Cross Spectral analysis of Heart Rate Variability connected to work related stress

Measures of HRV via power spectrum analysis are traditionally employed by using 2-5 minutes of ECG averaging in a predefined frequency range, i.e. 0.12-0.40 Hz, corresponding to the range within we normally breathes. The computation of the HRV-power might be reliable for a resting person. However, this, rather wide frequency band, does also include power from other frequencies which most likely is highly irrelevant information. This method will also give an incorrect power estimate when the breathing frequency is no longer within or close to the pre-defined frequency range. By continuously detecting the respiratory centre frequency and base the HF-HRV bandwidth analyses on that value it should be possible to narrow the frequency range of the HF-HRV estimate. Consequently, only information that is of interest, i.e. heart rate variations due to respiration, without irrelevant signal information of unknown origin is quantified.

The spectrum analysis methods in available commercial equipments for measurement of HRV power are based on traditional older methods, typically a windowed periodogram. In research, parametric estimation, e.g., Auto Regressive (AR) models have been proposed. However, in recent years, the technique of using Multitaper or Multiple Window spectral estimation (MWS) has become more popular. Multitapers imply an efficient use of finite length data with respect to bias and variance. The idea, first presented by David Thomson, (Thomson,1982), was to average windowed periodograms with the aim to reduce the variance of the spectral estimate. The commonly used method today rely on that different data intervals give almost uncorrelated spectral estimates and when the spectral estimates are averaged, the variance of the result is reduced. Thomson suggested that different data windows, multitapers, should be applied to the same data sequence and the properties of the windows should give uncorrelated periodograms for the final average. The rationales are that tapering reduces the leakage between frequencies, and that averaging reduces the variance of the estimate. For spectra with large spectral dynamics, e.g., peaked spectra, which is typically the case for HRV, the performance of Thomson's method degrades due to cross-correlation between subspectra. A number of other methods, e.g., the Peak Matched Multiple Windows (PM MW), have shown to give a better estimate in the sense of smaller bias and variance. Cross spectrum between HRV and breathing signals can be seen as a refined technique for analyzing the HRV power. The cross spectrum makes the frequency areas, not including the breathing frequency, to be suppressed in the analysis, see Figure 1). The power spectrum methods in this context can be designed to specifically gain a pre-defined frequency bandwidth around the respiratory frequency.
Figure 1: Multitaper spectrogram of HRV and respiratory frequency, top and middle, and a respiratory power-normalized cross-spectrum (bottom) of the two signals. The subject has been breathing with increasing frequency following a metronome. Strong power is shown by red color and weak power by blue color. In the top and middle spectrograms of HRV and respiration, an irregular power development is seen over time.