

APPLICATION NOTE

Application Note 129 Heart Rate Variability

05.22.14

Analyses: Statistical Measures

SDANN SDNN - index

The **SDANN** is the **standard deviation of all the 5-minute NN interval (normal RR) means** (i.e., the standard deviation of 288 NN means), while the **SDNN-index** is **the mean of all the 5-minute of NN interval standard deviations** during the 24-hour period (i.e., the mean of 288 NN standard deviations),

SDANN will be calculated in one of two methods, based on whether the R-R interval is calculated using **Find Cycle** or the **Find Rate**.

RR interval calculated using Find Cycle

To obtain SDANN and SDNN-index, first obtain the mean heart rate at 5-minute intervals. The following steps outline the procedure.

1. On the acquired data, set measurements for Mean and Stddev on the R-R interval channel.



2. Choose Analysis > Find Cycle.



- 3. In the Cycles/Peaks tab, select "fixed time intervals".
 - Select starting time = "Start first interval at 0.0000 seconds"
 - Set interval width = 5 minutes or 300 seconds.

AcqKnowledge - Analysis - Cycle Detector
Cycles/Peaks Selection Output
Locate cycles from:
○ peaks ○ events ④ fixed time intervals
Starting Time
C Current cursor position
Interval width: 200,00000
Seconds Viewald Southood

4. Click on Selection Tab. Set Left edge to "Previous interval + 0.000000 seconds"

AcqKnowledge - Analysis - Cycle Detector
Cycles/Peaks Selection Output
C Current interval + 0.0000000 seconds
Right edge Current interval

5. Click on the **Output** Tab. Select "Display measurements as channels in a graph" as the output option.

AcqKnowledge - Analysis - Cycle Detector	
Cycles/Peaks Selection Output	
Paste measurements for each cycle into the Journal Display measurement values as channels in graph Save measurements into Excel spreadsheet file	

- 6. Choose Analysis > Find All Cycles.
 - The following graph displays the Mean and Stddev of the R-R intervals every 5 minutes.



Find All Cycles output for Steps 2-6

7. Set a measurement box to Stddev assigned to the Mean channel and assign the Mean measurement to the Stddev channel.



The **SDANN** consists of the standard deviation of all 5-minute RR interval means.



The SDNN-index consists of the mean of all 5-minute RR interval standard deviations.

8. To obtain **SDANN** and **SDNN**-index, use the I-beam tool to highlight valid 5-min intervals. (Example on next page.)

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Heart Rate Variability



SDANN and SDNN-index for ECG signals captured in real-time.

RMSSD

NOTE: A BIOPAC Basic Script for computing RMSSD, SDSD and pNN50 statistics is available for download at: <u>http://www.biopac.com/ScriptDetails.asp?ID=1045</u>

The **RMSSD** is the RMS of the Successive Difference between adjacent R-R intervals. Referring to the figure below, the successive differences would be:

$$RR_{1} - RR_{2} = D_{1}$$

$$RR_{2} - RR_{3} = D_{2}$$

$$RR_{3} - RR_{4} = D_{3}$$
...
$$RR_{n-1} - RR_{n} = D_{n-1}$$

These differences are then used in the RMS equation:

$$RMSSD = \sqrt{\frac{\sum_{i=1}^{i=n-1} D_i^2}{n-1}}$$

Where i = interval index

n = number of total intervals

n - 1 = number of interval differences



Successive R-R intervals used for the calculation of the RMSSD

The following page offers a suggested procedure for calculating the RMSSD using the R-R interval derived for the SDANN-index/SDNN-index metrics.

Deriving the RMSSD metric through the RR interval waveform

- 1. Create a separate R-R Interval graph from the source ECG waveform.
- 2. Select the ECG channel.
- 3. Choose **Analysis > Find Rate** and select the Output tab.
- 4. Choose Interval (sec) as the Function.
- 5. Check the "Put result in new graph" and click **OK**.

Cycle Parameters Output				
Function: Ir	nterval (sec)	•		
┌	eraging mode			
© Fixed tir	ne window:	1.000000	sec	
C Fixed no	umber of cycle	s; 5		
Rec	ompute on ev	ery cyde		



6. Switch the new R-R interval graph view to **Chart** mode.

Chart mode					
	1				
AcqKno	rledge - Rate *				
File Edit	ransform Analysis Display Script MP150 Window Help Media				
	. Q. ₱ P. ♥ → A.				
🐟 🔜	`@ ≉ 조 ⋈ फ ਟ ╥ 🛝 🛝 🍃 🛛 🎬				

7. Hide or delete the R-R graph TIME channel and expand the Interval view using **Display >Autoscale Horizontal**.

- 8. Convert the R-R interval graph from seconds to msec. Choose **Analysis > Waveform Math** and enter parameters as shown in the following figure.
 - Use the channel containing the RR interval as the Source and Destination.
 - Set operand to multiply (*)
 - Set "K" value to 1000 and click **OK**.

AcqKnowledge - Transformation	n - Waveform Math	
Source 1 CH2, Interval 💌 🎽	S <u>o</u> urce 2	Destination
<u>K</u> : 1000.000000		
✓ Transform entire wave		OK Cancel

9. Double-click on the vertical axis units label; rename units to "msec" and click OK.

AcqKnowledge				
Enter channe	el 2 units text			
msec				
ОК	Cancel			
1-				
	o			
	් 400.00			

10. Duplicate the R-R Interval channel using: Edit > Duplicate Waveform.



- 11. Select a measurement of
- 12. Set the line style for each channel to dot plot using: Display > Show > Dot Plot
- 13. Use the Zoom tool ⁹ to display the first few samples of each channel.



- 14. Select the top interval channel, highlight a section of 2 samples (Delta S = 2) then use: Edit > Cut to remove.
- 15. Select the duplicate interval channel, highlight a section of 3 samples (Delta S = 3) then use: Edit > Cut to remove.



The resulting graph should contain two R-R waveforms separated by one beat.

(Check by choosing Select > All with Delta S selected for both channels)

- 16. Revert back to a line plot style on both R-R Interval channels: **Display > Show > Line Plot**
- 17. Use the Expression transformation to take the square of the difference between the two channels.
 - Choose Transform > Expression.
 - Enter SQR(CH2–CH3) into the Expression field.
 - Destination: New
 - Click **OK**.

NOTE: Your original and duplicate R-R Interval channel number assignments may vary from that used in the above and example formula. If so, use the correct channel numbers in your expression.

AcqKnowledge - Transformation - Expression		
Evaluate expression:		
Preset: Custom New Preset Delete		
SQR(CH2-CH3)		
Sources: CH2, Interval 💌 Eunctions: SQR() 💌		
Destination: New		
✓ Transform entire wave OK Cancel		

18. Vertically and horizontally Autoscale the resultant SQR waveform and choose: Edit > Select All.

TUTELAG	an water and the providence of	1200.00 900.00
Interval	ware were and the second of th	300.00 ☆ 1200.00 900.00 ¥ 600.00
	SQR(CH2-CH3)	300.00 <u>⊥</u> a 150000.00 50000.00 0.00 <u>⊥</u> a
	0.00 360.50 721.00 1081.50 cycle index al	

19. Set a measurement to:

SC 🔽 Mean

to get the mean of the square of the differences.

- 20. Set a measurement to **Calculate** to extract the square root of the mean:
 - Source 1 = the Mean
 - Operand = ^ (exp)
 - Source 2 = 0.5 (Constant)
 - Press OK.

Measurement Arith Parameters	metic	
Source 1	Operand	Source 2
Row A : Col 1	•	▼ K, Constant ▼
Constant = 0.	5	

21. Result: RMSSD = Calculate

SC	•	Mean	•	=	16	84.88063 volts
SC	-	Calculate	-	6	=	41.04729

Application Note 129- Part 2

Heart Rate Variability-SDSD & NN50 Calculation

The **SDSD** is the Standard Deviation of the Successive Difference between adjacent R-R intervals. Referring to Figure 1 below, the successive differences would be:

$$RR_{1} - RR_{2} = D_{1}$$

$$RR_{2} - RR_{3} = D_{2}$$

$$RR_{3} - RR_{4} = D_{3}$$
...
$$RR_{n-1} - RR_{n} = D_{n-1}$$

These differences are then used in the SDSD equation:

$$SDSD = \sqrt{\frac{\sum_{i=1}^{i=n-1} (D_i - D_{mean})^2}{n-1}}$$

Where:

i = interval index

n = number of total intervals

n-1 = number of interval differences

$$D_{mean} = \frac{1}{n-1} \sum_{i=1}^{i=n-1} D_i$$



Figure 1 - Successive RR intervals used for the calculation of the SDSD

Deriving the SDSD metric:

- 1. Select the duplicate-channel R-R interval graph used in the **RMSSD** section in Part 1. (For easier viewing, hide the SQR channel used in the previous section by selecting and choosing Alt+Click.)
- 2. Use the Expression tool to just take the difference between the two channels: (original duplicate).
 - Choose Transform > Expression.
 - Enter (CH2–CH3) into the Expression field. (Or enter your channel numbers containing the original and duplicate R-R interval. These may vary from the example)
 - Destination: New
 - Click **OK**.

AcqKnowledge - Transformation - Expression				
Evaluate expression:				
Preset: Custom New Preset Delete				
(CH2-CH3)				
Sources: CH2, Interval 💌 Eunctions: ABS() 💌				
Destination: New Qperators: -				

				-
R Norman (John	R interval	neronal per	annon till form skille	
C Marantikak	Copy of RR inter	val shifted by 1 :	sample di in aligi	1.0000 01.000
R	R Difference W	sveform		
100	86.0	10.0	100.5	-0.0

3. Change the Difference vertical scale units from "Volts" to "msec" to reflect the R-R interval channel units. (Click on the Difference channel's units label to open the units text dialog.)

Stddev

SC

4. Set the Difference waveform to a

measurement, and then choose: Edit > Select All.

Result:

SDSD = Stddev

NN50 count

pNN50

The **NN50** count is the number of pairs of adjacent **NN** intervals differing by more than 50 ms. This value can be derived using a waveform created by the difference between an R-R interval graph and a 1-sample shifted copy of the interval.

1. Use the R-R Difference Waveform created in Step 2 of Page 2 to calculate the NN50 count metric.

	RR interval	
and the second	Manager and a second	
	Copy of RR interval shifted by 1 sample	
stractifi	applementation and a second	
Alemiter	RR Difference Waveform	
1.01	86.0 10.0 10.5	-

- 2. Perform the following operations:
 - Duplicate the R-R Difference Waveform: Edit > Duplicate Waveform
 - Select all of the duplicate waveform: Edit > Select All
 - Take the absolute value: Transform > Math Functions > Abs

The resulting waveform should resemble the image below:

	-			· · · · · · · · · · · · · · · · · · ·					-00-00
Herich	Linu)	aluta	el mitela	Lalmielle	have	ري. ماروني م	alial and		380.00
100	-		360.25	· · ·		720.50	100		-200 00

Abs of the R-R Difference waveform

Now apply a Threshold transform to count how many peaks are > 50 msec. (Transform > Math Functions > Threshold)

AcqKnowledge - Transformation - Thresho	AcqKnowledge - Transformation - Thresho
Source channel: CH9, (CH2-CH7) Enter lower threshold 50 msec	Source channel: CH9, (CH2-CH7) Enter upper threshold 50.01 msec
OK Cancel	OK Cancel

4. After autoscaling, a waveform showing a series of spikes with a maximum value of 1 when a threshold value exceeds 50 msec and 0 otherwise. The following image is an expansion of a region.



- 5. Select the Threshold channel
 - Set the first top row measurement for Area.
 - Choose Edit > Select All.
 - The Area measurement result will reflect the number of peaks > 50 msec.

NN50-count = Area

Area 🔻 = 145.00000

Peak count after applying Area measurement

6. Set another measurement to **Delta S** to obtain the total number of samples.

	Delta	S	-	=	1441 Samples	
pNI	150 =	145 / 14	41	*	100 = 10.06 %	

Application Note 129- Part 3

Heart Rate Variability

Geometric Measures

Geometric measures are most applicable to long term recordings (24 hours preferred), where any histogram of values follows a normal distribution. A comprehensive overview of the metric is provided in Guidelines: Heart Rate Variability, European Heart Journal (1996) 17, 354-381, <u>http://eurheartj.oxfordjournals.org/content/17/3/354.full.pdf</u>

HRV triangular index

TINN – Triangular Interpolation of NN

Using a discrete scale, the measurement is approximated by:

(Total number of NN intervals) / (Height of the histogram of all NN intervals using 7.8125 ms bins)

Note, most experience has been obtained with a bin length of approximately 8 ms (precisely 7.8125 ms=1/128 seconds), which corresponds to the precision of current commercial equipment (Guidelines: Heart Rate Variability). The following steps outline a procedure to determine the index.

1. Obtain the ECG waveform.



- 2. Duplicate this waveform in another channel and select that channel.
- 3. Choose Analysis > Find Rate and set the output function to Interval.
- 4. Click **OK** to output the R-R intervals to a new channel.

AcqKnowledge - Analysis - Find Rate				
Source channel: CH3, Interval				
Cvde Parameters Output				
Function: Interval (car)				
Eixed time window: 1 000000 sec				
C Fixed number of cycles; 5				
Recompute on every cycle				
Putresultimew graph				
✓ Transform entire wave				

5. Autoscale and select the R-R interval channel.



- 6. Convert the graph from an amplitude scale of seconds to milliseconds using Transform > Waveform Math.
 - Set Interval channel as Source 1 and Destination
 - Set operand to * and Source 2 to K.
 - Set K value to 1000 and click **OK**.

AcqKnowledge - Transforma	ition - Waveform	Math	
Source 1 CH3, Interval 💌 🔭	S <u>o</u> urce 2	Destination CH3, Interval	-
<u>K</u> : 1000			
✓ Transform <u>e</u> ntire wave		ОК	Cancel

7. Autoscale the waveform and change scaling units to "msec". (Click on "Seconds" label to launch units text dialog.)



- 8. If the first few data points are suspected to be corrupted with artifact, use the Selection tool to highlight as many points as necessary, then remove those points from the waveform using: **Edit > Cut**.
 - Use the Zoom to accurately check data quality at the start of the graph. (Zoom back after checking.)
- 9. Choose **Edit > Select All** to highlight the entire waveform.
 - Set a measurement for P-P (Peak to Peak).
 - Set another measurement for **Samples** or **Delta S**. (Will be used for the triangular index calculation → the total number of NN intervals.)

- 10. Set a measurement to **Calculate** and establish the following parameters:
 - Source 1 = Row A: Col 1 (or corresponding location of P-P measurement)
 - Operand = /
 - Source 2 = K, Constant
 - Constant = 7.8125
 - Click OK.

AcqKnowledge - Measurement Arithmetic
Measurement Arithmetic
Parameters
Source 1 Operand Source 2
Row A : Col 1 💌 / 💌 K, Constant 💌
Constant = 7.8125
OKCancel
SC Calculate Calculate

The Calculate value renders the number of "7.8125" msec bins for the Histogram.

11. Choose Analysis > Histogram.

- Enter the measurement value derived from Calculate and select "Autorange."
- Click OK.

AcqKnowledge - Analysis - Histogram					
Source channel: CH3, Interval					
79 bins 🔽 Autorange					
Highest bin:	10.000000	msec			
Lowest bin:	-10.000000	msec			
✓ Transform	n <u>e</u> ntire wave	OK Cancel			



Histogram output from R-R interval example

12. Using the I-Beam tool, highlight the area between the point of initial increase on the bell curve distribution and the end of the decrease (a return to a baseline or flat-line) to encompass the curve maximum.



13. Within the **Histogram** graph:

- Set the initial first row measurement to Max.
- Set another measurement to **Calculate**.

14. For **Calculate**, set the following parameters:

- Source 1 = K, Constant
- Operand = /
- Source 2 = Row A: Col 1 (or corresponding location of Max measurement).
- Constant = Samples or Delta S value from source graph (= 1016502).

AcqKnowledge - Measurement Arithmetic
Measurement Arithmetic
Parameters
Source 1 Operand Source 2
K, Constant 🔽 / 💌 Row A : Col 1 💌
<u>C</u> onstant = 1016502
OK Cancel
SC - Calculate 0 = 25.41122

(Total number of NN intervals) / (Height of the histogram of all NN intervals using 7.8125 ms bins) Triangular index = 1016502 / 40002 = 25.41

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