Spectral Analysis vs. Scale Covariance Approach
A first comparison

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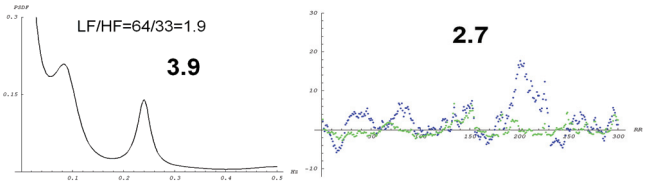
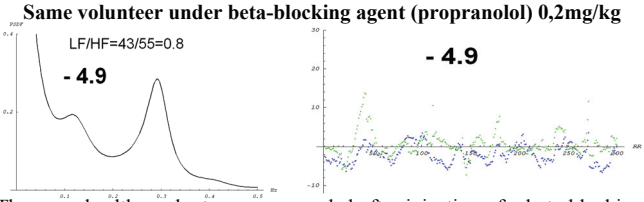
A scale covariance approach, to the problem of discriminating the sympathetic(SP) and parasympathetic(PSP) activities in HR variability, was devised and implemented in the ANSiscope. Though the featured measure is through wave functions, it can also be represented as a phase space trajectory. From the former, independent degrees of activity can be obtained, whereas the latter describes the resultant of these activities as the global outcome for the autonomic nervous system(ANS). A comparison with the famed spectral analysis is sought and as it requires mutual ground, a common framework for comparing measurements was found. The antagonism between systems as observed through a normalized power spectrum density function (PSD) is better compared with the predominance of systems as measured by the ANSindices combination adjusted by the following compromise: $(BalANS^{|N|})_1=\left(\frac{1}{N}\sum^N,\ldots\right)(\partial_{ANS})_1=CG_1^{|2|}+(\partial^0_{ANS}+\partial^N_{ANS})/2N$ where $\partial_{ANS}=C\cdot\sqrt{\frac{2}{N}\frac{4}{5}}\sqrt{N}\left(\frac{1}{N}\sum^N,\cdots\right)\left((idx_{SP}/2+3.4)-\left(idx_{PSP}+\frac{31}{9}\right)\right)\approx 2.85\left(\frac{1}{N}\sum^N,\cdots\right)(idx_{SP}/2-idx_{PSP})$ is a generalization from the addition law found between SP and PSP for the resulting predominance. On the side of PSD analysis, we transform the LF/HF ratio from an open scale (0 to Infinity) to the very closed scale (-50 to 50) used here for the sake of comparison: $(\log_a(LF/HF)-\epsilon)\div\sqrt{1+(\log_a(LF/HF))^2/50^2}$. This comparison value is marked bold in the following examples. The PSD analysis is parametric, an estimated autoregressive spectrum is calculated using the Yule-Walker method with an adapted order. The VLF variance was substracted from the total variance.

Healthy volunteer at rest in supine condition



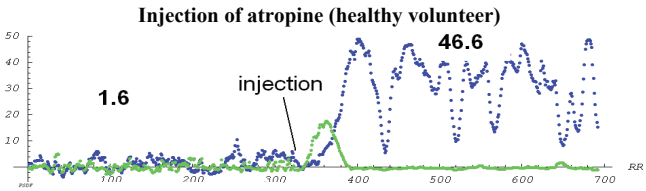
The two indices of the ANSiscope present superimposable activities, indicating well interacting SP and PSP systems which furthermore remain in baseline activity. One can see a transitory activation of SP (around 200) which may explain a positive global value of 2.7, instead of a negative value expected in these conditions where a predominance of the PSP activity would be expected (see below). PSD analysis indicates a higher predominance of SP activity due to this sudden transitory increase of the SP and could not distinguish it from the overall situation. This example was used to calibrate the comparison measurement framework.

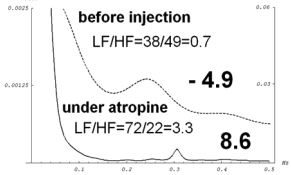
Same volunteer under beta-blocking agent (propranolol) 0,2mg/kg



The same healthy volunteer was recorded after injection of a beta-blocking agent in supine condition. The SP index of the ANSiscope is now oscillating under 0. The PSP activity remains higher than the SP during the entire recording, this is well represented by the negative -4.9 value.
Decrease of the SP component and thus of the LF/HF ratio is also observed from the PSD analysis and represented by the exact same -4.9 value.

Injection of atropine (healthy volunteer)

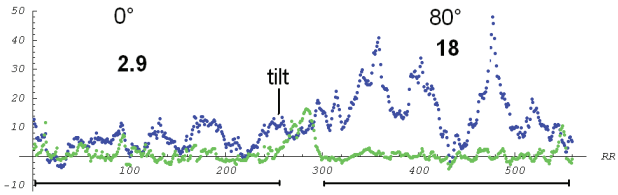




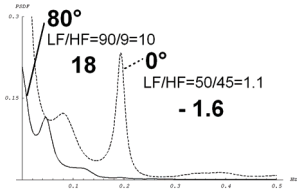
PSD analysis shows a decrease of both SP and PSP components. The global value indicates a change of the predominance from PSP to SP systems. But these modifications prevent the possibility to recognize a specific inhibition of the PSP system.

The ANSiscope shows a transitory change of PSP activity at the moment of the injection, which may be explained by the antagonist effect during set up of the blockade, as if the PSP was fighting against the inhibition mechanism until complete blockade, reached only a few seconds after injection. SP activity becomes high, showing the huge impact of the SP system on the heart, acting as a reserve of activity for the whole ANS.

Head up tilt

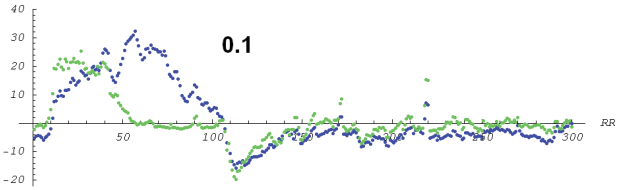


This healthy volunteer was recorded before, during and after a passive head up tilt from 0 to 80° (reached in 20 sec). Both analysis show a predominance of the SP and a decrease of the PSP after the tilt.

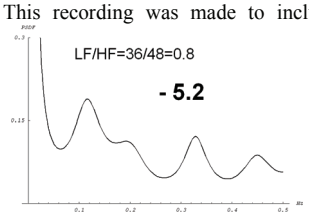


The ANSiscope allows to visualize the behavior of SP and PSP activities during the tilt, showing a constant increase of the SP system and a transitory activation of the PSP system. Once tilting is achieved, indices indicate a high activity of the SP system in the form of peaks, which recall peak release of catecholamines, a decrease of the PSP due to the baroreflex, necessary to maintain appropriate blood pressure in the standing condition. An extraordinary coincidence of values is found with our comparison framework for the tilt test aftermath.

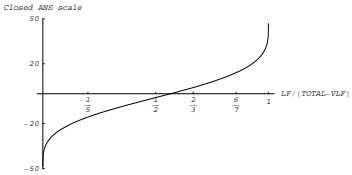
Injection of isoproterenol



This recording was made to include the injection of isoproterenol, which activates the SP system. The PSD analysis shows a predominance of PSP activity while one of SP activity was expected. From this analysis, it is impossible to detect any temporal change in this measurement.



The ANSiscope shows a transitory increase of the PSP system which may be explained by the first vasodilatation provoked by this drug. Full activation of the SP system is parallely observed. One can observe the complete modifications of the PSP and SP systems, beat par beat, in real time. In this context, the pure separation in the measurement of the SP and PSP activities is manifest.



This first comparison demonstrates the substantial equivalence of results for cases of clear changes of the ANS leading to a stationary state (e.g. after a tilt test or a beta-blocker injection). In other words, accepting to compromise the measurements given by the ANSiscope to enable such a comparison, we obtain suprising evidence that what the PSD analysis withholds is already contained in the new scale-covariant measurement. However in cases where the fuzzy identity of the LF component is at stake, where there are intermittent or non-stationary behaviors or when phenomena take place on a short time scale or require exact discrimination between the ANS' subsystems, PSD analysis cannot compete with the wealth of information accurately given by the ANSiscope's measurements. The clarity, stability and instantaneous nature of these measurements cannot be possibly compared with.