sinus rhythm and removed by filtering. The cause can usually be found in the ECG. In most cases, these are misrecognized R waves due to movement and muscle artifacts.

Note: If the heart rate curve has not yet been filtered, the artifact ratio is by definition 0%. But this is not to be confused with an artifact-free heart rate curve!

ECG quality

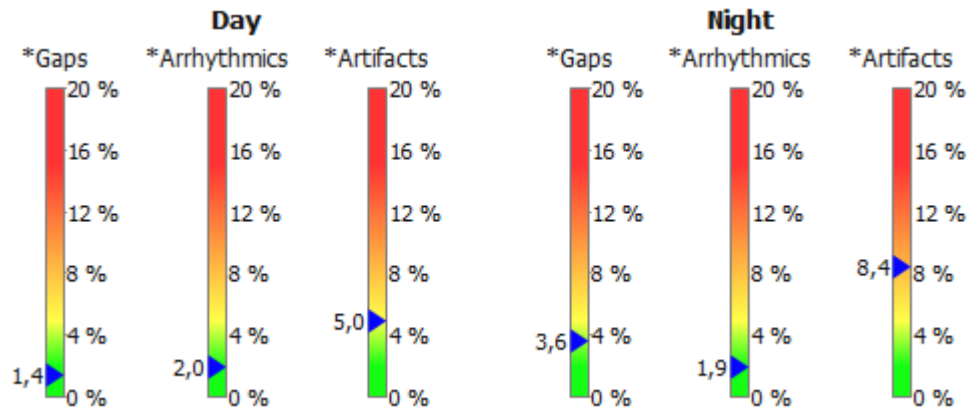
False or unrecognized heartbeats are usually caused by signal disturbances of the ECG. For this reason, the HRV scanner analyzes the ECG for typical disorders, e.g. net hum or motion artifacts and calculates an ECG quality between 0-100% for half-hour periods. Well-usable ECGs usually have an ECG quality of > 80%. Highly sinking ECG qualities are a sign of signal interference, e.g. during sports or as a result of poor electrode contact. The lower the ECG quality and the higher the interference in a certain period of time, the more restrained should the HRV of this period be interpreted.



Picture: Display of the measuring quality in the 24h-course. The individual sources of error (gaps, arrhythmia, artifact ratio) are displayed as error bars for every half hour, the ECG quality as a blue curve with an ECG quality for every half hour.

Note: If the 24h analysis was generated from a heart rate list (also called the RR or IBI list), there is no ECG quality indication due to the missing ECG.

The average error rates are reported separately for day and night. In general, the lower the error rates, the more plausible is the HRV analysis.

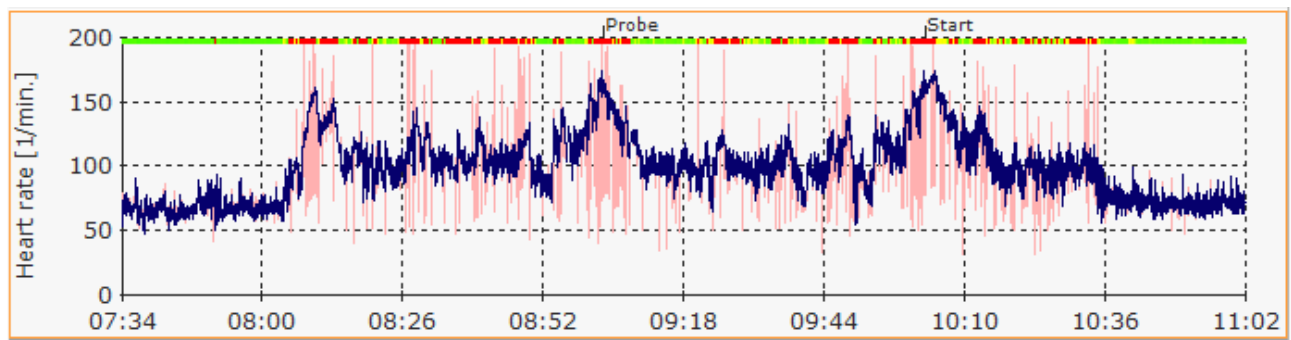


Picture: Average quality of measurement separated for day and night.

In the ECG study in healthy volunteers, from which the normal values for 24h HRV were derived, the error rates on average were: gaps: 0.1%; Arrhythmic: 1.8%; Artifacts: 1.1%. (The arrhythmia score of 1.8% on average in the study is not based on arrhythmias or artefacts, but is the result of numerous young study participants and their age-typical high HRV.) The arrhythmia value of the study participants older than 30 years was 0.2%).

Note:

The ECG quality is shown in the heart rate diagrams as a thin colored line according to the traffic light principle. As a result, indications of possible disturbances in the ECG signal are already obtained during the inspection of the heart rate curve. Since the calculation of the ECG quality is very computationally intensive and takes between 5-20 seconds, depending on the performance of the PC, the calculation has been moved to the background. Once the calculation is complete, the ECG quality is displayed. However, you can continue to work with the HRV scanner as you like, while the calculation runs in the background.



Picture: Display of the ECG quality according to the traffic light principle as a thin colored line at the top of the heart rate diagrams. In the above example, ECG disturbances are caused by motion artifacts during physical activity.

Abnormalities in the HRV

A good starting point for the HRV analysis is an overall assessment of whether it is a "normal" HRV measurement. "Normal" in this context means that most HRV parameters are in the normal range. For this purpose, the HRV scanner compares the respective result with the corresponding age-corrected standard value table of 67 different HRV parameters and uses this to calculate the respective rank value (ranking, percentile). Results beyond the 1% and 99% percentiles are considered "conspicuous". A high percentage of the "conspicuous" parameters may be an indication of a possible disorder in the autonomic regulation or a problem with the measurement quality.



Picture: 70-year-old male with vagal dysfunction and severe sleep apnea.



Example: 23-year-old competitive athlete with intensive training phases during the day and a restful night's sleep.

Spiderweb charts with normative percentiles

Similar to the existing ranking diagrams of the short-term HRV analysis, so-called spiderweb diagrams are now also available for the 24-hour analysis, which allow an evaluation of the HRV, see figure. The difference to the rank diagrams lies in the scaling. The ranking charts of the short-term measurements map the age-corrected percentiles (rank value) on a scale of 0% -100%. A conclusion on the underlying absolute HRV value is thus not possible. Different in the 24h analysis: The spiderweb diagrams in the 24h analysis show the absolute HRV value. This makes it easier to record changes from day to night. To determine whether it is a high, medium or low HRV value in comparison with the age group, the 95%, 50% and 5% percentiles of the respective age group are shown.

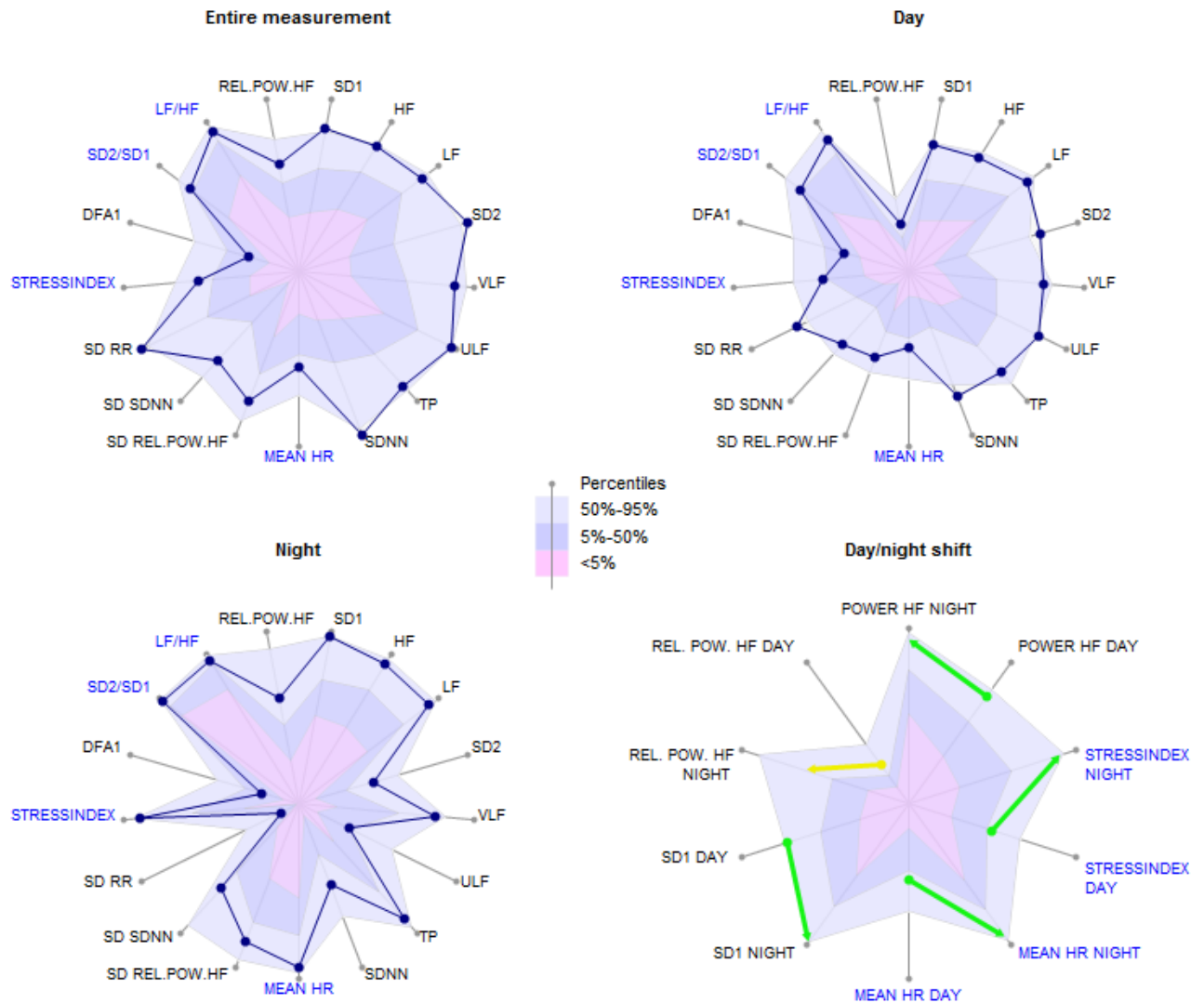


Image Spiderwebs: 23-year-old competitive athlete. Each spiderweb chart shows the 5%, 50% and 95% percentiles.

Scaling

The spiderweb diagrams are always scaled the same regardless of the subject, subject age and measurement period (day, night, total, shift). On the label of the absolute scales was omitted for reasons of readability. Due to the identical scaling, the diagrams are comparable with each other and between different subjects:

For example, on the above graph, you can see from the percentiles that the "Rel. Pow. HF", (relative power of the HF band) for most people during the day is significantly less than during the night. This corresponds to our intuitive expectation, because activities during the day require a certain amount of sympathetic activity, which leads to a reduction of rel. Power HF.

The spiderwebs show frequently used HRV parameters, which should normally not be missing from any HRV analysis. "Blue" parameter such as "Stress Index" or "Mean HR" indicate parameters where low absolute values are medically more favorable than large absolute values. The scale is interchanged with these "blue" parameters: the highest value of the scale lies inside the diagram, the smallest outside.

New in the HRV scanner are the parameters "SD RR", "SD SDNN" and "SD Rel. Pow. HF ". It is the standard deviation (SD) of the respective parameters. These are therefore measures of variation of the HRV and provide information on how strongly the individual parameters change in the respective time period (day / night / total). They are thus a measure of the change in the load. The greater the differences between stress and relaxation and the more frequent the load changes, the higher the standard deviation of HRV.

„SD RR“, also called SDANN: standard deviation of the mean value of the RR intervals in all five-minute sections of the entire record.

„SD SDNN“ Standard deviation of the SDNN of all five-minute sections of the 24-hour recording.

„SD Rel. Pow. HF“: Standard deviation of the relative power HF band of all five-minute sections of the 24-hour recording.

Note: The HRV Scanner calculates the SD-X values in moving windows with a window width of 5 minutes and a step of one minute.

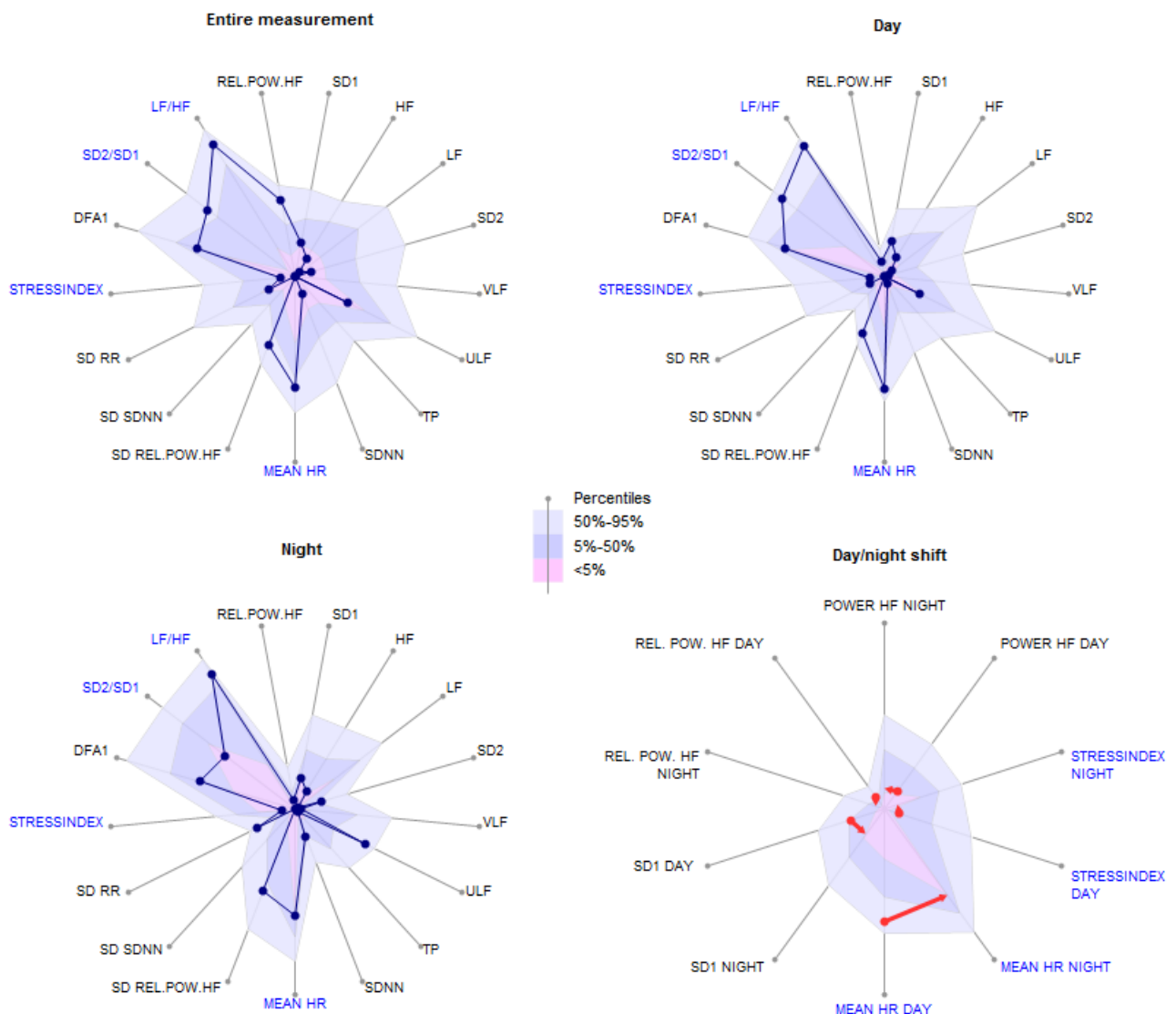


Figure: 74-year-old CHD patient with poor nighttime recovery

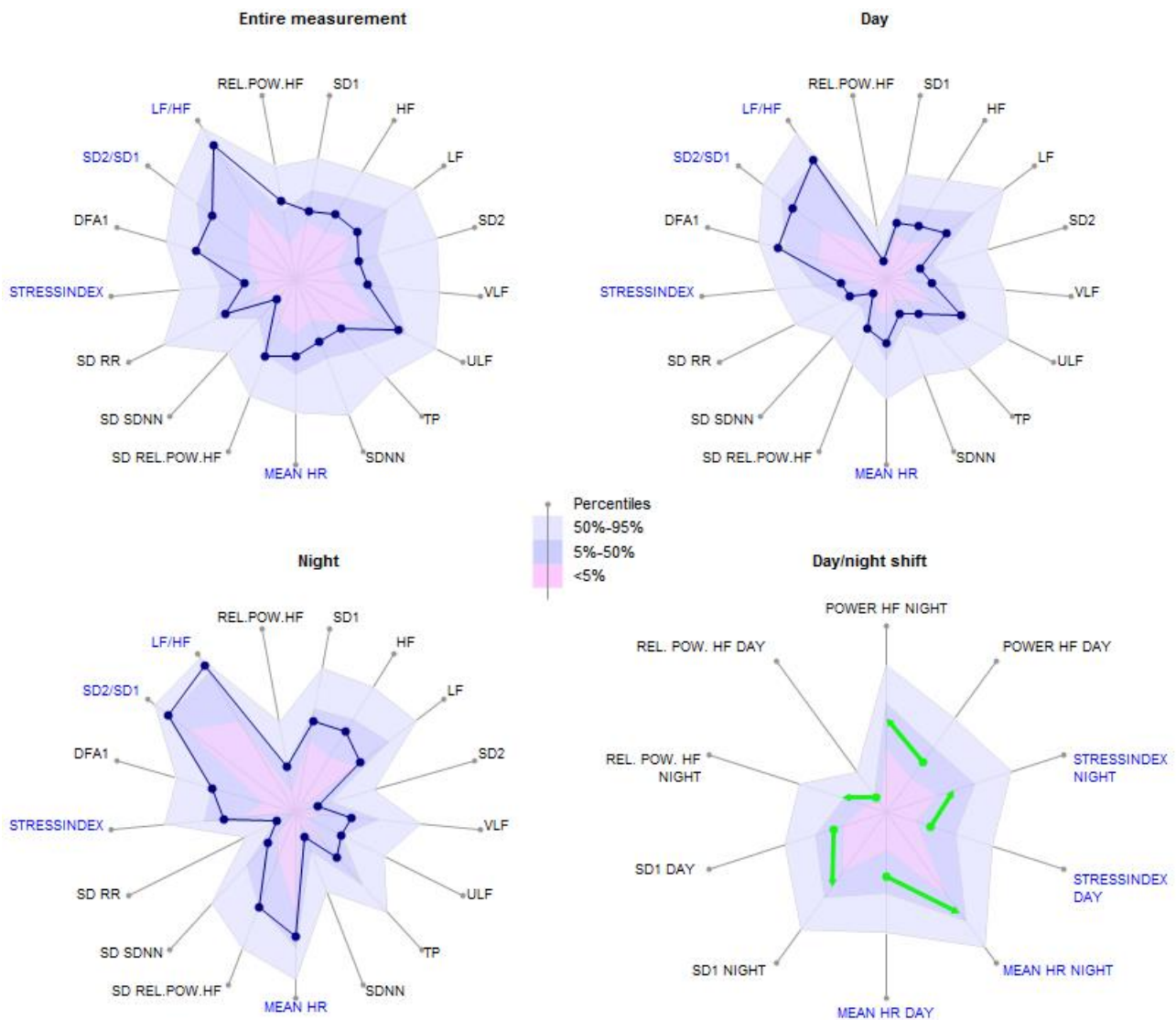
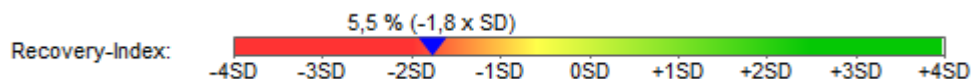


Figure: 43-year-old with average neurovegetative regulation, normal finding.

Assessment of nocturnal recovery

The Spiderweb Diagram "Day / Night Shift" displays the average daily value for some selected parameters and the corresponding night value immediately next to it (counterclockwise). The corresponding percentiles are also shown. An arrow colored after the traffic light principle shows the change of day and night. If the absolute HRV value deteriorates, a red arrow is displayed. If the absolute HRV value and the percentiles improve, a green arrow will be displayed. If the absolute HRV value improves, but the night value ranking falls by more than 5%, the arrow is yellow (not optimal regeneration). The average relative improvement in HRV parameters is also calculated as a numerical value and is available as a recovery index on the Sleep graph:



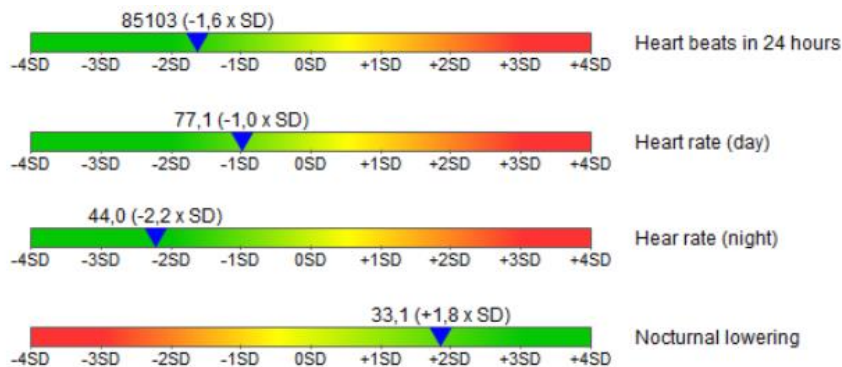
Picture: Recovery index of a patient with a sleep disorder.

The recovery index expresses the average percentage improvement in important HRV parameters during the night compared to the day. The numerical value in parentheses indicates how the calculated recovery index compares to a standard sample. On average, the subjects in the study on healthy subjects achieved a recovery index of 31% with a standard deviation of 14%. In the above example, the recovery index is almost two standard deviations below the mean, so it is a well below average recovery.

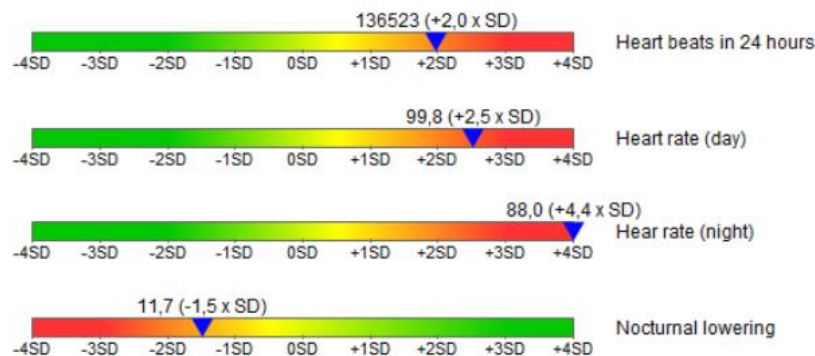
Note: The Recovery Index quantifies the difference in HRV from day to night. Are there hardly any stresses during the day, e.g. due to bed rest or long lay periods, the recovery index may be low, although the parasympathetic tone is high at night. Therefore, to interpret the recovery, it is recommended that you look at the daily stress load and parasympathetic and sympathetic activity using the following performance indexes.

Heart beats in 24 h, heart rate and nocturnal lowering

Numerous studies have shown that as the heart rate increases, the risk of mortality increases both in general (regardless of the cause of death) and in relation to common causes of death, such as cardiovascular disease and cancer. How fast the heart beats or how often in 24 hours is therefore one of the best-documented risk parameters. In the HRV scanner, the heart rate is monitored over 24 hours in the form of the number of heart beats per day. The separate observation of day and night and the fall of the heart rate at night allows a more accurate characterization of the subject's heart rate behavior.



Example of a well-trained 30-year-old athlete with a large decrease of the heart rate at night



Example of increased heart rate both during the day and at night with insufficient nighttime recovery.
47-year-old CHD patient

Specific performance indexes for the sympathetic and parasympathetic nervous system

To assess the vegetative balance, the HRV scanner calculates performance indices for day and night.

- PNS Index, (Parasympathetic Index): Based on parameters whose absolute value increases with increasing parasympathetic activity: mean RR distance, PNN50, Power HF, Rel. Power HF, SD1
- SNS index, (Sympathetic index): Based on parameters whose absolute value increases with increasing sympathetic activity: mean heart rate, SD2 / SD1 ratio, stress index.

To calculate the respective index, an age- and variance-corrected Z value is determined for each parameter and converted into a standard normal distribution by Z transformation. The resulting index is the average of the Z-transformed values of the individual parameters.

Accordingly, a PNS index of +1x SD means that the underlying parasympathetic parameters are, on average, one standard deviation above the average of a normal age group of the same age.

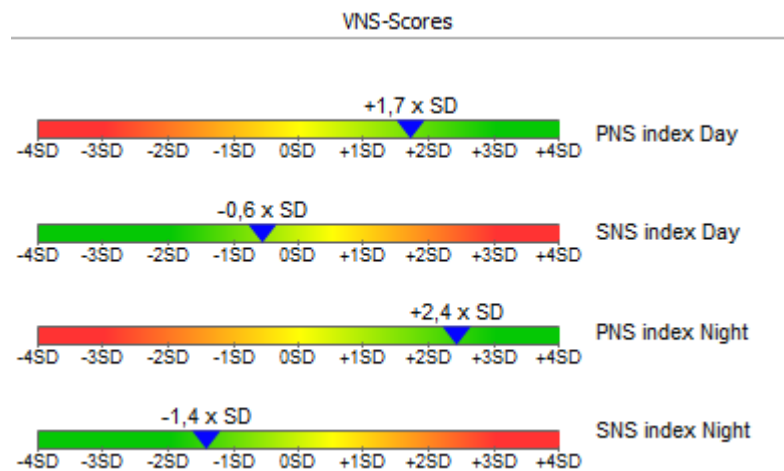


Figure VNS scores competitive athlete

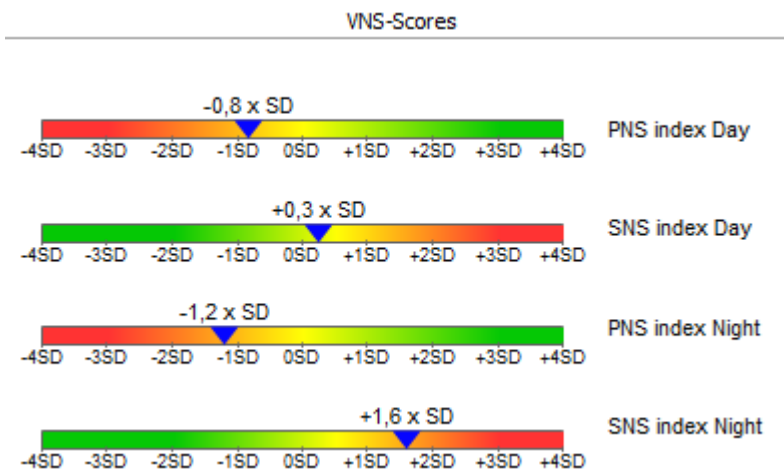


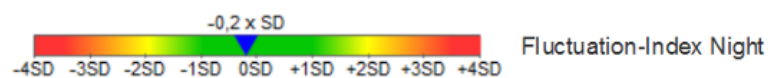
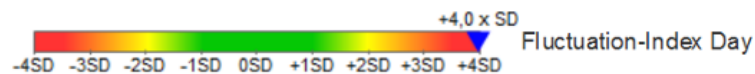
Figure VNS scores of a CHD patient

Fluctuation-Index: The Variability of the Variability

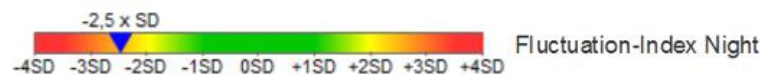
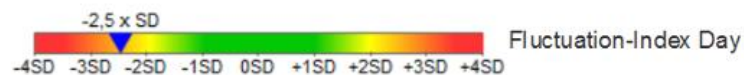
In addition to the absolute level of HRV as a measure of the functional state of the autonomic nervous system, the consideration of changes in HRV over 24 hours also provides valuable information about possible strains or overloads.

For this purpose, a fluctuation index is calculated separately for day and night. The 24h heart rate curve is split into 5-minute segments, for each of which a number of HRV parameters are calculated. For each HRV parameter, its standard deviation is calculated as a spread measure and converted into a standard normal distribution using normative values. If, for example, the associated fluctuation value for the SDNN has the value 0, this means that the fluctuations in the SDNN correspond exactly to the mean fluctuation of the norm population of the same age. A value of + 1SD corresponds to a variation of SDNN, which is one standard deviation above the mean of the age cohort.

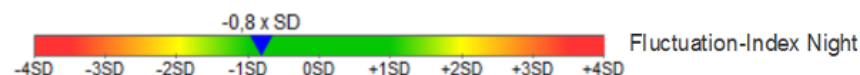
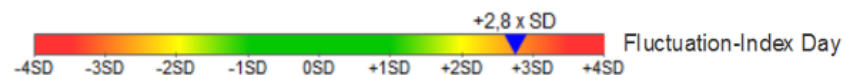
The resulting fluctuation index is the average of fluctuations of several HRV parameters. High values of the fluctuation index, in particular greater than +2 SD, indicate that HRV has bigger changes or changed more frequently than is the norm in corresponding age group.



Example: 56-year-old CHD Patient with numerous stress phases during the day



Example: 85-year-old CHD patient with consistently high sympathetic activity day and night without sufficient recovery periods.



Example: 23-year-old competitive athlete, training day. High change between strain and recovery during daytime, normal HRV fluctuation at night.

„Functional HRV Age“ and „Premature Aging (PMA)“

Age is one of the most important risk factors for cardiovascular diseases. As we age, cardiovascular events such as heart attack are more likely to occur. For this reason, the age is usually included as an important factor in the calculation of risk scores, see, for example, the Procam score. Reduced HRV may also indicate an increased cardiovascular risk.

Interesting is the joint consideration of HRV and age: With increasing age, the neurovegetative regulatory capacity and thus the HRV decreases, see figure:

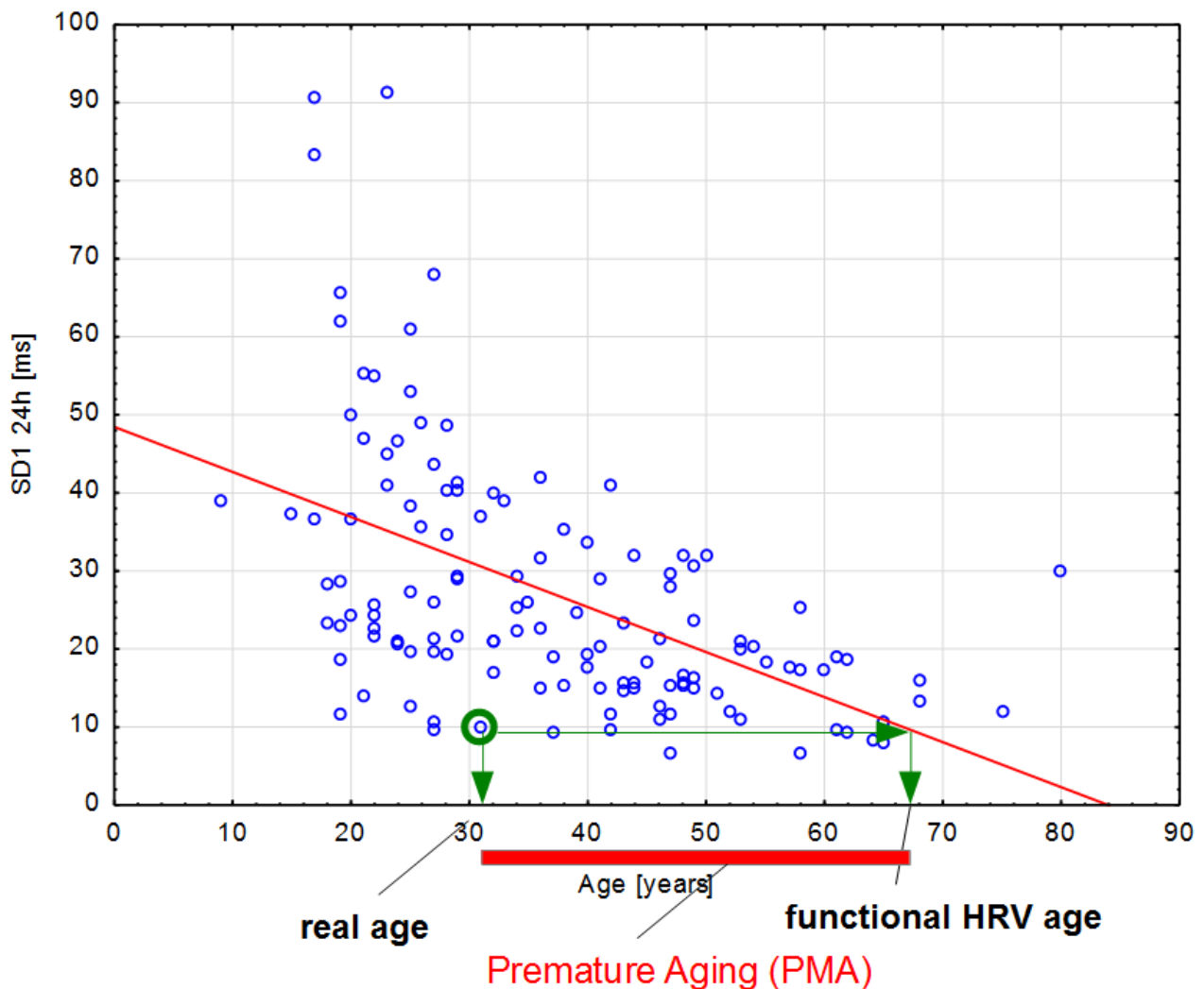


Figure: Decrease in HRV using the example of SD1 with increasing age in a standard collective of healthy volunteers.

For many HRV parameters the age of the subjects is even the most important factor for the differences in the HRV between different subjects (inter-individual variance). Low HRV values below the regression line can be interpreted in this context as premature aging (PMA) of the neurovegetative system. The extent of premature aging can be quantified by the functional HRV age (age value resulting from the intersection of the HRV value with the 50% percentile of the normal population). The difference of the functional HRV age from the actual age is the PMA Value and expresses how many years the neurovegetative system is older than the actual age. Negative PMA values indicate that the neurovegetative system is younger than his or her chronological age.

The functional HRV age and PMA value are calculated in the HRV scanner for 52 HRV parameters, which have in common that they correlate highly with age ($r > 0.5$). The resulting functional HRV age is the median of the 52 individual values.

Note: In the short-term HRV analysis, the functional HRV age is also calculated and reported as "biol. HRV age". The key difference in the calculation is the consideration of the heart rate in determining the functional HRV age in the new 24-hour analysis. It has been clearly shown in our examinations that the HRV not only depends on the age, but also strongly on the heart rate. In turn, age and heart rate are only weakly correlated, i.e. largely independent of each other. (Getting older, the heart rate usually decreases slightly). If the heart rate is not taken into account HRV is overestimated at low heart rates and underestimated at high heart rates. For this reason, we recommend using the more modern concept of functional HRV age in 24h analysis and less the biol. HRV age of the short-term analysis. In the latter case, the heart rate should always be taken into account in the interpretation.

However, the required heart rate correction for determining the functional HRV age reaches its limits in the case of strongly deviating heart rates. In such a case, the functional HRV age should be interpreted with restraint. However, the HRV-Scanner issues a warning message if it detects very high or very low heart rates.

To interpret the functional HRV age, the corresponding PMA diagram provides valuable information.

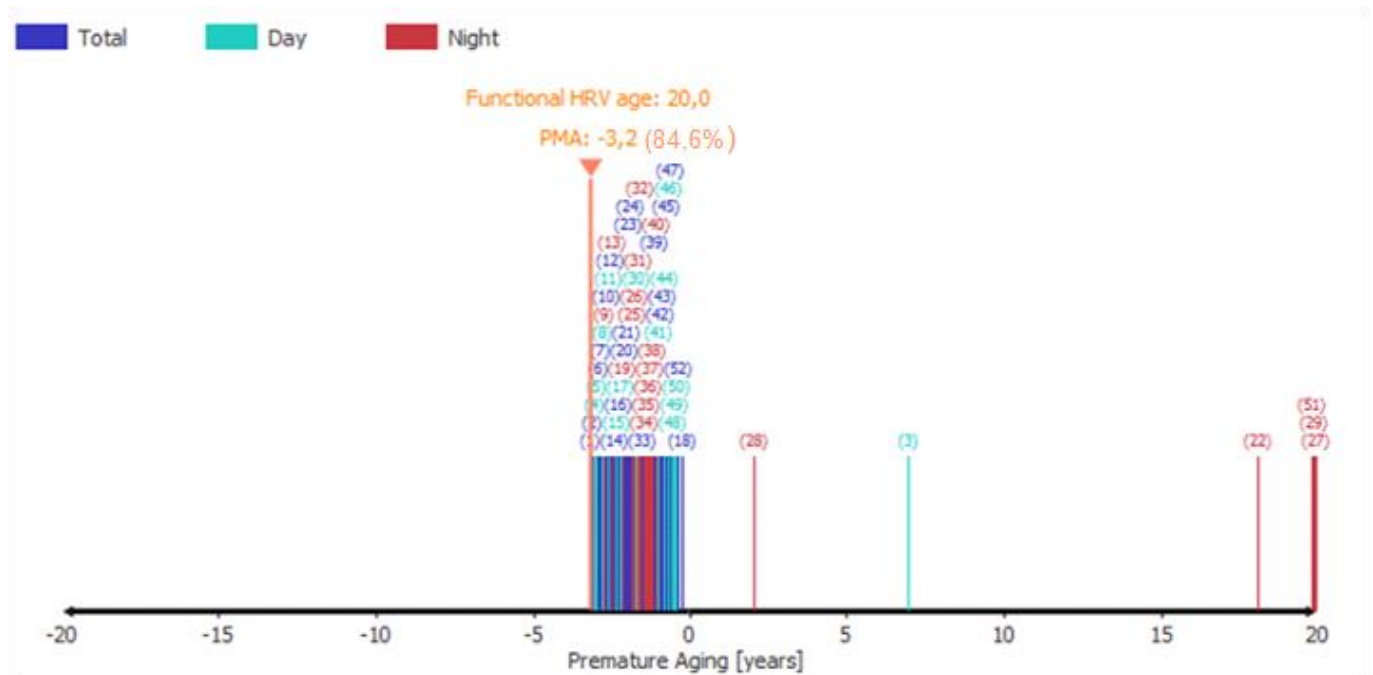


Figure: PMA diagram of a 23-year-old competitive athlete. The numbers in parentheses above the marks indicate the ID of each parameter. The percentage next to the parenthesized PMA value indicates the percentage of parameters that support the current PMA value.

Each vertical mark corresponds to the PMA value of a single HRV parameter. The color indicates whether it is a parameter of the entire measurement, only the daily values or only the night values. It can be seen in the example at first glance that almost all parameters have a negative PMA value, i.e. the resulting functional HRV age is lower than it corresponds to the actual age. It is therefore an above-average powerful neurovegetative control system.

Note:

The functional HRV age is limited to a range between 20-85 years. If, for example, an HRV age of 10 years results internally, the value is corrected to 20 years and output. For this reason there are no PMA values in the above example of a 23-year-old younger than -3 years.

For better readability of the diagram, marking lines with the same PMA value are not drawn one above the other but drawn next to the previous line. This creates the impression of a broad bar and it becomes intuitively visible in which area most PMA values lie.

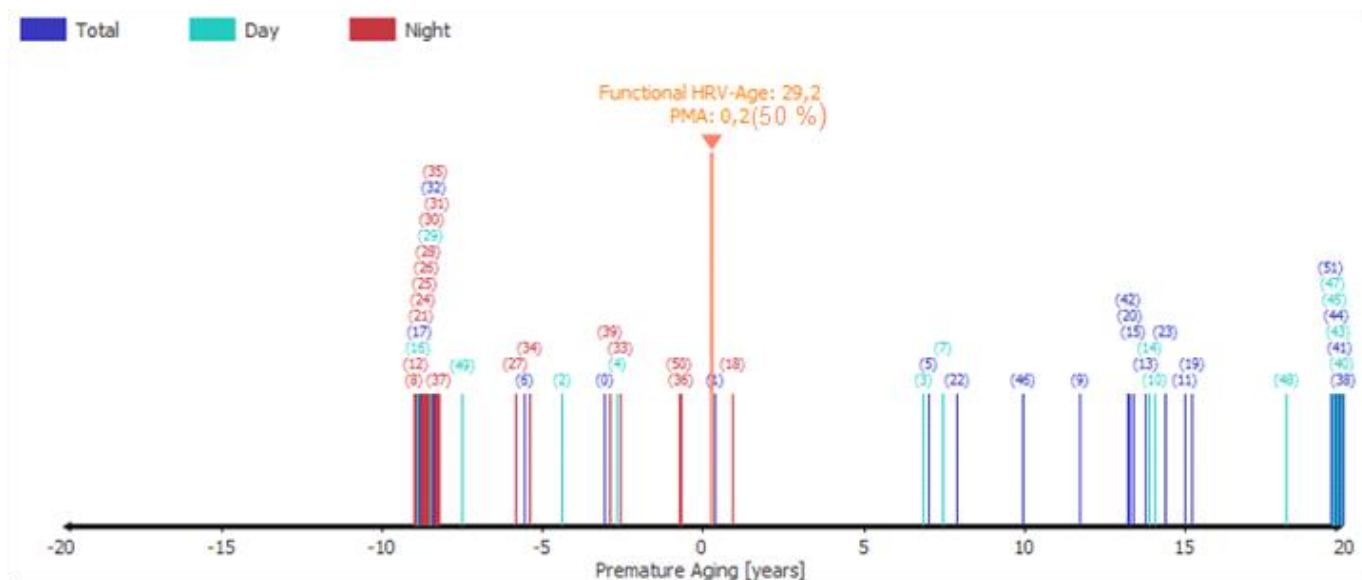


Figure: PMA chart of a 29-year-old subject. The tag values indicate a significantly higher premature aging than the night values. This is an indication that neurovegetative regulation is limited during the day. Possible causes are, for example, excessive stress during the day.

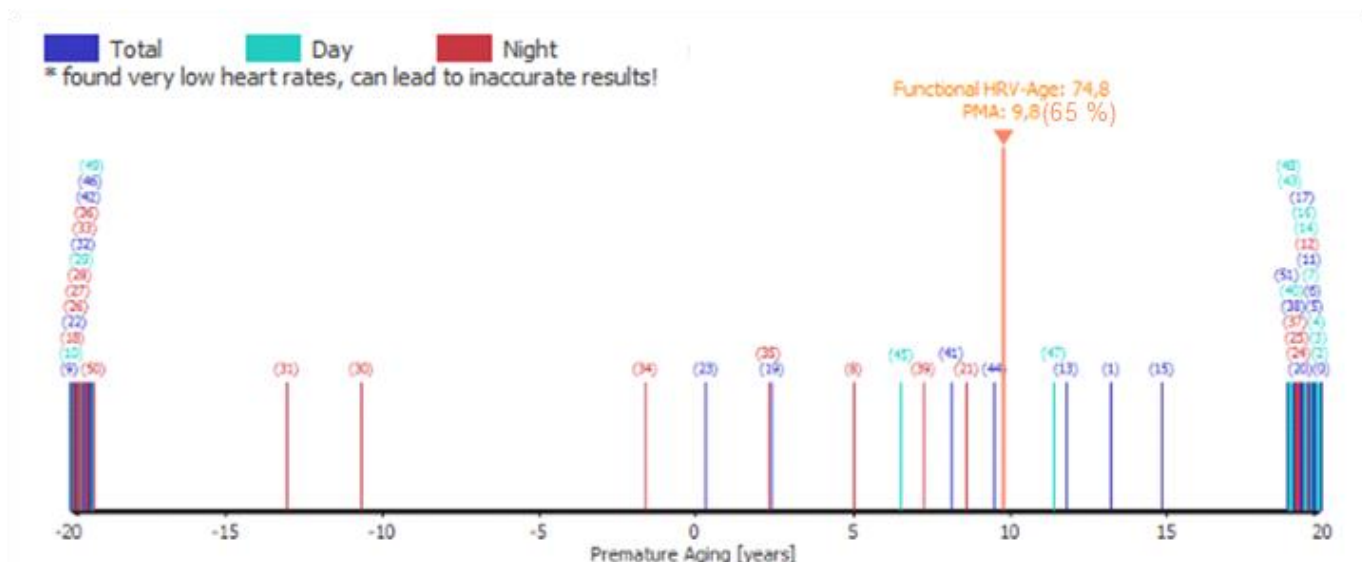


Figure: PMA diagram of a 65-year-old subject. The single PMA values split into two opposing clusters. At the same time, a heart rate alert is issued. The proportion of conspicuous parameters is around 40% for day and night, which is decidedly high. Such an HRV measurement is valid only under reserve. The PMA value and the functional HRV age should not be used.

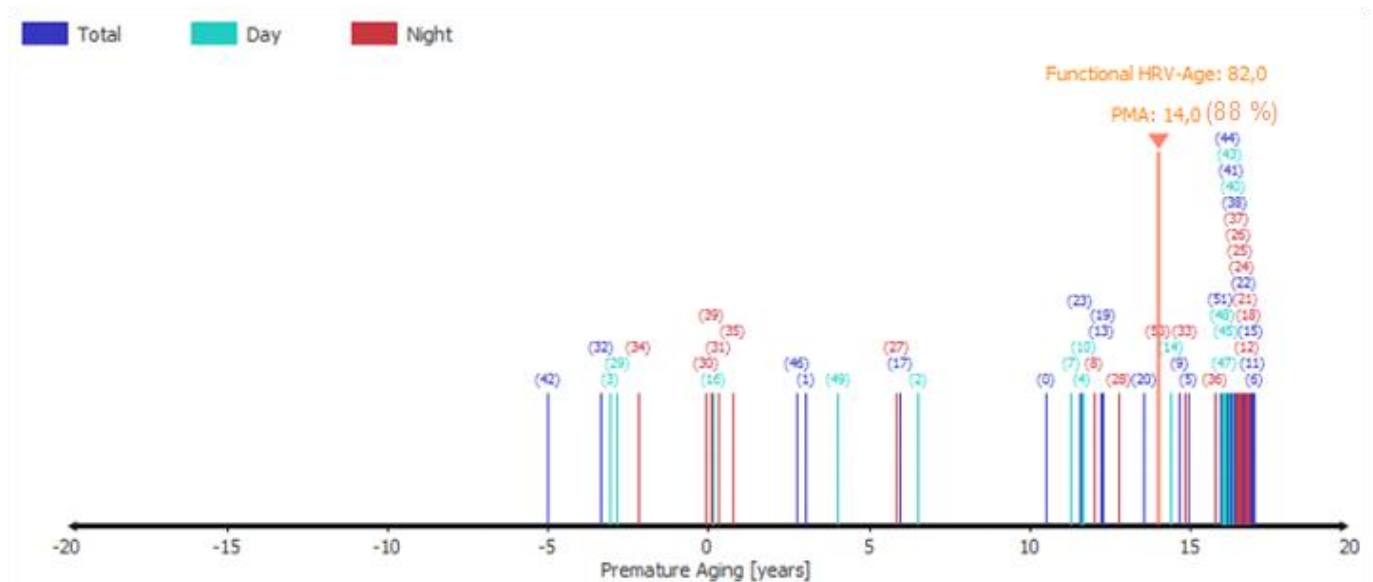


Figure: PMA diagram of a 68-year-old CHD patient. Almost all parameters have a positive PMA value. The functional HRV age is 14 years over the actual age.

Functional HRV age as a risk

We investigated whether cardiovascular disease can be distinguished from healthy individuals based on the functional HRV age. For this purpose, the data of a healthy control group ($n = 140$) were compared with those of a patient group with angiographically confirmed CHD ($n = 191$). For all calculated HRV parameters including "functional HRV age", the effect size (Cohen's d) of the group difference was calculated. The greater the difference between two groups relative to a particular parameter, the greater its effect size. To assess whether an effect size is large or small, see the table:

Effect size	d	Reference
Very small	0.01	Sawilowsky, 2009
Small	0.20	Cohen, 1988
Medium	0.50	Cohen, 1988
Large	0.80	Cohen, 1988
Very large	1.20	Sawilowsky, 2009
Huge	2.0	Sawilowsky, 2009

(https://en.wikipedia.org/wiki/Effect_size#Cohen's_d)

Of all the 311 HRV parameters studied, the "functional HRV age" with an effect size of 1.896 was the parameter with the greatest effect size and thus the best discrimination between patients with CHD and healthy subjects. Typical HRV parameters such as SDNN ($d: 0.872$), SD1 ($d: 0.654$) or Power HF ($d: 0.881$) had significantly lower effect sizes.

The top rank of effect size for "functional HRV age" persisted when CHD patients were separately enrolled in the group without beta blocker ($d: 1.571$) and beta blocker ($d: 1.972$).

Conclusion: Age is a risk for cardiovascular disease, as well as a limited neurovegetative regulation. The "functional HRV age" is a virtual age value, which basically makes a description of the neurovegetative regulation in the sense of: "The neurovegetative regulation corresponds to that of an xx year old".

The higher the "functional HRV age", the higher the cardiovascular risk. Due to the heart rate correction in the calculation of the "functional HRV age", the latter is independent of the heart rate and can even be calculated in patients undergoing beta blocker therapy.

Sleep

Sleep is a highly active process in which various degrees of activation are cycled. Deep sleep phases alternate with light sleep phases and phases of high, wakeful EEG activity with rapid eye movements (REM). During normal nighttime sleep, the influence of the parasympathetic nervous system predominates, with reduced sympathetic tone. In the REM phases, the sympathetic tone increases.

A restful sleep is essential to maintain good health. Insufficient sleep or sleep disturbances can cause serious health problems if they last longer. A well-known example is the increase in cardiovascular risk when sleep apnea occurs.

There are many problems falling asleep and staying asleep, as a result of which the quality of sleep is reduced. The natural sequence of the various sleep phases is then usually disturbed. This also has an effect on the autonomic nervous system: the predominance of the parasympathetic nervous system, which is important for recovery, is diminished or completely absent.

The diagnosis of sleep disorders is complex and usually requires the registration of many different physiological parameters in the sleep laboratory (polysomnography). The HRV analysis cannot replace this, however, the HRV analysis can sometimes provide valuable information on the presence of a sleep disorder: For example, there are characteristic changes in the frequent obstructive sleep apnea:

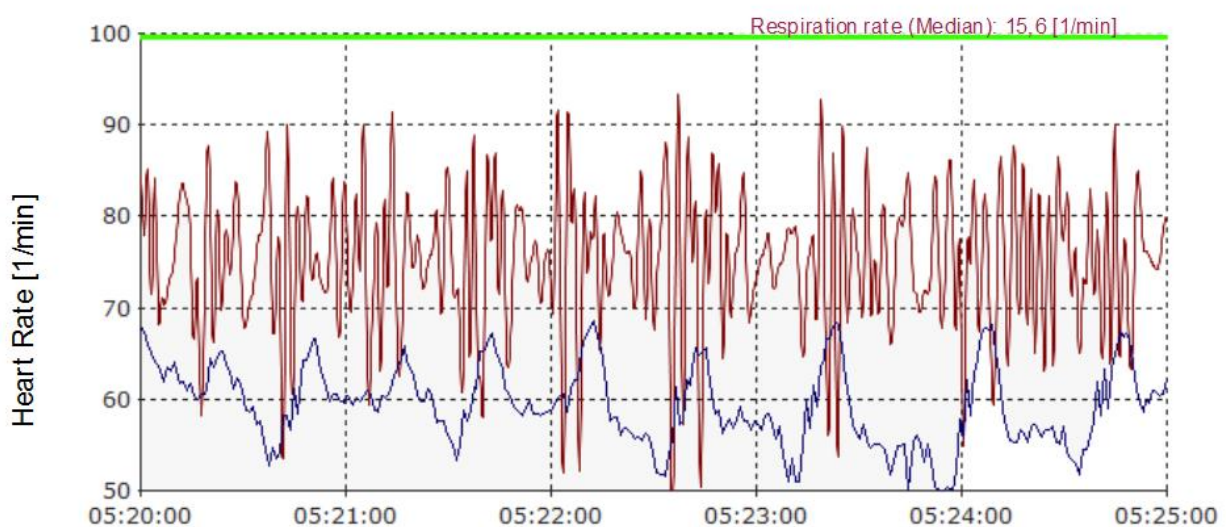


Image: Characteristic patterns of respiration (derived from ECG) and heart rate with pronounced, polysomnographically confirmed sleep apnea. There are 1-2 apnea phases per minute, accompanied by larger heart rate oscillations and a spindle-shaped breathing pattern.

The HRV scanner searches for respiratory, heart rate, and HRV patterns that are characteristic of sleep apnea. The strength and frequency of these patterns are quantified in the form of an "OSA score". The OSA score was developed using the SHHS study, which comprises several thousand polysomnographic datasets. (Quan SF, Howard BV, Iber C, Kiley JP, Nieto FJ, O'Connor GT, Rapoport DM, Redline S, Robbins J, Samet JM, PW, The Sleep Heart Health Study: design, rationale, and methods 1997 Dec; 20 (12): 1077-85. PubMed PMID: 9493915.)

For validation, the algorithm was tested on the datasets of the freely available OSA database. (T Penzel, GB Moody, RG Mark, AL Goldberger, JH Peter, The Apnea ECG Database, Computers in Cardiology 2000, 27: 255-258.) The correlation of the HRV scanner OSA score with the polysomnographically determined AHI (apnea Hypopnea index) was 0.83. Sensitivity and specificity to detect a moderate severity OSA (AHI >= 15) were 95% and 96%, respectively. High OSA scores in the HRV scanner can therefore be considered an indication of a possible sleep apnea.

However, a high OSA score does not automatically mean that obstructive sleep apnea is certain. Incidentally, this applies to all screening examinations; a positive test result is not necessarily synonymous with illness, even if that is often interpreted that way. The pretest probability (prevalence) also plays a major role:

For example, breast cancer screening has a sensitivity of about 90% and a specificity of about 94%. With a prevalence of breast cancer of 0.8%, this results in a positive predictive value (posttest probability) of about

10% for breast cancer with a positive mammogram finding. That is, only one in ten women with a positive mammographic finding actually has breast cancer. (Kerlikowske K, Grady D, Barclay J, Sickles EA, Serious V. Likelihood Ratios for Modern Screening Mammography.) JAMA, 1996 Jul 3; 276 (1): 39-43.) (Depending on the underlying study, this value is slightly larger or smaller, but always on a similar scale).

The critical size of a diagnostic test is the likelihood ratio (LR) of the test because LR and prevalence can be used to calculate the probability of post testing, i.e. the likelihood that a positive test result will actually be present. For more information on the LR see also:

https://en.wikipedia.org/wiki/Likelihood_ratios_in_diagnostic_testing

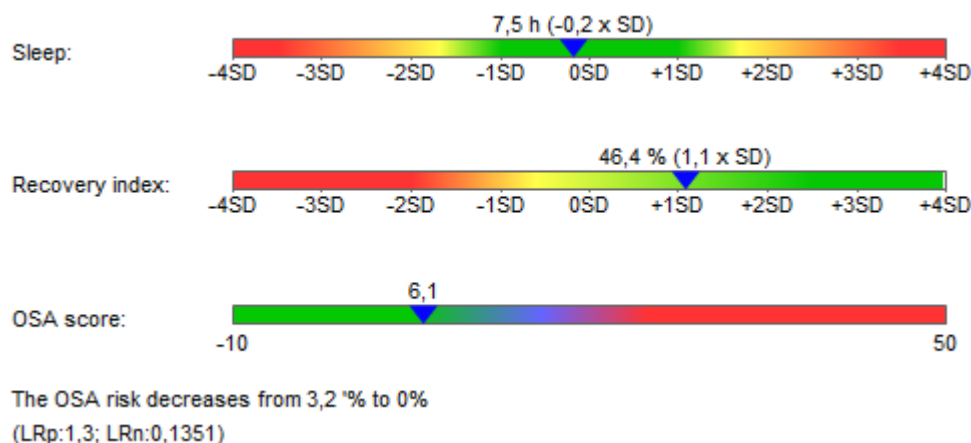
In short, the positive likelihood ratio (LRp) indicates how much more often a sufferer receives a positive test than a healthy one. The negative likelihood ratio (LRn) indicates how much more frequently a patient receives a negative test result than a healthy one.

Incidentally, the LR for mammography screening is about 14, i. Positive mammography is 14 times more common in breast cancer patients than in women without breast cancer.

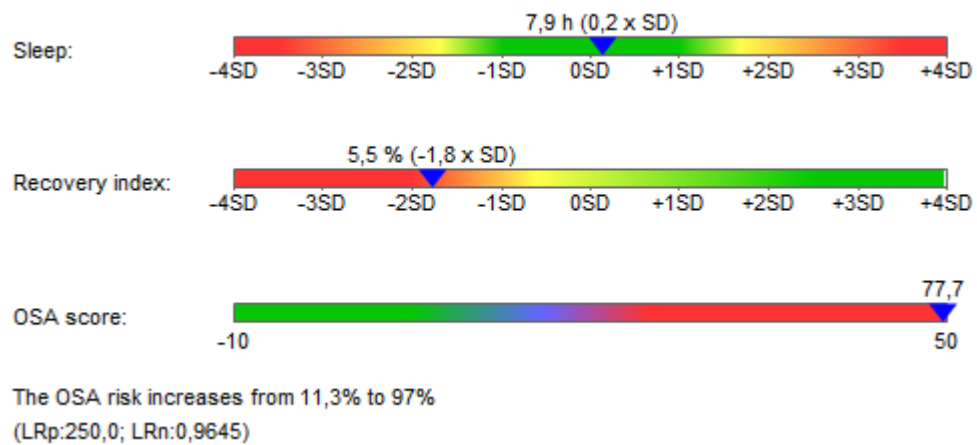
The HRV scanner calculates the associated likelihood ratios (LRs) for each OSA score. The prevalence table and LRs are also used to calculate the likelihood (posttest probability, positive predictive value) of sleep apnea (Punjabi NM., The epidemiology of adult obstructive sleep apnea, Proc Am Thorac Soc. 2008 Feb 15; 5 (5). 2): 136-43 doi: 10.1513 / pats.200709-155MG.).

	20-44 Years	45-64 Years	>64 Years
Men	3,2	11,3	18,1
Women	0,6	2,0	7.0

Table: OSA prevalence



Picture: Sleep parameters of a healthy subject. A low OSA score lowers the probability of OSA



Picture: Sleep parameters of a patient with polysomnographically confirmed OSA.

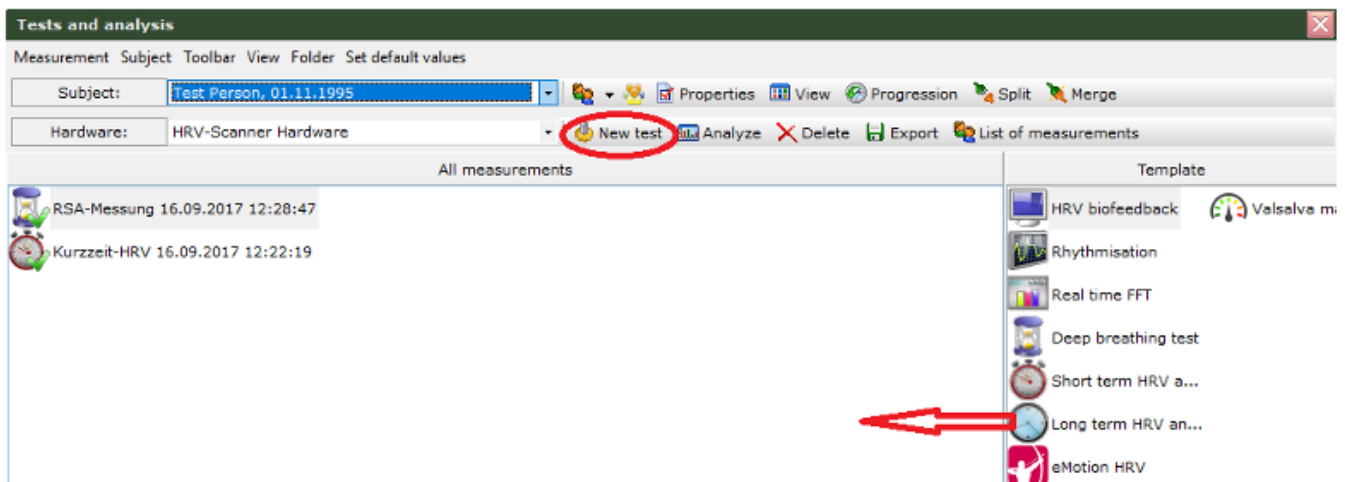
Note: HRV analysis cannot replace the diagnosis of OSA using polysomnography. However, high OSA scores in the HRV scanner, especially in conjunction with clinical symptoms such as increased daytime sleepiness, should make one think of sleep apnea.

Working with templates in the HRV-Scanner

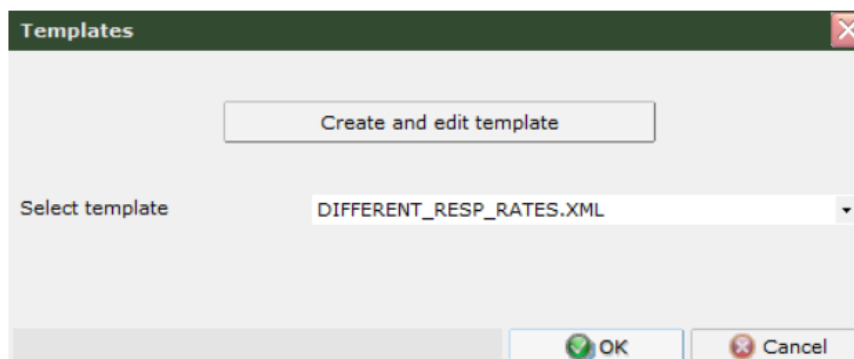
Templates extend the analysis options of the HRV-Scanners. Instead of a maximum of three phases it is now possible to define and analyze up to 60 different parts for each measurement.

Creating Templates

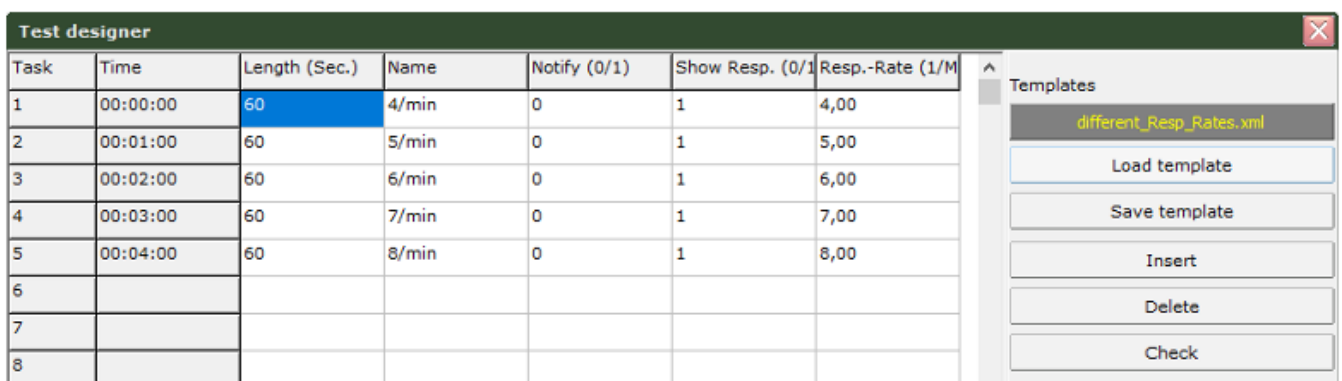
In order to create a new template, start a new long term HRV test as usual.



A window will appear where you can either create and edit a template or select a template.

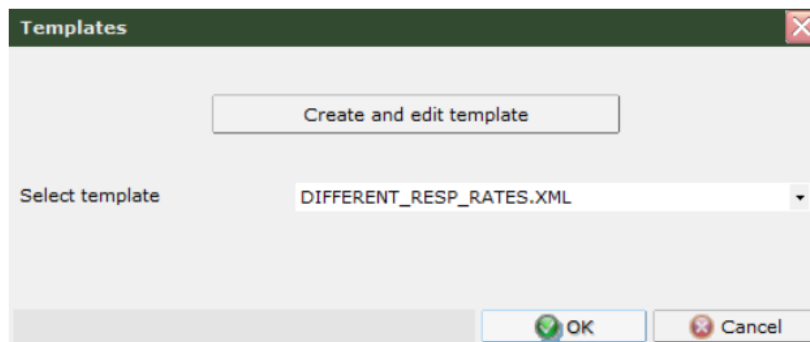


Press on 'Create and edit template' in order to start the Test-Designer.



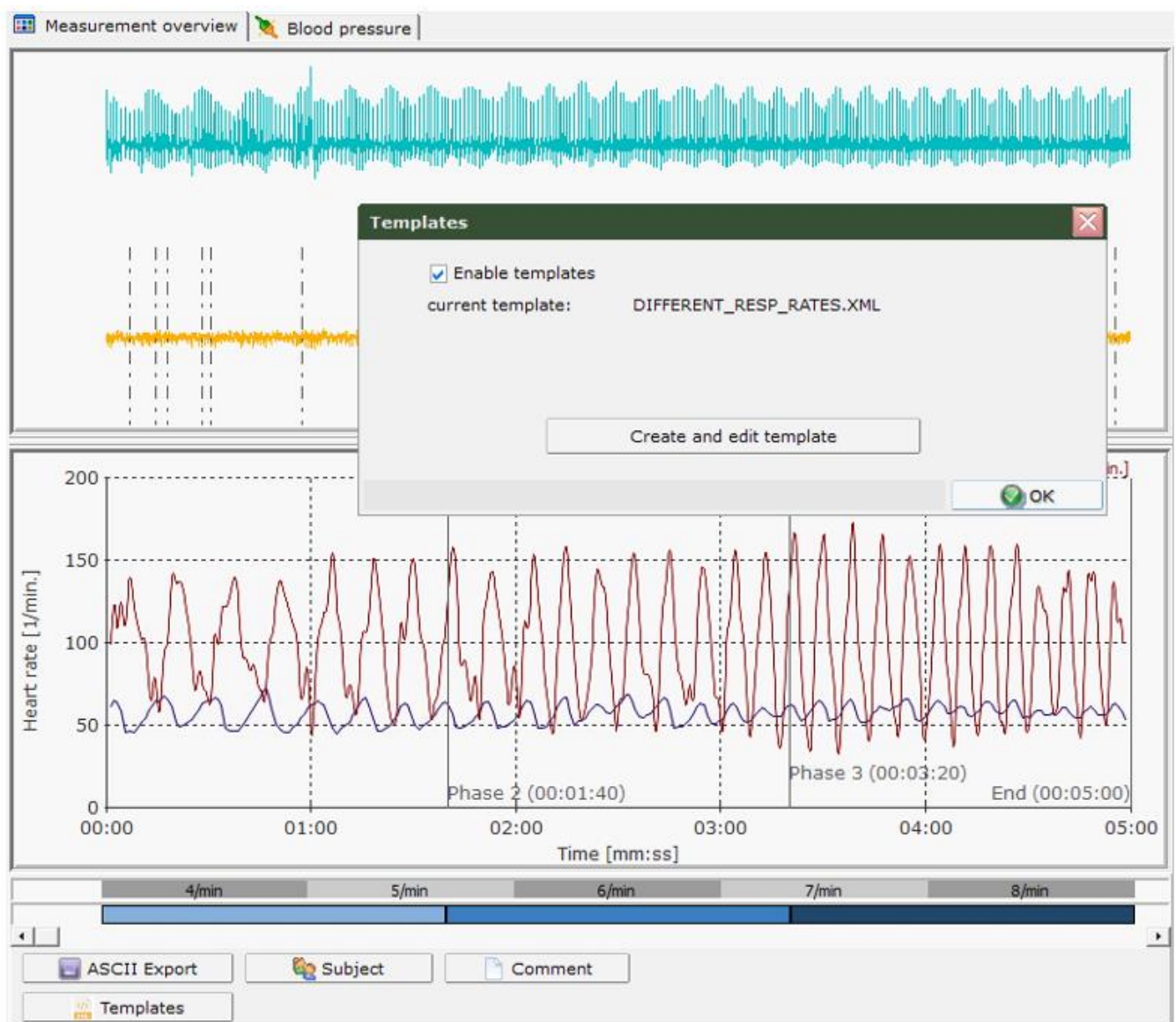
Define the desired number of tasks. By means of the 'Notify' field you can activate a message box, which occurs several seconds before the related tasks starts. The field 'Show Resp.' determines whether a breathing aid is displayed or not. In 'Resp-Rate' you can specify the corresponding respiration frequency. Save the template after completion. Please notice that it has to be saved in the folder 'XMLTemplate'.

Choose the desired template and press OK in order to start the measurement.



Analysis with Templates

Every recorded measurement can additionally be analyzed with templates. In case of a long term measurement, the corresponding template will be automatically loaded. For all other measurements templates can be added or created. If a template is active the respective tasks of the template are depicted above the phase bars.



Please note that all changes on the templates of a certain measurement are saved in the corresponding data file and do not affect other templates or measurements!

For every task of the template several parameters and diagrams are calculated and shown on a spreadsheet.

23.03.1966 - Langzeit-HRV 04.10.2023 19:15:44

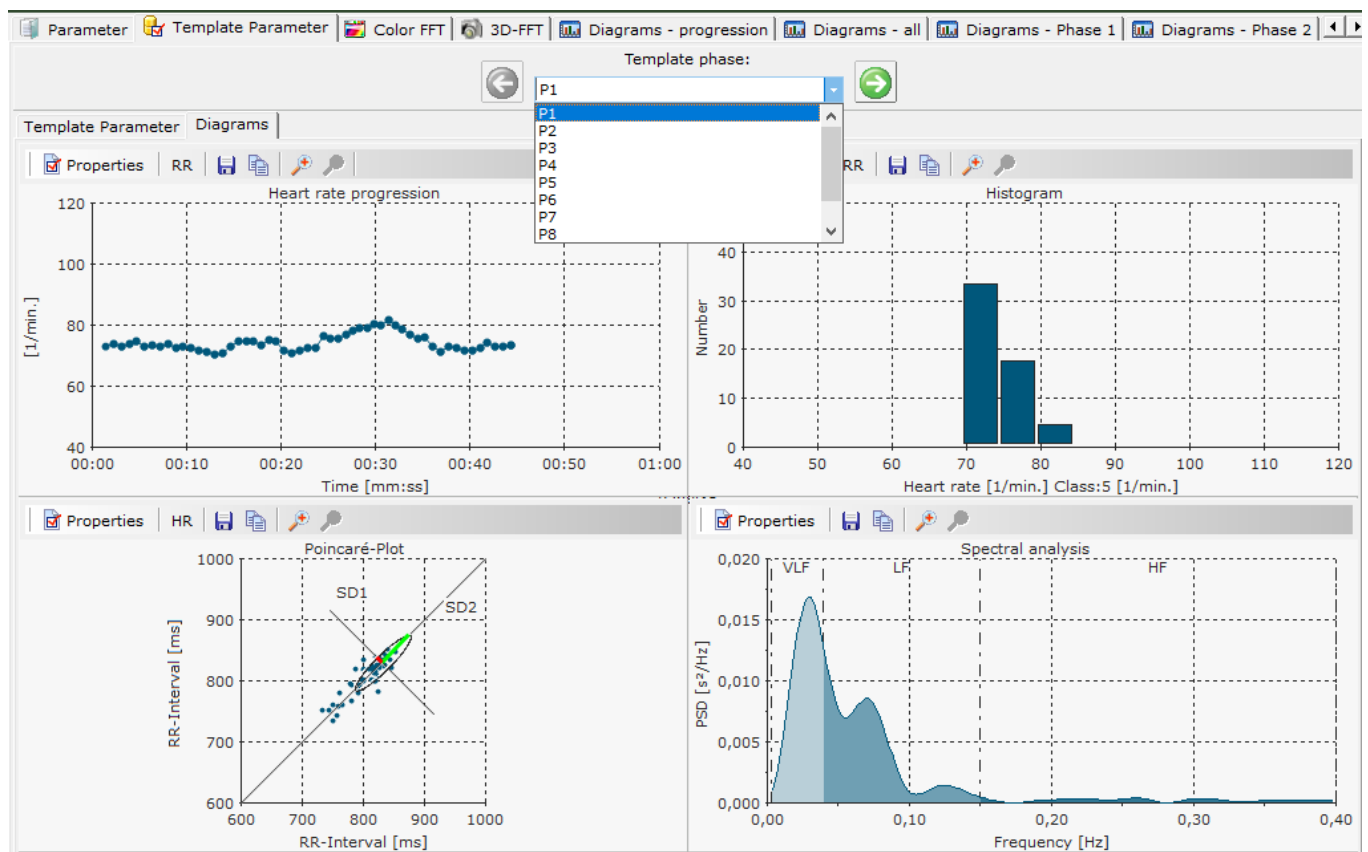
Parameter **Template Parameter** Color FFT 3D-FFT Diagrams - progression Diagrams - all Diagrams - Phase 1 Diagrams - Phase 2

Template phase: P1

Template Parameter | Diagrams

NAME	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
START	00:00:00	00:00:45	00:01:30	00:02:15	00:03:00	00:03:45	00:04:30	00:05:15	00:06:00	00:06:45
SCHEDULED LENGTH [SEC.]	45	45	45	45	45	45	45	45	45	45
ACTUAL LENGTH [SEC.]	43	44	45	44	44	44	44	44	44	44
QUALITY INDEX [%]	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
MISSING BEATS INDEX [%]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
ARRHYTHMIC INDEX [%]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CV HR [%]	3,62	3,72	7,60	2,44	3,72	4,21	4,00	8,86	2,43	5,16
CV RR [%]	3,51	3,62	7,84	2,45	3,60	4,31	4,07	9,28	2,42	5,23
LF/HF RATIO	8,11	2,25	17,55	3,08	1,93	13,19	29,20	31,31	2,47	1,73
MEAN HR [1/MIN]	74,39	72,04	72,97	70,91	73,23	74,74	70,03	71,10	71,26	73,15
HR MAX [1/MIN]	81,74	79,37	83,10	74,26	80,86	80,32	75,66	82,53	75,09	80,32
HR MIN [1/MIN]	70,34	67,80	59,58	67,11	69,28	68,34	64,17	57,36	66,82	65,29
HR RANGE [1/MIN]	11,40	11,57	23,52	7,14	11,58	11,98	11,49	25,17	8,28	15,03
MEAN RR [MS]	807,54	833,98	827,09	846,70	820,36	804,16	858,19	850,70	842,49	822,42
PNN50 [%]	0,00	0,00	3,70	0,00	0,00	0,00	0,00	9,62	0,00	0,00
PNN20 [%]	9,43	7,55	35,19	15,38	11,11	20,00	21,57	50,00	19,23	11,11
POWER HF [MS²]	54,31	56,28	172,64	65,99	51,47	58,89	46,88	198,71	78,50	55,08

The task to be displayed in the diagrams can be selected using the selection box or the arrow keys. The associated parameters are highlighted in color in the list.


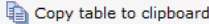


Parameters that are not calculated because for example the task duration was too short are being displayed with the numeric code '999999'.

SDNN [MS]	28,32	30,23	64,87	20,73	29,55	34,62	34,90	78,95	20,42	42,98
ST.DEV. [1/MIN]	2,70	2,68	5,55	1,73	2,72	3,14	2,80	6,30	1,73	3,77
STRESSINDEX	367,49	287,11	79,54	372,31	999999	999999	195,11	57,35	999999	999999
LN(STRESSINDEX)	5,91	5,66	4,38	5,92	999999	999999	5,27	4,05	999999	999999
DFA1	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999
DFA2	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999
AUTOCORREL.	0,8770	0,9298	0,9371	0,7777	0,9083	0,8911	0,8932	0,9221	0,7083	0,9560
SLOPE OF AUTOCORREL.	-0,0950	-0,1570	-0,0923	-0,0278	-0,1376	-0,0371	-0,0333	-0,0848	-0,0796	-0,1028
RESP. RATE	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999
CROSS CORRELATION	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999
HEART RATE / RESP. RATE RATIO	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999

The table can be exported analogously to other parameter list in ASCII-Format.

LF/HF RATIO	8,11	2,25	17,55	3,08	1,93	13,19	29,20	31,31	2,47	1,73
MEAN HR [1/MIN]	74,39	72,04	72,97	70,91	73,23	74,74	70,03	71,10	71,26	73,15
HR MAX [1/MIN]	81,74	79,37	83,10	74,26	80,86	80,32	75,66	82,53	75,09	80,32
HR MIN [1/MIN]	70,34	67,80	59,58	67,11	69,28	68,34	64,17	57,36	66,82	65,29
HR RANGE [1/MIN]	11,40	11,57	23,52	7,14	11,58	11,98	11,49	25,17	8,28	15,03
MEAN RR [MS]	807,54	833,98	827,09	846,70	820,36	804,16	858,19	850,70	842,49	822,42
PNN50 [%]	0,00	0,00	3,70	0,00	0,00	0,00	0,00	9,62	0,00	0,00
PNN20 [%]	9,43	7,55	35,19	15,38	11,11	20,00	21,57	50,00	19,23	11,11
POWER HF [MS²]	54,31	56,28	172,64	65,99	51,47	58,89	46,88	198,71	78,50	55,08
POWER LF [MS²]	440,49	126,38	3029,64	203,41	99,55	776,93	1368,63	6221,55	193,59	95,23
POWER TOTAL [MS²]	888,95	504,98	5239,14	314,26	556,06	1093,54	1489,81	8411,43	341,28	1635,37

Notice:

The table contains a couple of new, experimental HRV parameter. The number of these parameter and their calculation basis may change in the future. Therefore, we reserve the right to change the number and the calculation basis of template parameter in future releases. If the template parameter is used in scientific studies, we recommend to contact BioSign in order to obtain more detailed information.

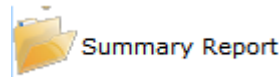
Summary Report

Performing a neuro-vegetative functional analysis usually involves the combination of several single functional tests, e.g. Short-term HRV, RSA, Supine / Standing (Schellong) and Valsalva maneuvers. The assessment of whether a neurovegetative disorder is present usually results from the overall view of all measurements results. With the HRV scanner, it is now possible to perform this overall evaluation automatically.

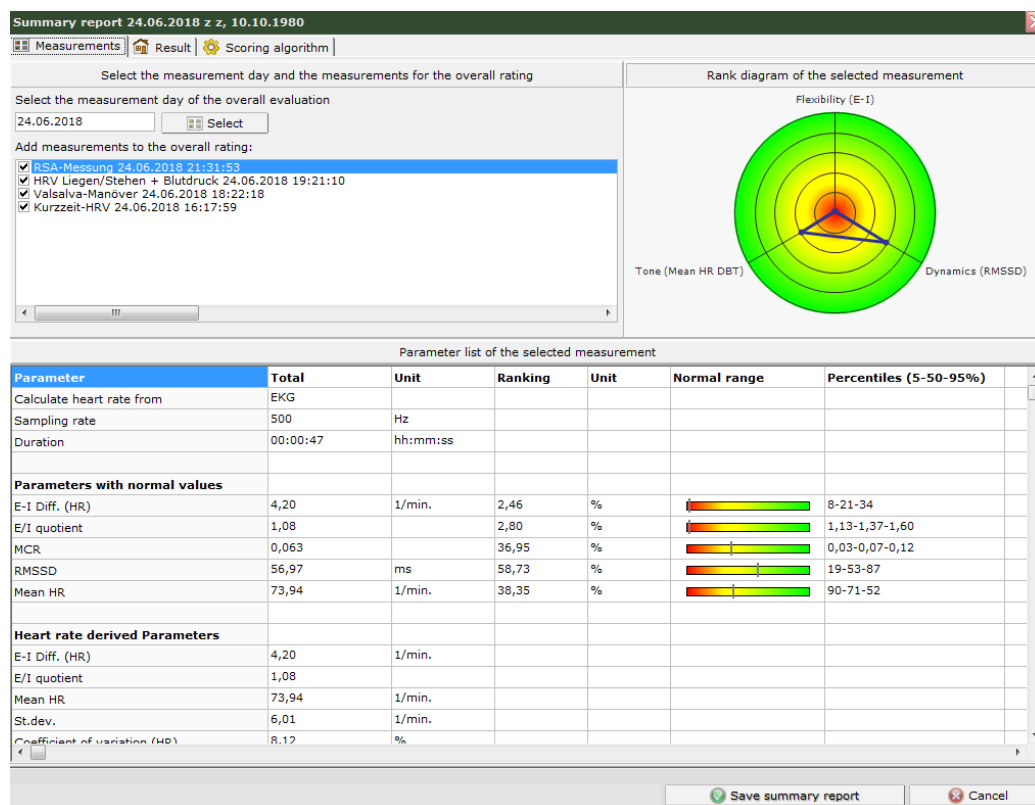
In order to create the overall rating, the individual measurements must be evaluated. The target parameters of the individual functional tests are weighted using a scoring system and summed up to a total score. The underlying scoring system is adjustable by the user and can be easily adapted to own requirements.

Creating a Summary Reports

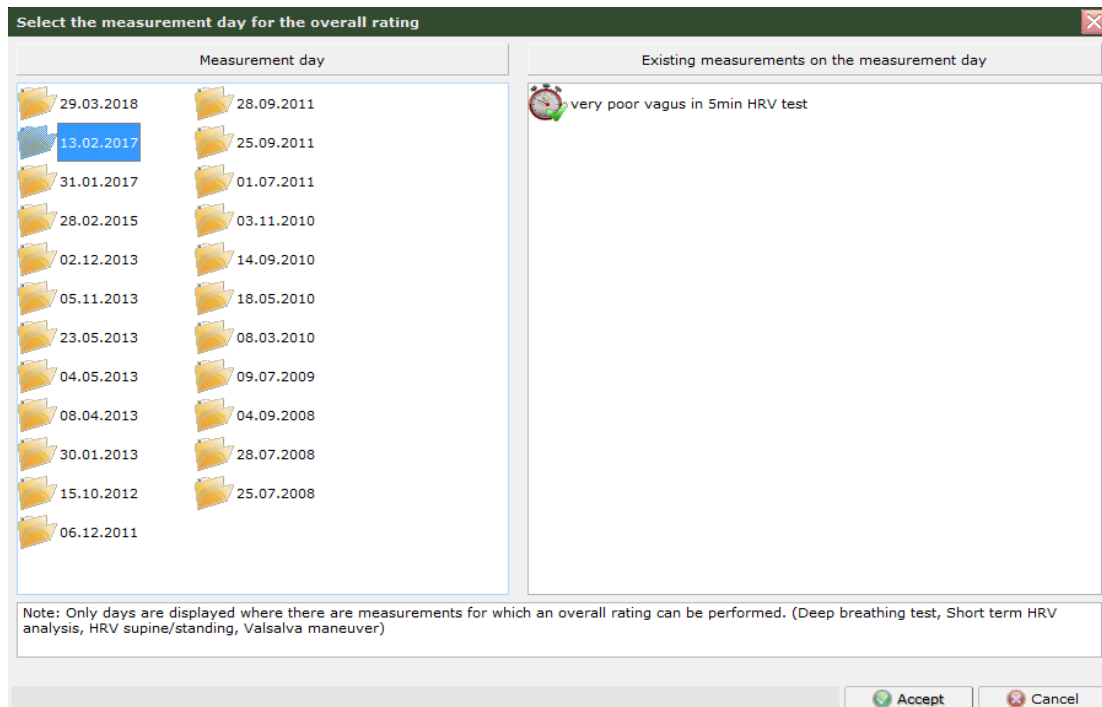
Creating a summary report is analogous to starting a new measurement.



Drag the summary report symbol with the mouse into the left window of the subject measurements. The overview window of the summary report shows the available measurements for the selected measurement day and the results of the currently selected measurement.

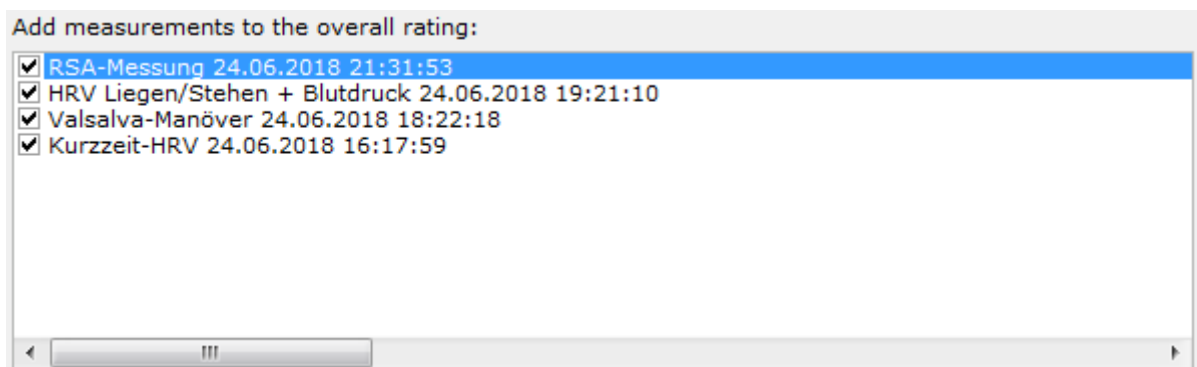


You can select the measurement day via a dialog. The summary report overtakes the date of the selected measurement day and is accordingly also sorted in the list of tests in the "Test and Analysis" window.



In the selection dialog for the measurement day, only days are displayed on which measurements are available, and for which a summary report can be generated (RSA measurement, short-term HRV, Supine / Standing HRV, Valsalva maneuver).

After selecting the measurement day you will see the available measurements in the list. Here you can select which measurements should be evaluated in the summary report.



Measurements that have not yet been evaluated, or in which there have been errors in the evaluation, cannot be used and must first be reworked.

Result

Summary report 24.06.2018 z z, 10.10.1980

Measurements
Result
Scoring algorithm

Overall rating

Note! During the evaluation 1 errors have occurred.

Achieved total score of all measurements (n = 6): 17/32 =53,13%

Rating: normal

* 0-30% auffällig; 30-50% grenzwertig; 50-101% normal

Scoring algorithm: test

Report

Results of the single measurements

Test	Type	Parameter	Value	Unit	Ranking[%]	Score[Pts.]	Total[Pts.]	Rating
RSA-Messung 24.06.2018 21:31:53	DBT	E-I	4,20	1/min.	2,46	0		
		RMSSD	56,97	ms	58,73	2		
		Mean HR DBT	73,94	1/min.	38,35	2	4/6	normal
HRV Liegen/Stehen + Blutdruck 24.06.2018 19:15	Short Term H	Coefficient of variation (R	6,05	%	28,82	2		
		SD1	22,52	ms	11,99	1		
		SD2	76,38	ms	38,40	2		
		Stress index	83,51	Pts.	40,68	2		
		Mean HR	64,75	1/min.	73,19	2	9/10	normal
HRV Liegen/Stehen + Blutdruck 24.06.2018 19:15	Ewing	30:15 Ratio	1,31		42,17	2	2/2	normal
HRV Liegen/Stehen + Blutdruck 24.06.2018 19:15	Blood pressur	Blood pressure change sy	-10,00	mmHg		ERROR		
		Blood pressure change di	-11,00	mmHg		0	0/2	auffällig
Valsalva-Manöver 24.06.2018 18:22:18	Max. score of	Valsalva Ranking	1,94		76,81	2	2/2	normal
Kurzzeit-HRV 24.06.2018 16:17:59	Short Term H	Coefficient of variation (R	0,66	%	1,91	0		
		SD1	1,61	ms	1,36	0		
		SD2	5,13	ms	1,62	0		
		Stress index	4641,50	Pts.	0,39	0		
		Mean HR	103,54	1/min.	0,37	0	0/10	auffällig

* "ERROR" means no fitting scoring algorithm was found for this parameter! Adjust the settings.

As a result you can see the overall rating of the measurement day in the upper panel, including the individual test with the respective parameters. "ERROR" means that no scope was found for a parameter in the scoring conditions, and thus there is an inconsistency in the scoring system. Correct the calculation algorithm in this case.

The following explains how to implement your own scoring algorithm.

Definition of the scoring algorithm of a summary report

Step 1: Selection of the individual parameters

Measurements | Result | **Scoring algorithm**

Bezeichnung: default

Overall rating | **Deep breathing test** | Short term HRV analysis | HRV supine/standing Ewing | HRV supine/standing Blood pressure | Valsalva maneuver

☒ **Tone (Mean HR DBT)**
if Ranking >= 0 and Ranking < 10 then point value = 0
if Ranking >= 10 and Ranking < 15 then point value = 1
if Ranking >= 15 and Ranking < 101 then point value = 2
Define point values

☒ **Flexibility (E-I)**
if Ranking >= 0 and Ranking < 10 then point value = 0
if Ranking >= 10 and Ranking < 15 then point value = 1
if Ranking >= 15 and Ranking < 101 then point value = 2
Define point values

☒ **Dynamics (RMSSD)**
if Ranking >= 0 and Ranking < 10 then point value = 0
if Ranking >= 10 and Ranking < 15 then point value = 1
if Ranking >= 15 and Ranking < 101 then point value = 2
Define point values

For each test, specific individual parameters are available. Among these you can select which parameters should be included in the evaluation.

Step 2: Defining the evaluation criteria for each parameter (defining scores)

Edit parameter conditions: Tone (Mean HR DBT)

if Ranking >= 0 and Ranking < 10 then point value = 0
if Ranking >= 10 and Ranking < 15 then point value = 1
if Ranking >= 15 and Ranking < 101 then point value = 2

Add a new condition | Delete a selected condition

Edit selected condition

if Ranking >= 0 and Ranking < 10 then point value = 0

* Ranking parameter (range 0% - 100%)

Accept | Cancel

The evaluation of the individual parameters is carried out by conditions and the allocation of scores. When defining the conditions, consider whether it is a relative rank parameter (percentile) with the unique range 0-100% or an absolute parameter (for example, blood pressure change) with its individual range. The individual conditions must be defined in such a way that the possible value range is completely covered. Please note that in case of blood pressure changes positive values (blood pressure rise) and negative values (blood pressure drop) can occur.


Step 3: Evaluation criteria for a single test

Depending on the results of the parameter evaluation, an evaluation is made for the individual test, so that each test receives a sum score.

Overall rating of the single measurement

Overall result of the test is "auffällig" and he gets a score of 0 if the total score of the test is ≥ 0 and < 2
Overall result of the test is "grenzwertig" and he gets a score of 1 if the total score of the test is ≥ 2 and < 3
Overall result of the test is "normal" and he gets a score of 2 if the total score of the test is ≥ 3 and < 7


Max. score of this test: 6


 Define rating and scores

The score of the individual test and the corresponding conclusion is defined from the individual parameters. The complete range of values from 0 points to the maximum achievable total score of a single test should be covered in the conditions.

Edit single test conditions: Short term HRV analysis

Overall result of the test is "auffällig" and he gets a score of 0 if the total score of the test is ≥ 0 and < 3
Overall result of the test is "grenzwertig" and he gets a score of 1 if the total score of the test is ≥ 3 and < 5
Overall result of the test is "normal" and he gets a score of 2 if the total score of the test is ≥ 5 and < 11

 Add a new condition

 Delete a selected condition



Edit selected condition

Overall result of the test is

and he gets a score of


if the total score of the test is \geq

and $<$

 Accept  Cancel

Step 4: Evaluation of the complete functional analysis

Overall result is "auffällig" if total score of all tests $\geq 0\%$ and $< 30\%$ % of the possible total score
Overall result is "grenzwertig" if total score of all tests $\geq 30\%$ and $< 50\%$ % of the possible total score
Overall result is "normal" if total score of all tests $\geq 50\%$ and $< 101\%$ % of the possible total score

 Define rating and percentages

The evaluation of a complete function analysis is based on the ratio of the achieved score to the maximum achievable score.

Edit overall rating conditions

Overall result is "auffällig" if total score of all tests> = 0% and< 30% % of the possible total score
 Overall result is "grenzwertig" if total score of all tests> = 30% and< 50% % of the possible total score
 Overall result is "normal" if total score of all tests> = 50% and< 101% % of the possible total score

Add a new condition Delete a selected condition

Edit selected condition

Overall result is

if total score of all tests> =
 %

and<
 % of the possible total score

Accept Cancel

You can adjust the percentage score for each conclusion separately.

Import Options

ASCII

Import measurement in the form of heart rate or RR distance lists into the HRV-Scanner.

ASCII biosignals

Import measurements in the form of biosignal lists (ECG voltage curve in mV) into the HRV-Scanner.

EDF - European Data Format

Import of data in EDF format. E.g. Import of data from the measurement memory of Faros 180.

eMotion HRV

Long-term measurements with the eMotion HRV recorder.

Polar

Import of measurements from Polar watches (HRM files) already transferred to the PC.

Suunto

Import of measurements from the Suunto Memory Belt already transferred to the PC.

SRM long term measurement

Import the measurement data from the SRM recorder

Technical Manual HRV-Scanner Hardware plus

The technical details on the HRV-Scanner Hardware plus can be found in the separate data sheet.

- 3 channel ECG
- Pulse wave over ear clip
- Breathing sensor over chest strap
- Pressure sensor for the Valsalva maneuver



Prepare the Breathing Sensor

Step 1)



Take:

- the respiratory sensor
- the breathing belt
- the fastening buttons

Step 2)



Insert the breathing belt from below through the side eyelet of the breathing sensor

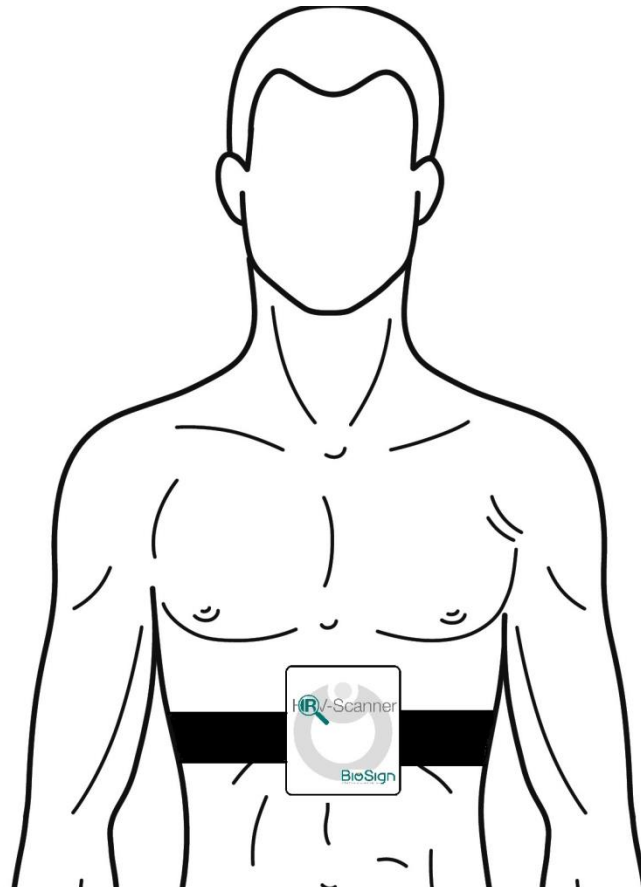
Step 3)

Close the end of the breathing belt with the help of the fastening button.

Step 4)

Do the same on the other side of the breathing sensor by running the other end of the breathing belt through the side eyelet and closing it as well.

The belt should be placed at the level of the lower ribs to detect chest and abdominal breathing. Place the sensor over the clothing (shirt).



The Valsalva pressure sensor set

The Valsalva pressure sensor set consists of 4 parts:

Mouthpiece		Filter	
Valve		Cap	

Before assembling the individual parts, please pierce a small hole of approx. 0.5 - 1 mm diameter e.g. with a pin into the red cap. This creates a flow and prevents the pressure from being built up by a closure of the glottis only with the mouth.



The pressure sensor set looks as follows:



Connect the Valsalva sensor to the HRV-Scanner plus hardware with a tube with a Luer lock at both ends. To do this, open the green cover on the filter and screw the tube on. The other end is connected to the metal connector on the HRV-Scanner plus hardware.

Spare parts for the Valsalva pressure sensor set can be obtained in our online shop or in the medical specialist trade.