An analysis of young normal subjects by the CZF.

We may now go to expose some other results obtained by the CZF method. We examined 14 young subjects, between 20 and 25 years old. According to our protocol, ECG recordings in all subjects took place at 8:30 AM at rest, in a quiet and comfortable environment. The electrocardiographic signals were digitized (sampled at a rate of 250 Hz), and stored on hard disk. We selected three time intervals of time recording, (8.30-11 minutes), (7 minutes), and (5-6.30 minutes). The ECG traces were analysed by the Nevrokard software and the obtained R-R intervals were subsequently analysed by the CZF method. We report here the obtained results.

As first we tried and reproduce the results obtained by Giuliani et al (Giuliani, A., P. Lo Giudice, A. M. Mancini, G. Quatrini, L. Pacifici, C. L. Webber, M. Zak, and J. P. Zbilut. A Markovian formalization of heart rate dynamics evinces a quantum-like hypothesis. Biol. Cybern. 74: 181–187, 1996). These authors demonstrated the possibility of a straightforward representation of cardiac dynamics in terms of a first-order Markov model. According to this model, heartbeat dynamics may be considered a random walk, where the system at each beat is presented with three alternatives:

a) To remain in the same state (i.e., having a beat of a length very similar to the previous one),
b) To shift to the higher class of beat duration,
c) To shift to the lower class of beat duration

So displaying a sort of quantum-like behaviour. This paradigm is particularly suited for CZF. By the above sketched model gives birth to a fractal structure of the R-R signal, given the above sketched Markov model holds at every scale (e.g. focusing on class a) intervals we will see a microscopic version of the same dynamics).

Two observables must be taken always in consideration in order to give an interpretation of the CZF graph. They are:

a) The values exhibited from the variability (in the three bands VLF,LF,HF);
b) the behaviour of the variogram against the frequency.

For R-R time series relating an ECG recording of about 7 minutes there are acceptable values of Variability in HF ranging from 1200 to 3500 msec² as maximum value and in the range 400-700 msec² as minimum values. For R-R time series relating 5-6 minutes also lower values may be accepted for the minimum values until 200 msec². Note that Variability of 1200-3500 msec² means calculated Variability about 35-60 msec., while calculated values about 400-700 msec² means Calculated Variability about 20-27 msec that result still acceptable as marker of variability.

We previously mentioned that we examined subjects at rest, in a quiet and comfortable environment according to the standard well known protocol. It must be clear that we are speaking here of a pure abstract theorization. The so called subject at rest is a pure abstraction. When recording an ECG, as minimum, the subjects are thinking to something. Also with all its rough approximations we may verify by the FFT that the shown peaks indicate a different height in such cases. Generally speaking, we must always be aware that the condition of each subject vary rather continuously in time respect to himself and respect to the other subjects also when they are normal subjects in resting conditions. It is certainly true that we have indicated previously some values of Variability obtained by the CZF method. However, we must always expect possible fluctuations about such values about 20% in order to be sure to enlarge the possible ranges with more realistic features. On the other hand, we have to outline here a particular characteristic of the CZF. As repeatedly outlined, this method calculates variability extended along the whole given R-R time series and for the valuable Lags. Variabilities are calculated as squared difference between R-R values shifted each time by a prefixed Lag, and thus we estimate that fluctuations valued in excess about the 20% should be
rather sufficient to account for the possible deviations respect to the values that we previously introduced in the case of young normal subjects.

The other important feature that we take in consideration is the behaviour of the variogram vs the frequency. It is evident that it must be rather uniform showing values of increased variability followed from values of decreased variability. Sudden changes in such uniform behaviour or, in any case, a non uniform distribution about such estimated values of variability induces to suspect some sudden modification of the heart rhythm and thus the presence of some abnormal rhythmics. Also a rather constant behaviour of the variogram not evidencing its characteristic decreasing behaviour at the increasing values of the frequency, should induce the suspect of some acting anomaly in rhythmics, failing in this case the evidence of the due variability in the analyzed R-R time series.

Let us look now to the results obtained from the examination of the previously mentioned young subjects. Note that we report here only the results obtained for 7 minute and for 5.-6.30 minutes., indicating the first by 7 and the second by 6. We exclude the results corresponding to (8.30-11) minutes for brevity but soon after we give such results by histograms.

An optimum subject under the profile of the exhibited values of variability and behaviour vs frequency is TA, VDA gives an optimum profile in the investigation of 7 minutes but it manifests a sudden change in the behaviour in the exploration on 6 minutes. We suggest that in such cases a more accurate investigation is required on subjects of such kind. MA may be considered very satisfactory in 7 minutes but a quite satisfactory behaviour in 6 minutes. VDB is very satisfactory. AM is satisfactory also if it manifests a too reduced variability about 0.4 HZ in the investigation about 6 minutes. SC is satisfactory. DCP is satisfactory also if with some insufficiency in the variability behaviour in CZF-6 minutes graph. RR, AT, CP, SCI are satisfactory as well as still also PF while GE and RS evidence a rather low Variability in the range 0.3-0.4 Hz.

For the LF evaluation the criterium must be that Variability must remain rather constant in the explored frequency band 1500-3000 m sec$^2$ (39-55 m sec$^2$).suspecting in particular for those behaviours that present a too accentuated decay respect to the frequency values in the LF band.
CZT (Corbe, Zbilut, Federici) Analysis
from 0:00:00 to 0:08:51 (duration = 0:08:51)

(765 spectral components, res=0.00127741 Hz)
VD-A 6

MA 7
Let us give also a look at the consequent histograms.
1) The examined subjects are the same that we analysed previously by the FFT.
2) First of all, let us appreciate the uniformity of the results that we obtained with relation to the calculated variabilities. We have now a graph and quantitative estimations of the marker of ANS activity. We have furnished also some general criteria to read and to interpret the CZF graphs Variability against frequency. Actually we have to conclude that by the CZF we have now a reliable marker for ANS.
3) It is of particular interest also the inspection of the ratio LF/HF. It remained rather constant among all the examined subjects with the rather obvious difference about the mean value of 0.73 ± 0.16 for 7 minutes recording and 0.86 ± 0.17 for recording of 5-6.30 minutes. 0.57 ± 0.04 was obtained in the case of examined recording of 8.30-11 minutes, that in fact represents a rather long interval of measurement for short time HRV analysis. In any case the CZF show an evident novel feature. There is a rather constant balance between Variability In LF and HF respectively, and we retain that this is of course the correct physiological interpretation since we must account that there is continuous balance, interference and thus coupling between the two modulating components of the ANS system. We observe of course that this is a feature that improbably arise by using the FFT analysis.
4) In conclusion: the results that we obtained by using the CZF result to be excellent when considered as markers of the ANS. There is still a novel feature that we may estimate by using the CZF method. We may appreciate, as previously explained, the ratio between the Power of the modulating components of the ANS and the correspondent Variability that is induced. This a very important new parameter that we may appreciate for the first time. Obviously we must always take in consideration the limits that enter in the R-R time series analysis by using the FFT. Just so, let us examine now the ratio of VLF_{FFT}/VLF_{CZF}, LF_{FFT}/LF_{CZF} and HF_{FFT}/HF_{CZF}. We have the following histograms:
Also with all the limitations arising from using FFT, we consider decidedly important to estimate how it is the ratio between the Power (estimated by PSD of FFT) of the ANS modulating components and the corresponding Variability that they induce, and that we estimate by the CZF method. By inspection of the previous histograms, such ratio remains rather constant among the different normal young subjects that we examined.

For VLF we had a mean value of such ratio of 18.62 ± 4.12 for 8.30-11 minutes, 12.40 ± 3.29 for 7 minutes and 12.31 ± 3.00 for 5-6 minutes.

For LF we had a value of such ratio of 22.67 ± 6.07 for 8.30-11 minutes, 16.30 ± 4.83 for 7 minutes and 16.02 ± 4.76 for 5-6 minutes.

For HF we had instead very fluctuating values with a mean value of 33.06 ± 12.93 for 8.30-11 minutes, of 22.12 ± 11.42 for 7 minutes and of 19.96 ± 10.60 for 5-6 minutes.
In brief, the estimation of such parameter seems to realize a satisfactory agreement for VLF and LF but not for HF.

In order to confirm such result, we proceeded to estimate the correlation coefficient between the Power estimated by the FFT and the Variability estimated by the CZF. We obtained a very satisfactory value of the correlation coefficient for the VLF and for the LF, but such statistical parameter indicated that we have not correlation between the calculated value of Power in FFT and Variability in CZF for the HF. Assuming that the CZF is the correct marker of ANS, we must conclude that the FFT gives its greater worse estimation just in the frequency band ranging from 0.15 –0.4 Hz, that is to say …in the periodicities included in the interval going from 2.5 to 6.6 seconds.

This concludes our approach on application of the CZF method on normal young subjects.