Swan & Stone

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Hello all,

Figure 1: A swing demonstrates resonance.

Welcome to ***Swan & Stone***, Volume 1, Issue 4: ***The Mechanics Of Resonance***. Resonance is a fascinating topic about which much is known in the field of physics. In essence it refers to the natural vibratory frequency of an object or system. Resonance is a fundamental property of matter, and as such, all matter, large and small exhibits it. A few examples of how humankind has employed the phenomenon of resonance include musical instruments which are designed to produce sound of a certain pitch, crystals which can be fabricated to vibrate at precise frequencies, providing extremely accurate and stable clock signals for most all contemporary digital electronics, and lasers which employ resonance to produce light that is perfectly "coherent", i.e. light rays of exactly the same frequency and wavelength. A simple swing is a resonant system in which we can actively participate. If we sit in a swing and begin to swing our legs and body the swing begins to move forward and backward to match our movement. As we continue, we find the sweet spot where the swing will go the highest with *optimal* effort on our part. Any more effort and the swing begins to become jerky and unstable; any less effort and we lose altitude. This sweet spot defines the natural resonant frequency of the system which includes our body – the "system" is a pendulum. The swing of the pendulum describes a sine wave both in terms of displacement from its vertical position and relative to its velocity (technically cosine), the sine wave being the essential natural signature of resonant vibration, which is by definition cyclic, and therefore describable in terms of the circle and its trigonometry. The relationship between the circle and the sine wave is depicted in this animation of the Unit Circle.

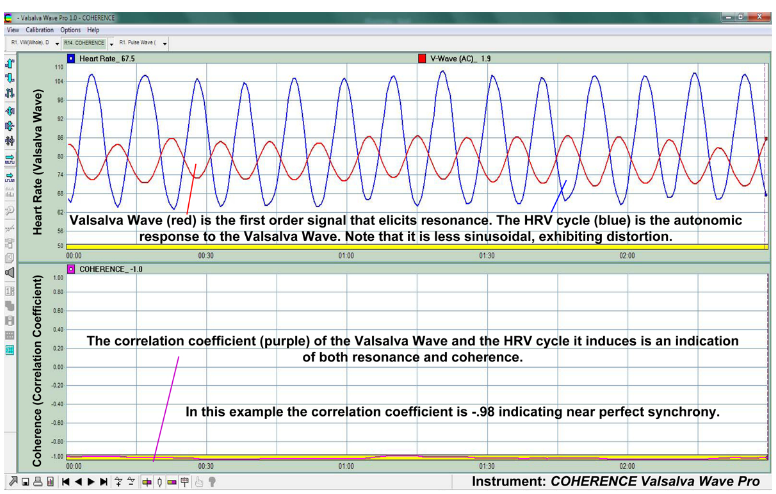

Figure 2: High resonance and coherence. (Zoom for clarity.)

The human cardio-pulmonary-circulatory system is a resonant system. In fact the system is composed of a number of resonant physiologic structures including the chest, diaphragm, lungs, heart, arterial tree, capillary networks, venous tree, and of course both mediums, air and blood, are an integral part of the system at large. If analyzed independently, each would be found to exhibit resonant properties of its own. In combination, the system at large demonstrates resonance, this requiring synchronous participation of all structures, not unlike the synchronous participation of musicians in an orchestra. The potential for this resonant participation of the organs of circulation is latent in all of us. The way it is invoked is via resonant "coherent" breathing. Referring to Figure 2, the signature of resonant breathing, *the Valsalva Wave* (red), appears highly sinusoidal, but because there are subtle variations in amplitude, phase, and frequency throughout the system, the outcome (the HRV cycle) is less sinusoidal and coherent and is instead a more complex signal that varies in amplitude, phase, frequency, (and coherence). As the body is a sophisticated biological system with both conscious and autonomic control, this is natural. (Perfect coherence over time would require amplitude, phase, and frequency of all contributing elements to remain absolutely stable).

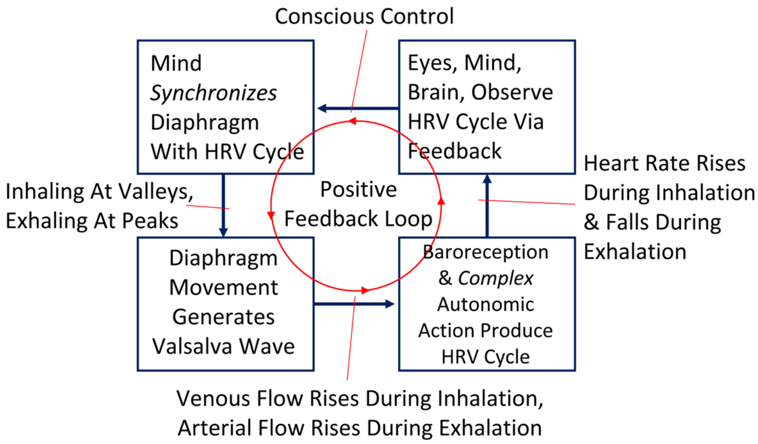

Figure 3: The mechanics of resonance with feedback.

As explained in Issue 3, the phase synchrony of the HRV signal with the Valsalva Wave that produces it (top panel of Figure 2) is the measure of resonance in the time domain. In this capture, the totality occurring over a period of 4.2 minutes, the correlation coefficient is -0.98. It is a recent capture of my breathing with the aid of Valsalva Wave Pro and represents my personal best to-date. The frequency of breathing that produced this synchrony is .098 Hertz or 5.86 breaths per minute. You can see the stats from my 3 most resonant sessions here, the 3 corroborating the same frequency. It is interesting to note that heart rate variability (AvHRV) and Valsalva Wave Variability (AvVWV) measures are quite different amongst the top 3, a testament to the complex role played by the autonomic nervous system relative to cardio-pulmonary-circulatory governance.

Referring to Figure 3, the fundamental method used to obtain these results is that of simultaneously monitoring the Valsalva Wave and heart rate at the earlobe (with a single clip), synchronizing inhalation with HRV valleys and exhalation with HRV peaks, and breathing such that the "Coherence Curve" (correlation coefficient) approaches -1, where the closer to -1 the better. This is sustained for 5 minutes as the session metrics are recorded. Afterwards, Fourier Analysis is performed on the Valsalva Wave data to transform time domain measures into the frequency domain measure, i.e., spectral analysis. The Valsalva Wave is used because it is a physical wave phenomenon, it is sinusoidal as compared to the HRV cycle, and it is the metric that we are producing via our breathing. The HRV cycle, being an outcome of complex autonomic action, is inherently distorted – by that action. The spectral analysis should demonstrate relative purity with the peak of the prominent frequency being dramatically higher than other frequencies. In this case, the relative power of the prominent frequency is 1162. Other frequencies do not exceed 140.

Subtle factors play an important part in realizing high synchrony (resonance) in the time domain, and a Coherence Curve approaching -1. I posit that this is due to the complexity of autonomic action involved. For example, a single thought can cause a shift in synchrony such that the Coherence Curve may drift upward from -0.9 to -0.6. This is one of the reasons why one's resonant breathing rate cannot be discerned accurately by observing heart rate variability (HRV) alone, as one cannot perceive subtle changes that cause deviation off of the resonant frequency. HRV is the outcome of baroreception and complex autonomic governance of circulation. This includes myriad concerns that are related to circulation, i.e. blood pressure, body temperature, energy production, etc. One can use an HRV-only instrument to record the heart rate and this record can then be post processed to discern frequency, but without correlating the heart rate with what the blood is doing there is no solid indicator of resonance in the heart rate record. The average HRV of my #1 record (personal best) is high, but across a broader set of data, the correlation between HRV and Coherence (resonance) is not high.

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