Breathing, Blood Flow, And The Brain

An Evolutionary Understanding

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ISNR - September 2013, Addison, Texas

Acknowledgements

Tato Sokhadze

Jonathan Toomim

Bob Grove & Jan Hoover

A DVD of this presentation is available at

www.ISNR.org

Ask for P19-13

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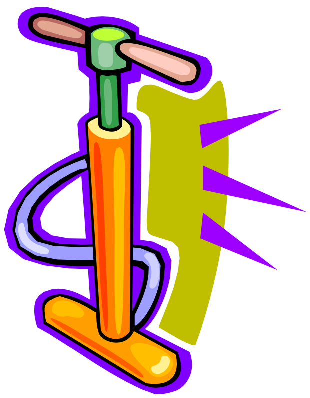
2. The search for the wave in the brain
3. Thoughts on the evolutionary origin and function of the wave

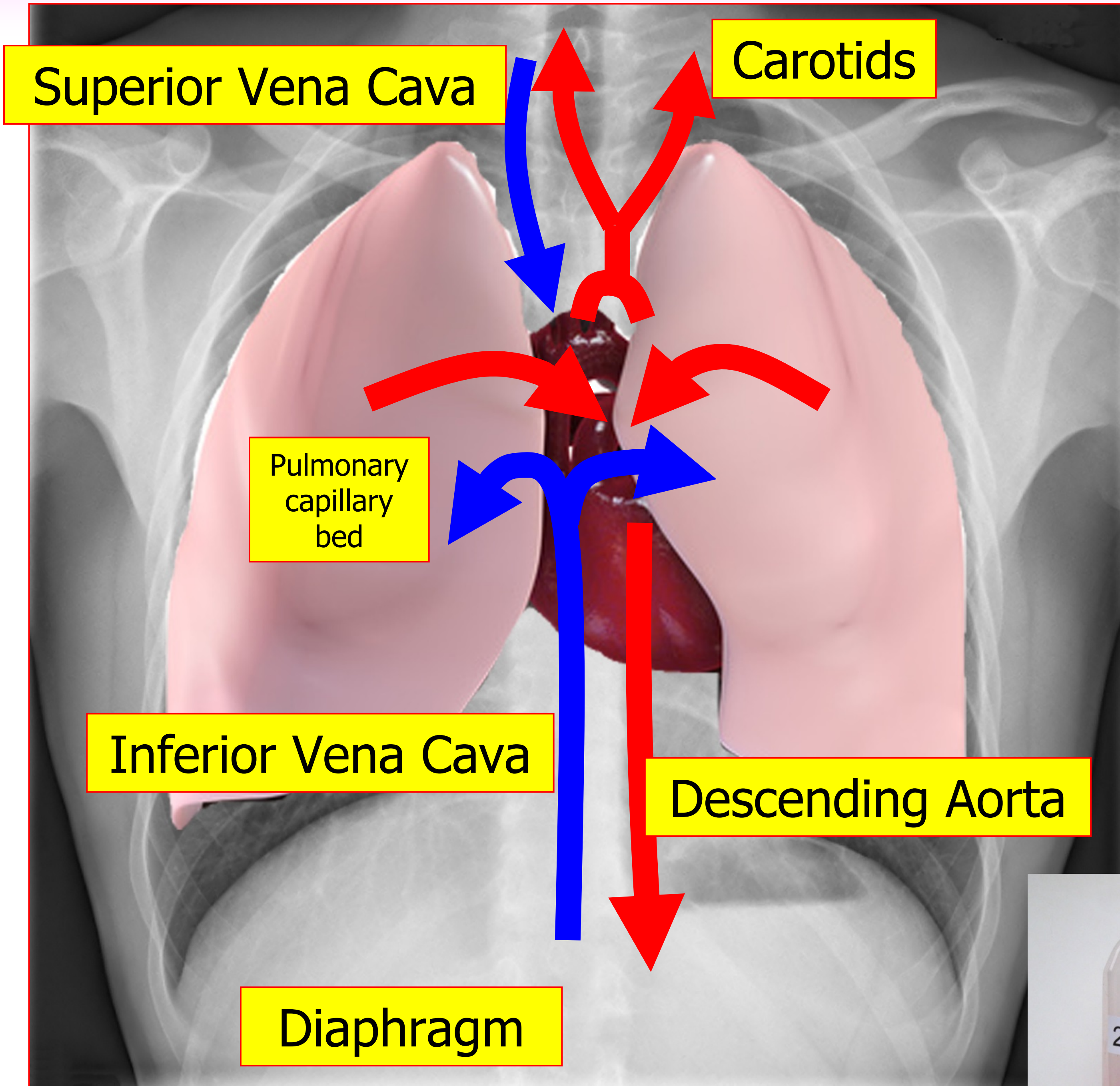
The “Thoracic Pump” Impetus For The Respiratory Arterial Pressure Wave And Breathing Induced Heart Rate Variability



The thoracic pump consists of the heart, lungs, chest wall, diaphragm, & intercostals.

It is an anatomical complex that facilitates both gas exchange & *circulation*.

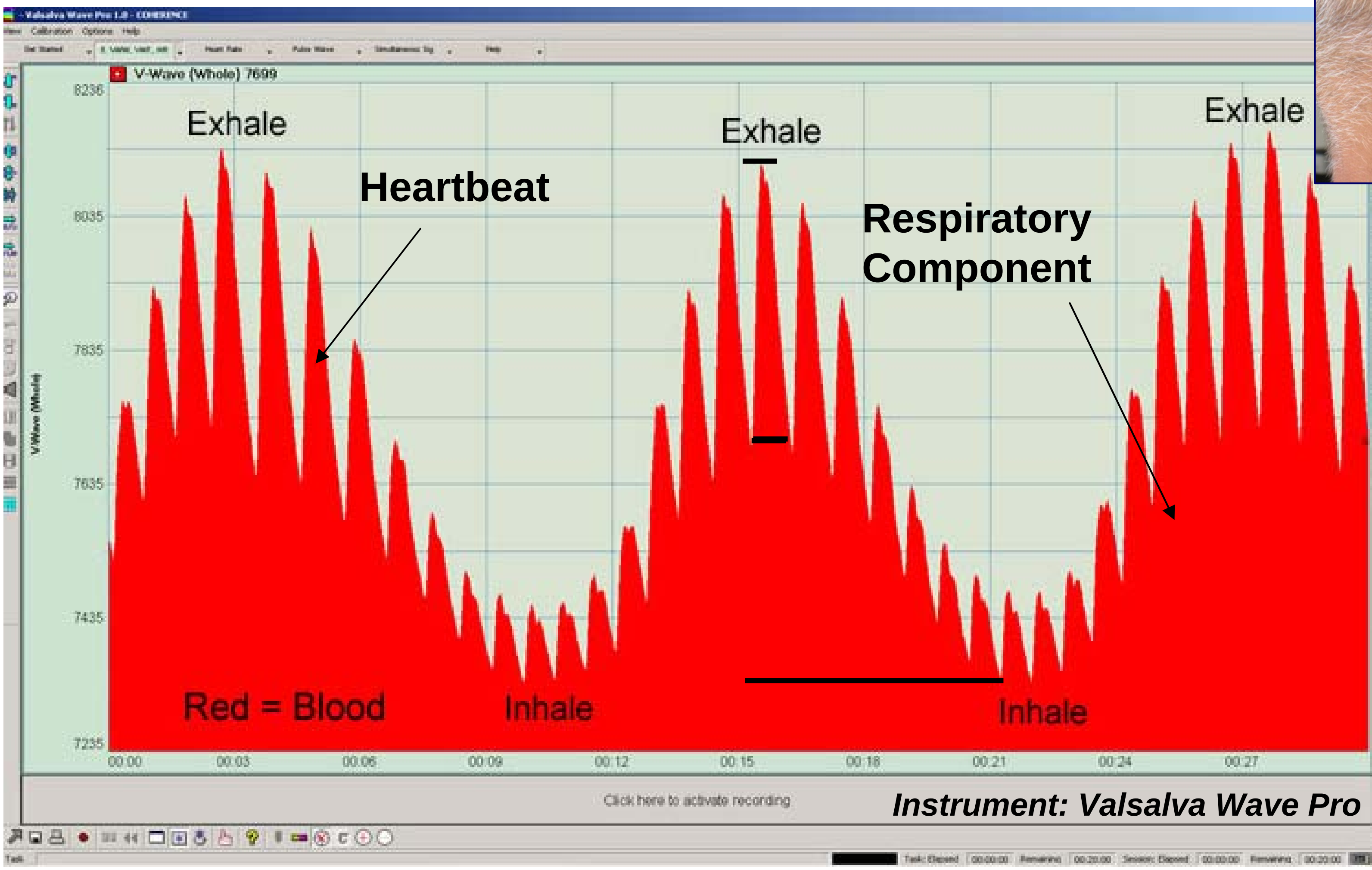
The Thoracic Pump



Anatomy is simplified for purposes of illustration

The Wave

The thoracic pump produces a wave of blood in the circulation.



The wave rises and falls with exhalation and inhalation respectively.

The Valsalva Wave:

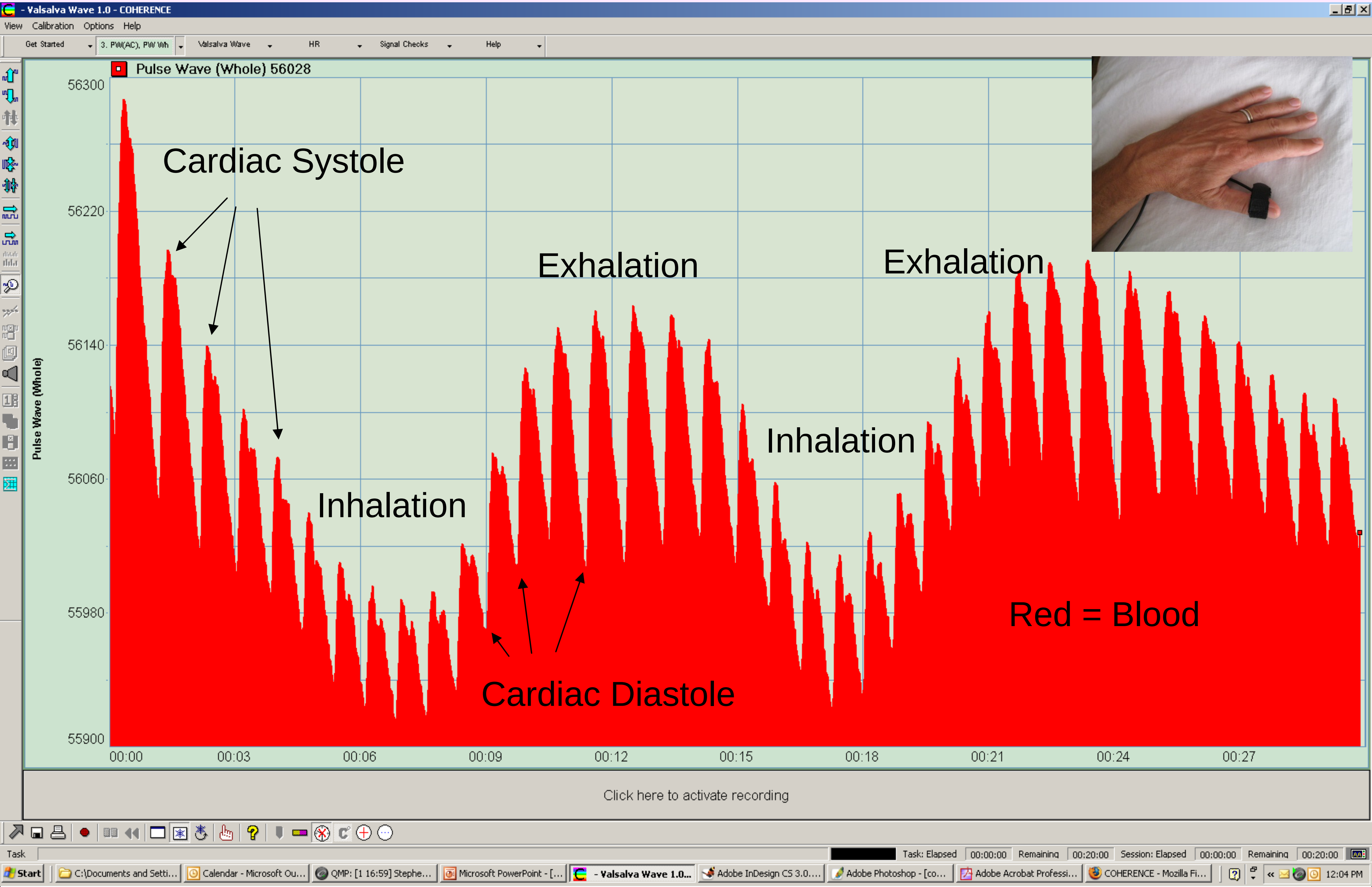
Dr. Bob Grove and I dubbed it
“The Valsalva Wave”,
named after Antonio Valsalva,
circa 1600s.

Antonio Valsalva was one of the first Western physiologists to observe that a relationship exists between breathing and blood flow.

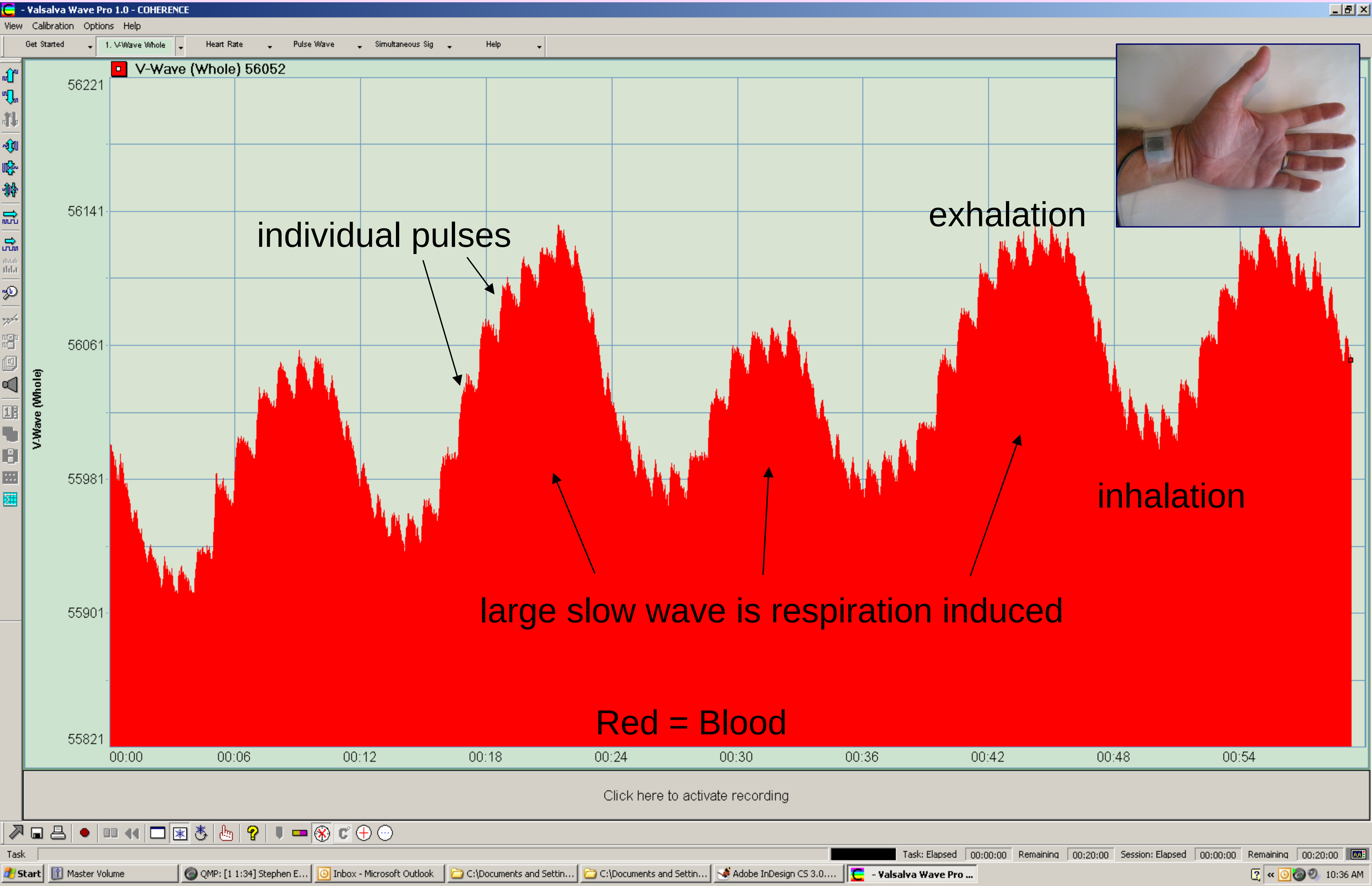
The Valsalva Wave describes the wholistic wave that rises in the arterial tree during exhalation and rises in the venous tree during inhalation -> A followed by V.

Previous references to the phenomenon, “respiratory arterial pressure wave”, “Mayer Wave” don’t capture the totality of the arterial/venous phenomenon, nor the mechanics behind it.

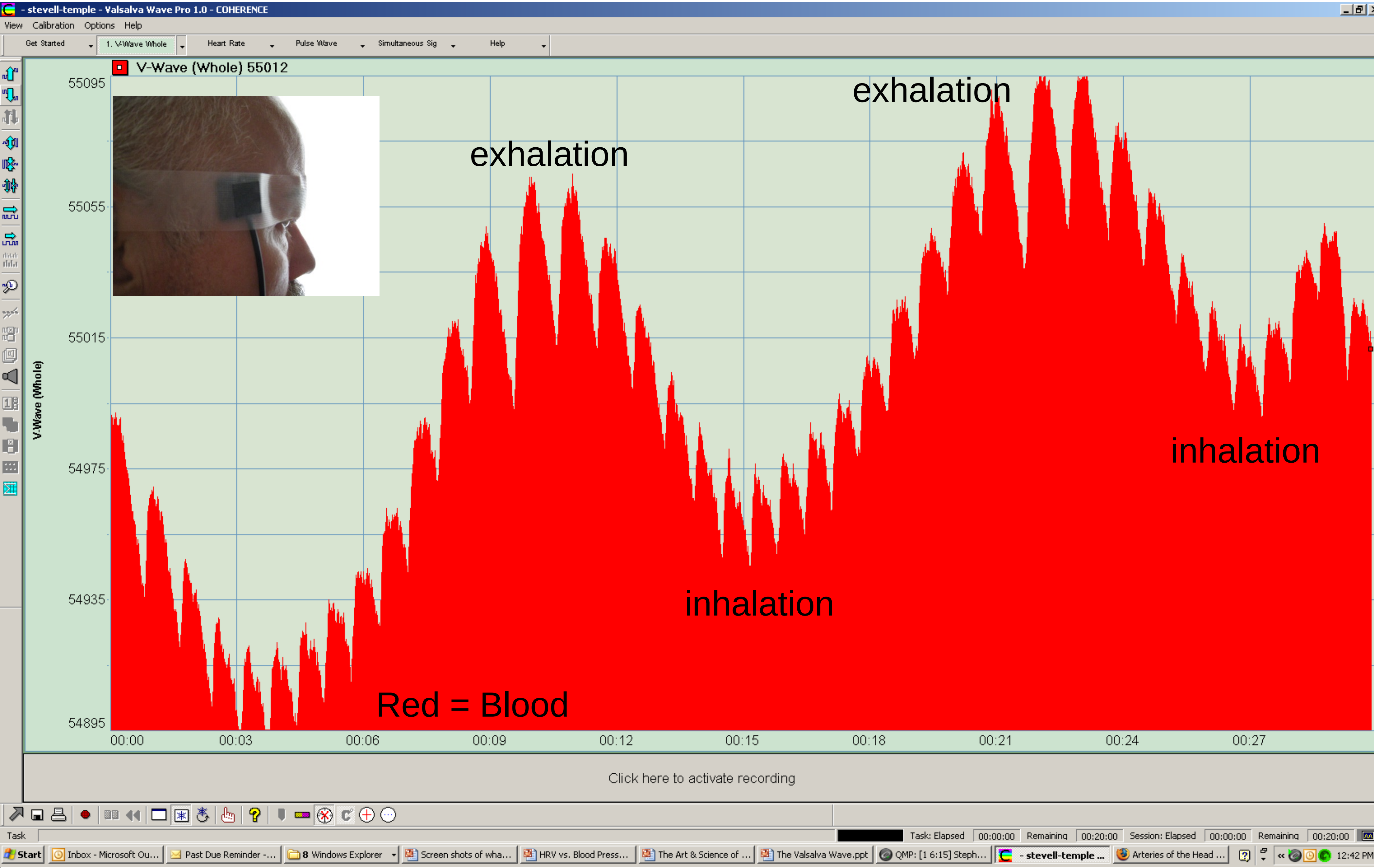
Viewed At The Thumb



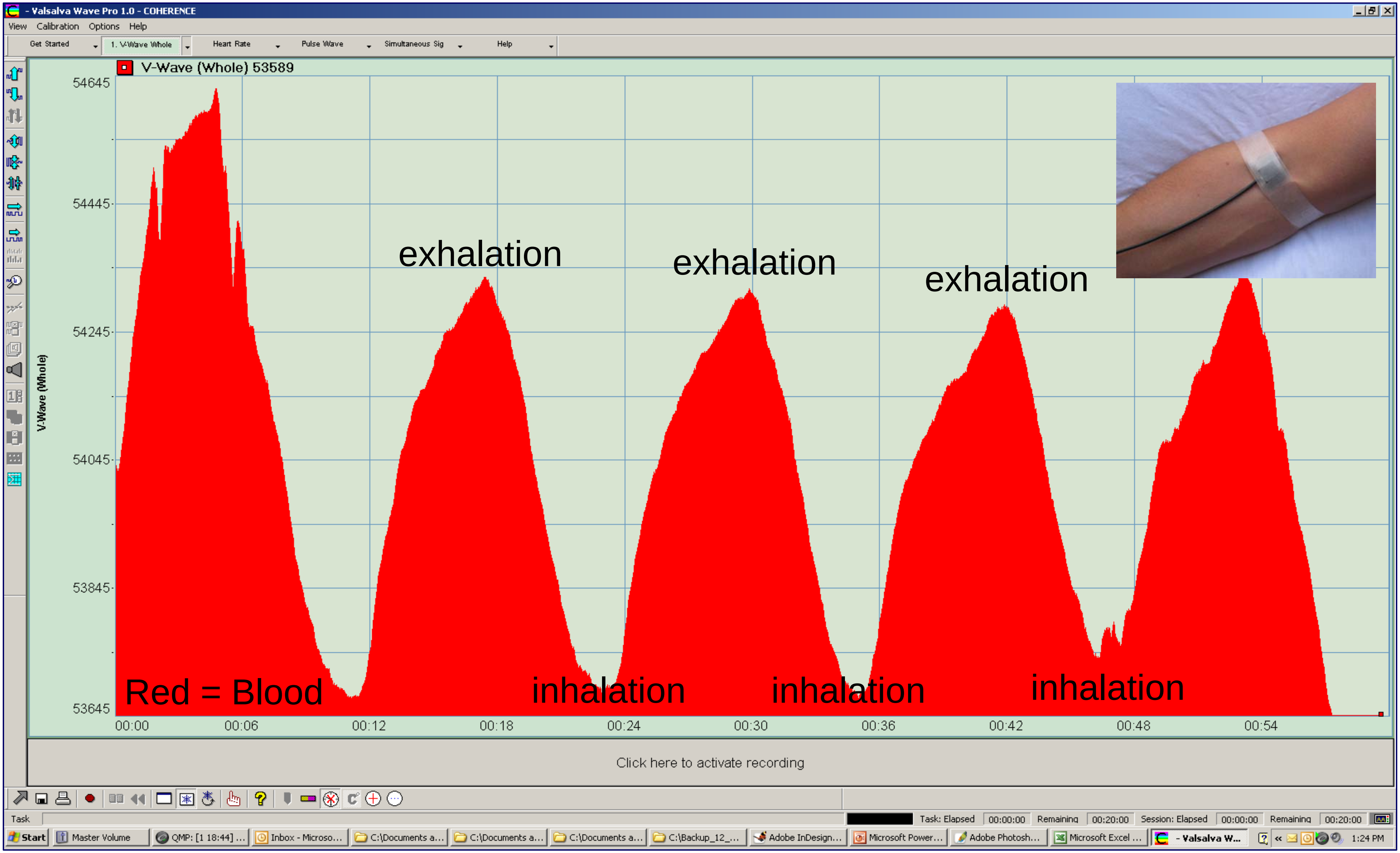
Viewed At Vicinity Of The Radial Artery



Viewed At The Vicinity of Temporal Artery

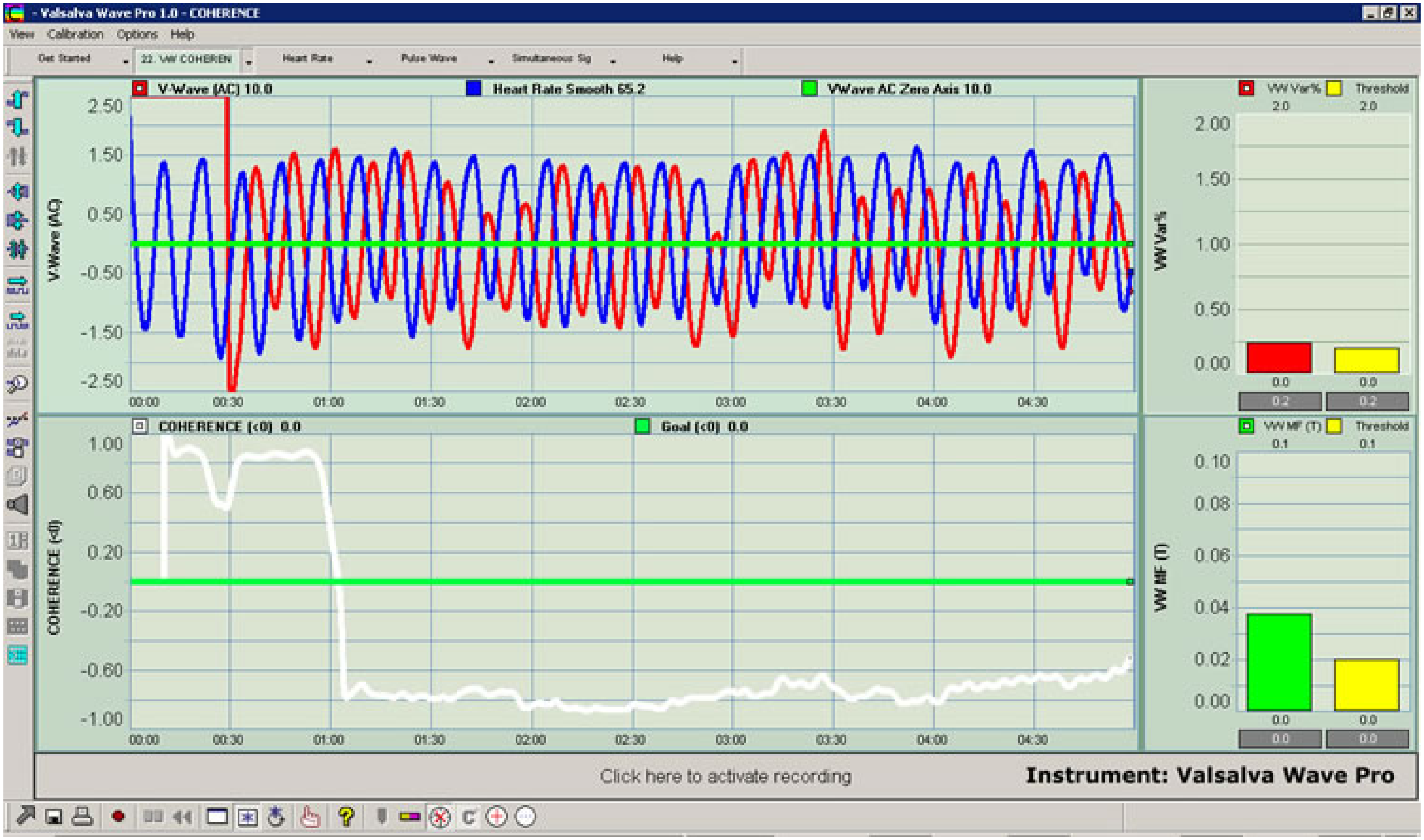


Viewed At The Medial Cubital Vein



Heart Rate Variability

It is generally accepted that this wave is the impetus for heart rate variability via baroreceptor action.



Here we see that HRV is nominally 180 degrees out of phase with the Valsalva Wave – at resonance.

A Question Has Remained...

We can see the wave in the arterial, venous, and capillary circulation anywhere we are able to look.

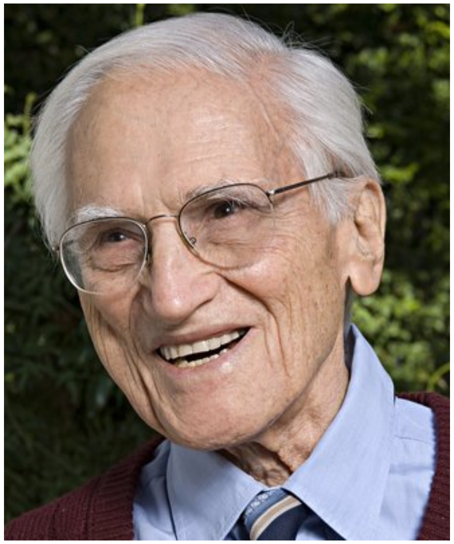
But does the brain experience the wave?

Hemo-Encephalography

In 1999, the late Hershel Toomim and Robert Marsh were awarded the US patent on HEG.

HEG uses light to observe blood in the brain through the skull.

In 2009, Hershel Toomim and I had the opportunity to discuss the wave. Had he seen it using HEG?



Hershel Toomim

His answer was, that he had looked for it, but "No", he had not seen it.

His thinking was that for cerebral homeostasis, the brain micro-manages blood flow, normalizing the wave.

Hemo-Encephalography

But could it be a matter of filtering, i.e. very low frequency signals were being excluded?

(The way we were able to see the wave plethysmographically was by eliminating the low frequency filtering of the state-of-the-art heart rate variability instrument.)

Hershel and I agreed to consider it..

He passed away in 2011 at age 95.

Hemo-Encephalography

This year I learned that Jonathan Toomim, Hershel's grandson had continued his HEG research.

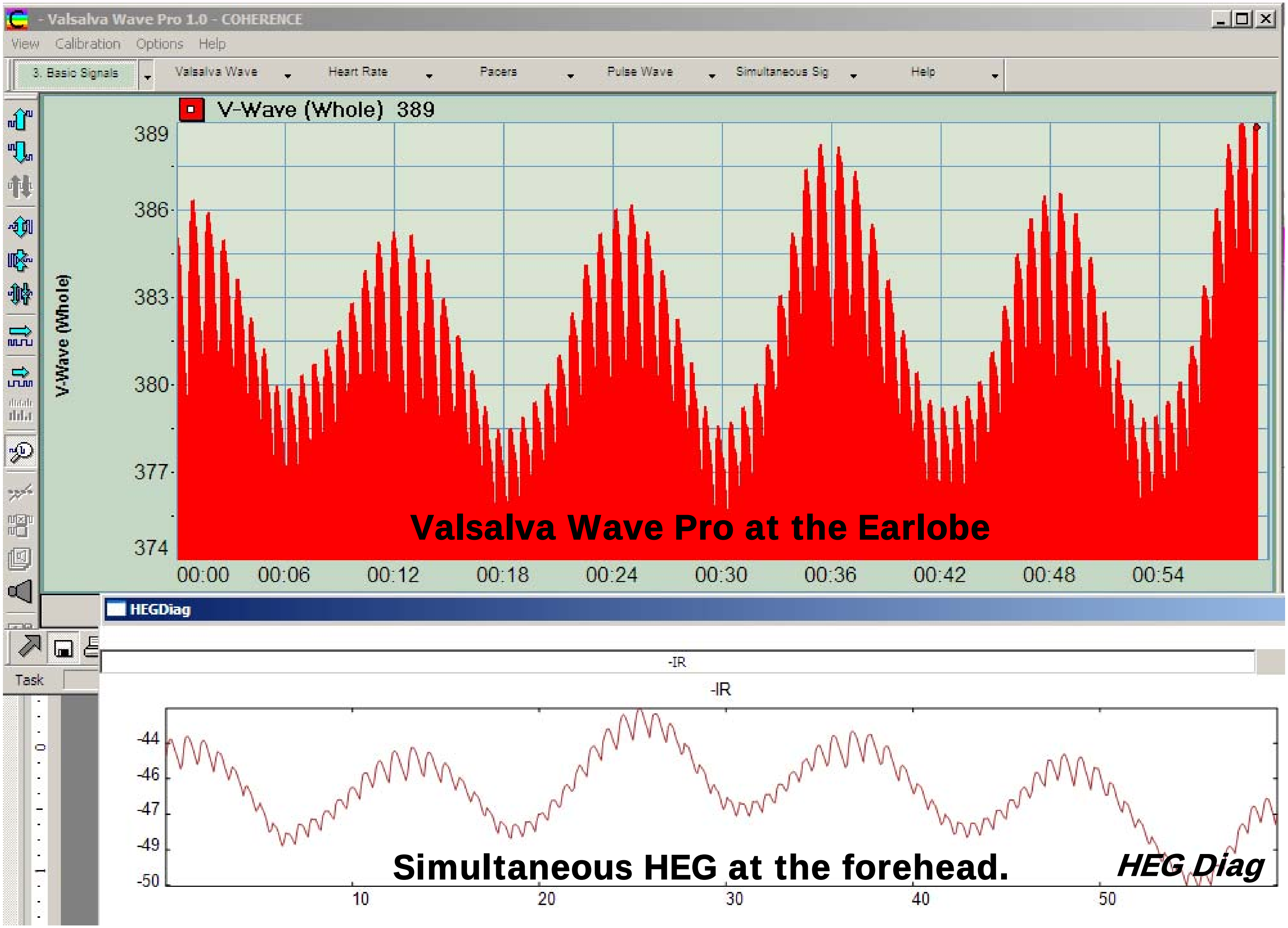
I connected with Jonathan via Skype, and learned that he had developed a research instrument without filtering.

One evening he demonstrated it via Skype.

When he breathed slowly deeply and rhythmically, the wave was clearly present.

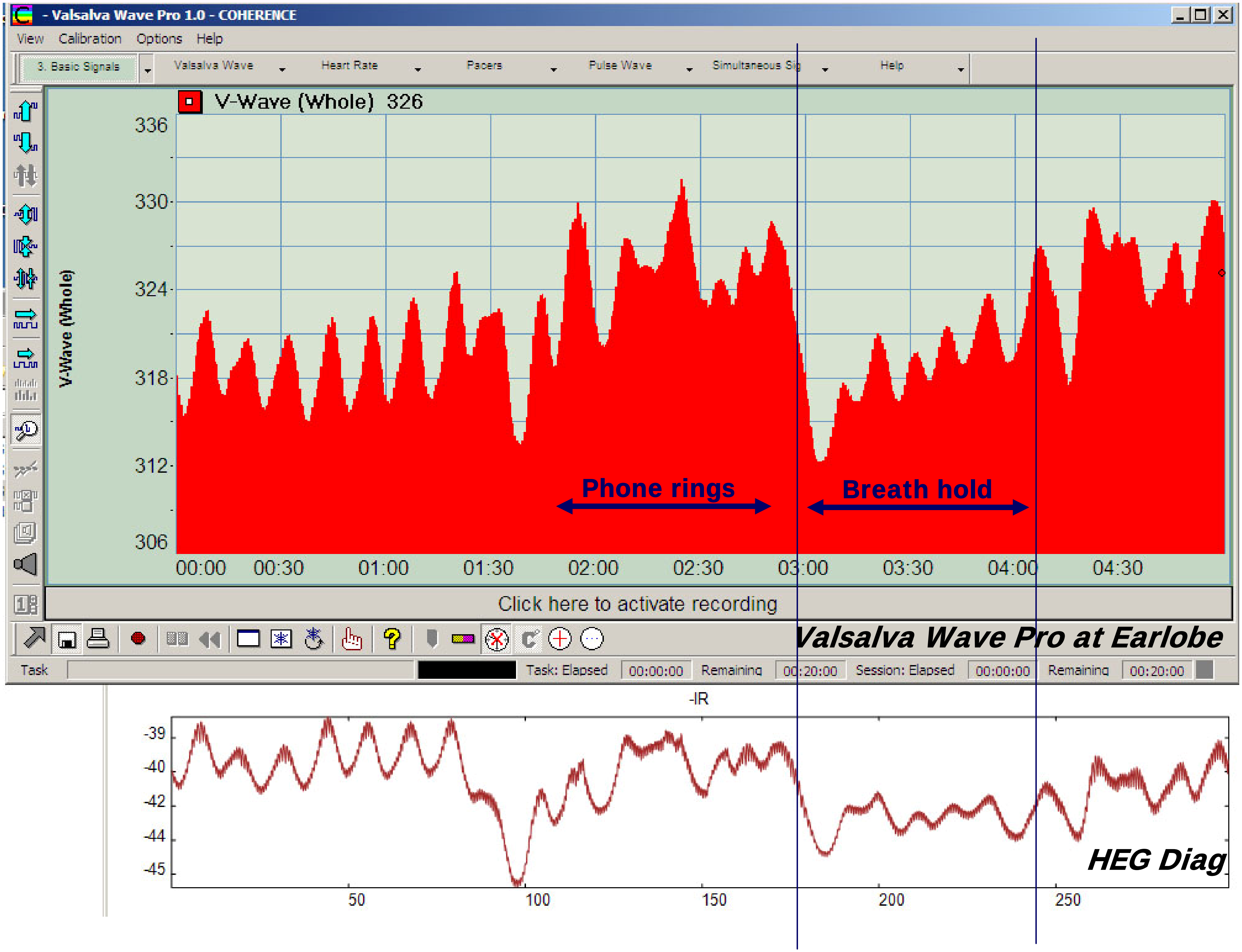
Also when he yawned – a key test.

Simultaneous VWave/HEG, 60 Seconds



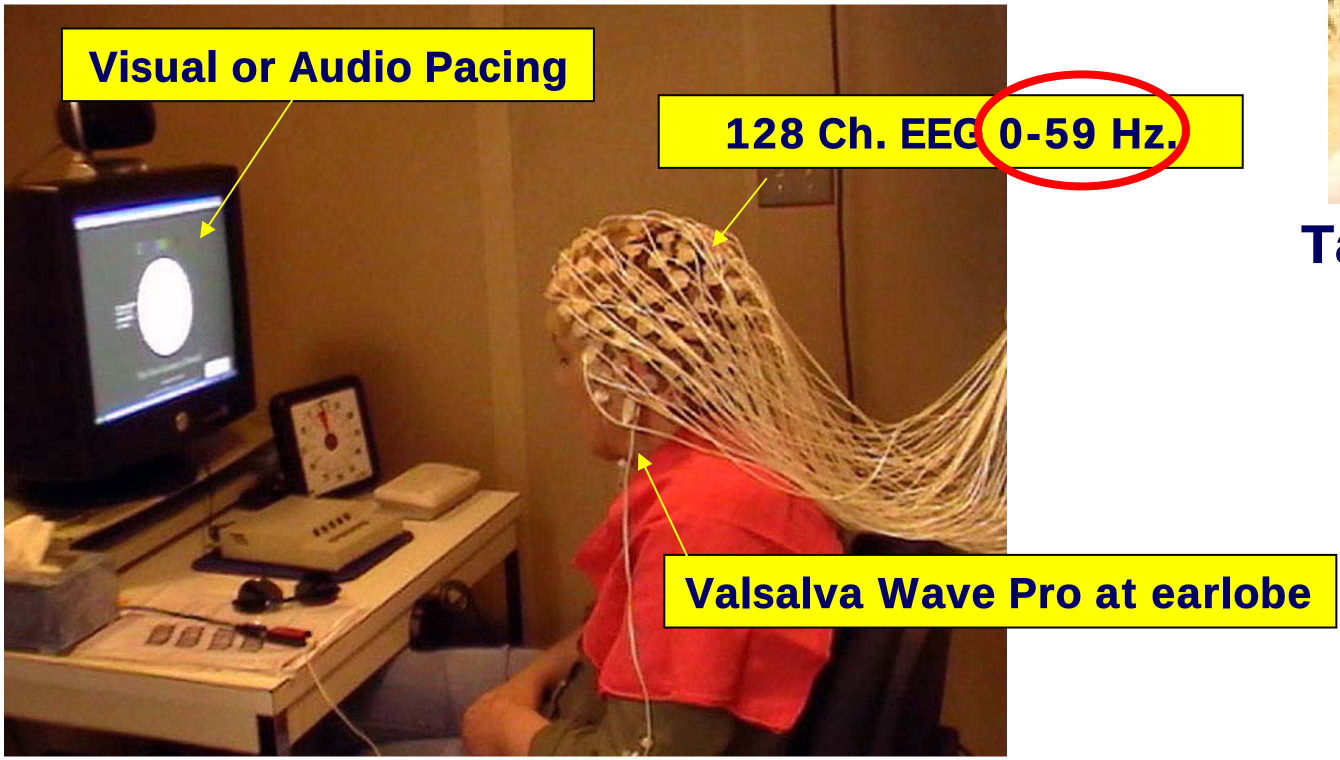
The Valsalva Wave is clearly visible in the brain including respiratory and heart beat components.

Simultaneous VWave/HEG, 5 minutes



EEG

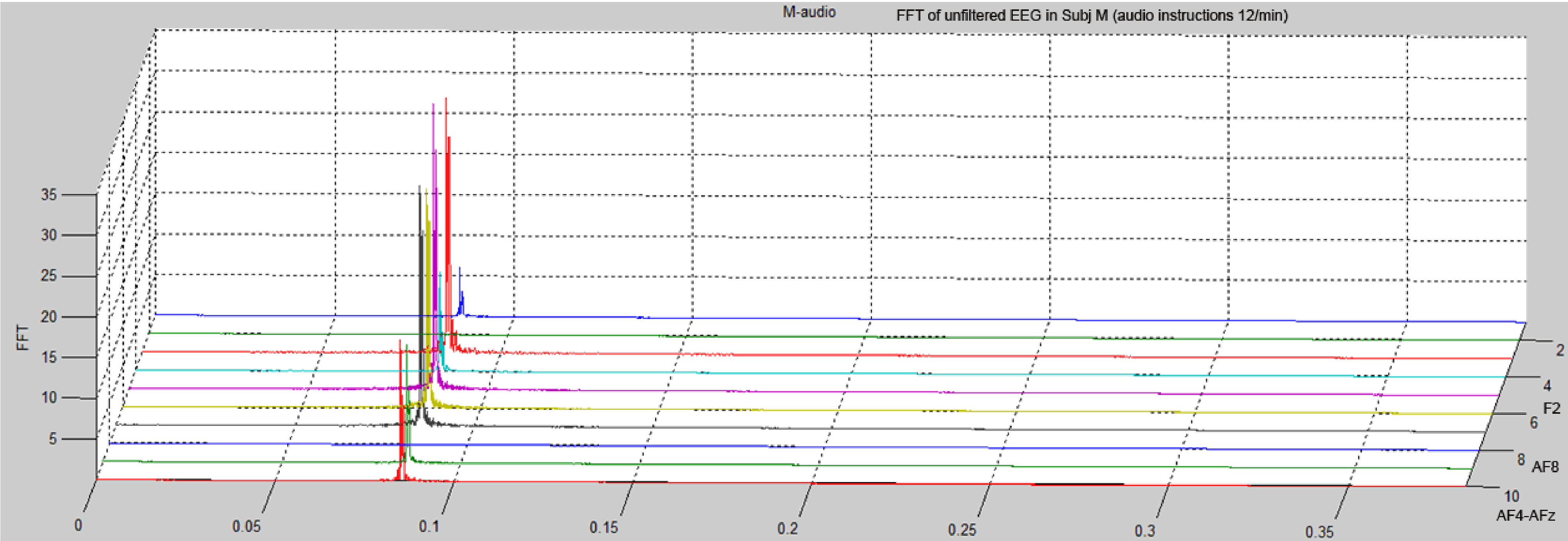
If this is true, the wave must be visible via EEG?



Tato Sokhadze PhD
U of L School Of
Medicine

Subject recording simultaneous wideband EEG and Valsalva Wave with paced breathing at 5 breaths per minute.

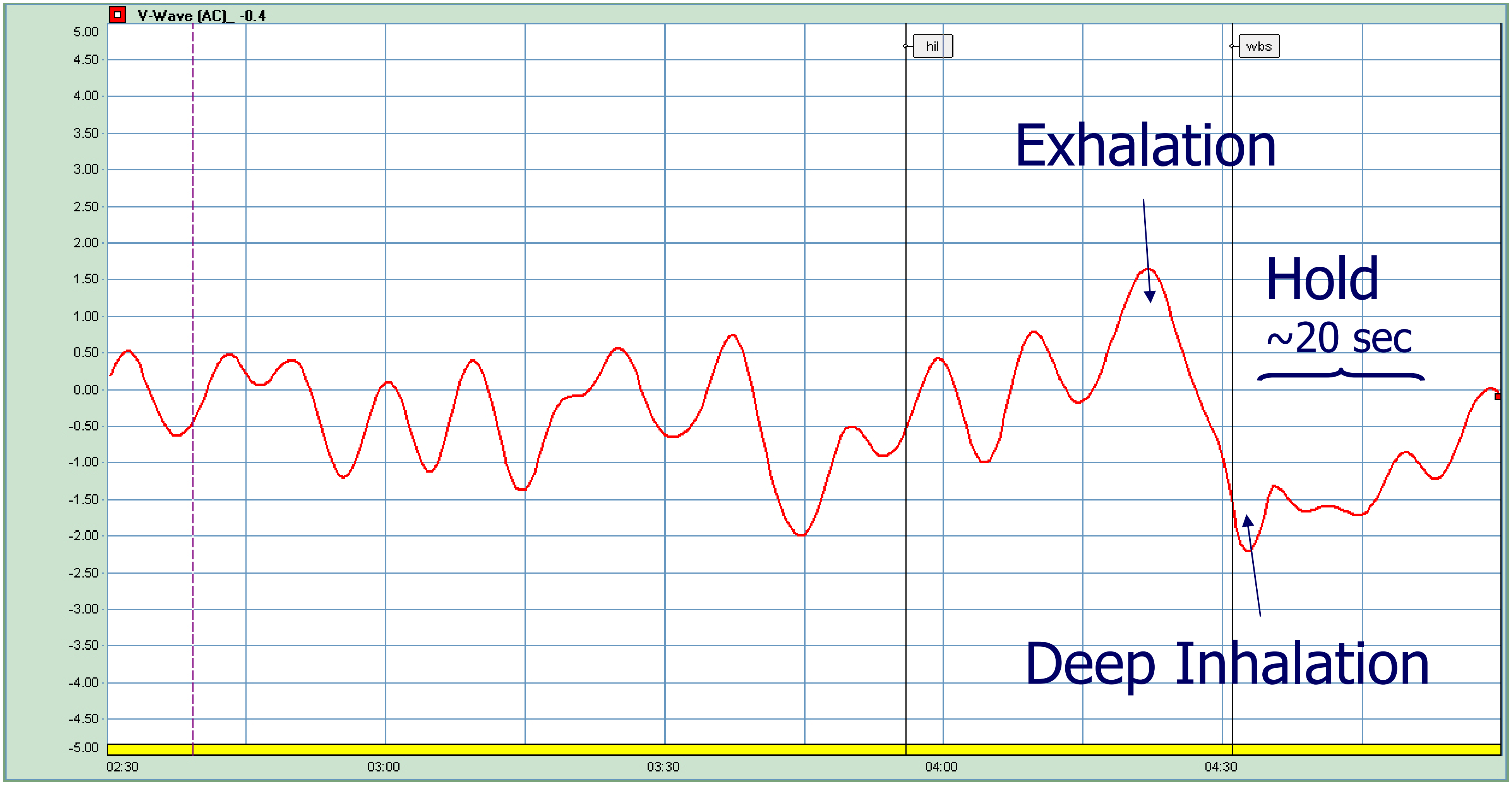
"M" EEG FFT – Audio Pacing



Breathing frequency (.085 Hz.) clearly predominant across electrodes.

"E" Breathing, Then Holding

Valsalva Wave at earlobe during breathing, then hold, then resuming:



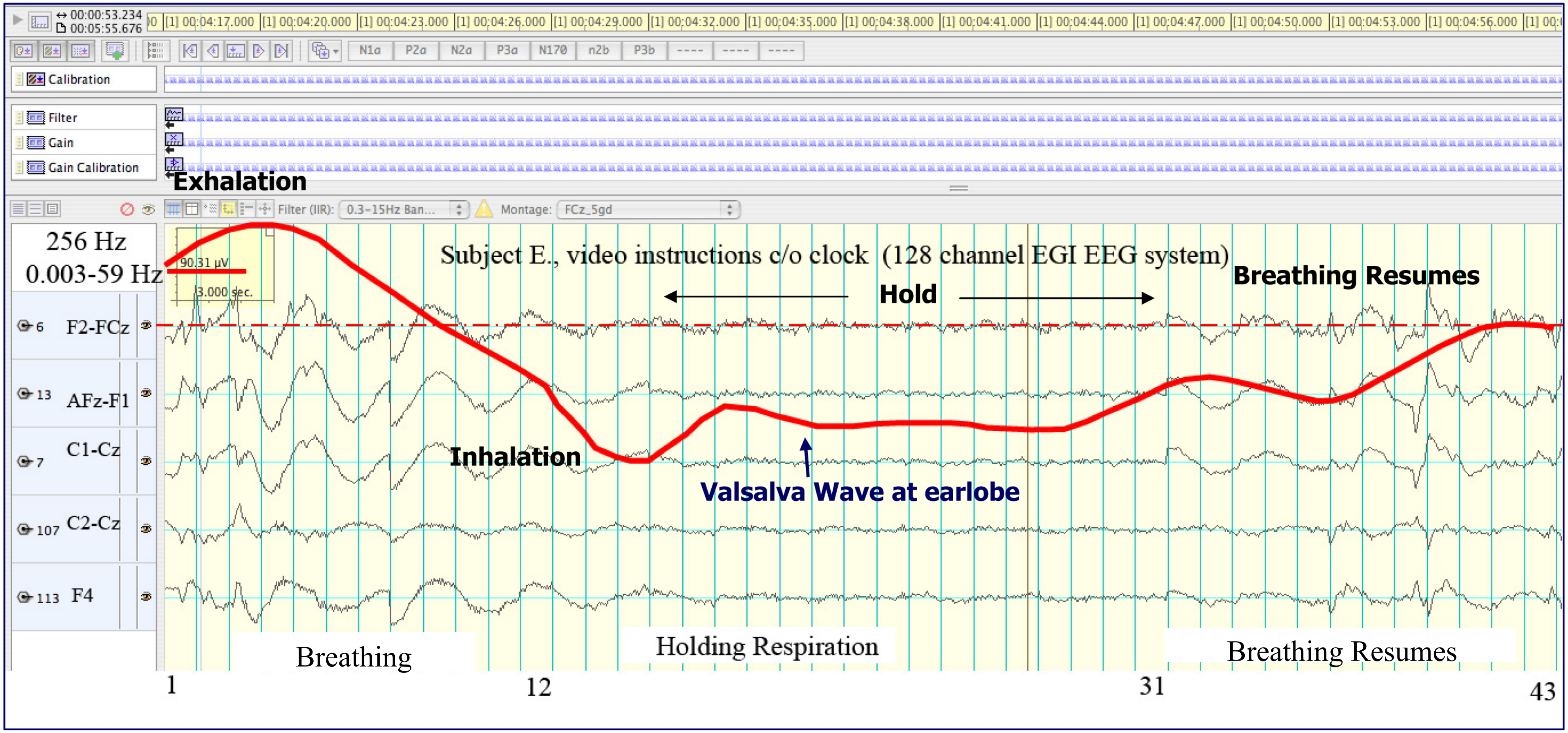
Instrument: Valsalva Wave Pro

4:20

EEG

"E" EEG at multiple points while breathing with visual pacer:

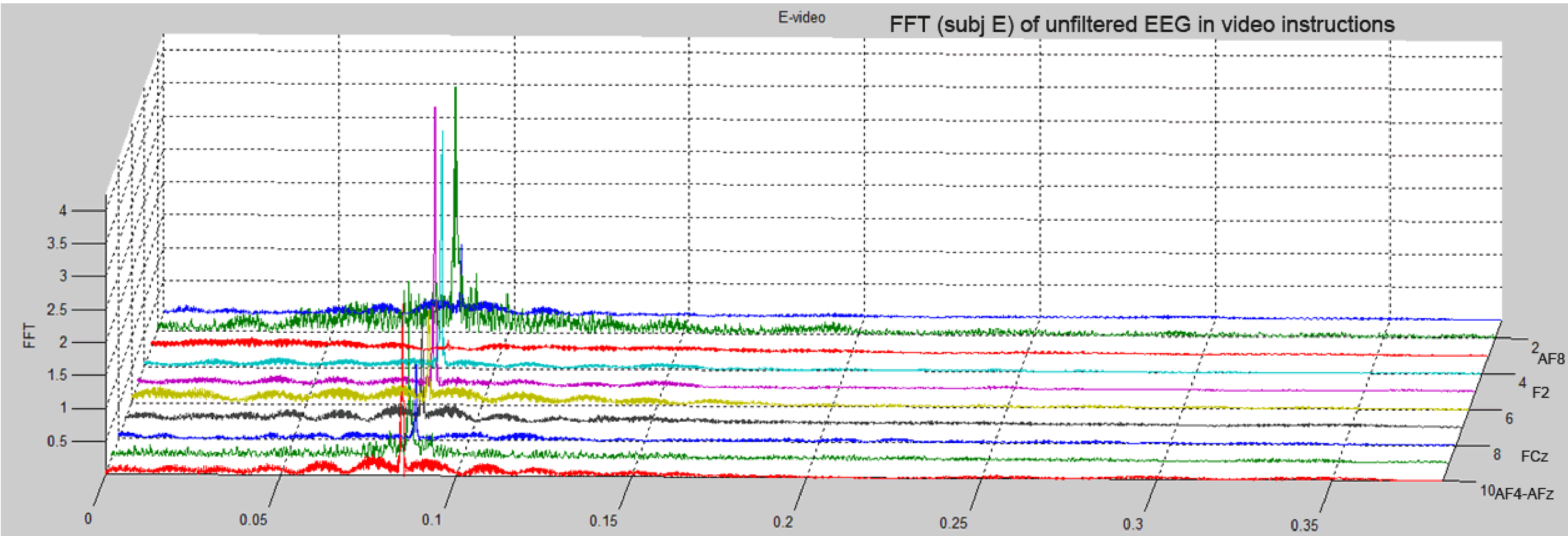
Breathing, then holding, then resuming breathing.



Instrument: Electrical Geodesics

Large waves in EEG rise, then stop, then rise again.

“E” EEG FFT – Visual Pacing



Breathing frequency (.085 Hz.) clearly predominant across electrodes.

Summarizing…

- During resonant breathing, we see the Valsalva Wave in arterial, capillary, and venous circulation.
- We see the wave in the brain using HEG. The wave correlates highly with the wave at the earlobe.
- We see high amplitude waves in the EEG that start and stop with breathing and breath holding, respectively.
- Correlation with the EEG and Valsalva Wave at the earlobe is a work in progress.

A Hypothesis

Vertebrate life evolved from:

HORIZONTAL

To:

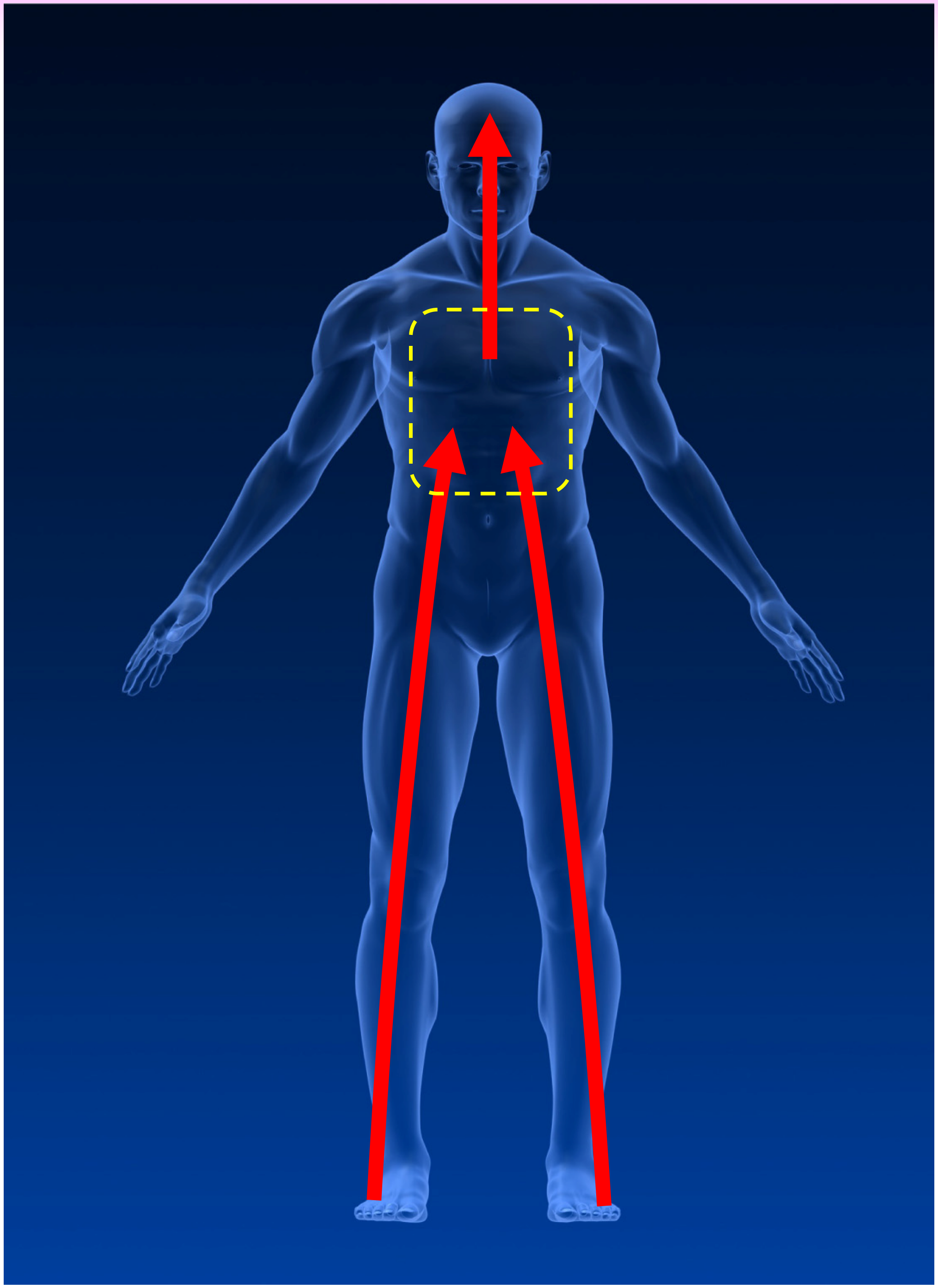
VERTICAL

- Sophistication of the diaphragm follows this evolution.
- Reptiles employ rib cage musculature and axial musculature to breathe.
- Some lizards have proto-diaphragms "complex" muscle groups that perform roughly the same function as the diaphragm.
- Mammals, especially upright mammals have relatively large and highly controlled diaphragms.
- In general, the more erect, the more sophisticated.
- If so, why?

Gravity

There is a requirement for blood to move upward against gravity:

- Venous blood must move from the feet to the chest.
- Arterial blood must move from the chest to the brain.
- The diaphragm and it's "Thoracic Pump" exists for this purpose – especially when we are both vertical and active.
- Some anecdotal evidence for this exists in the land mammal with the largest and most powerful diaphragm.



THE END

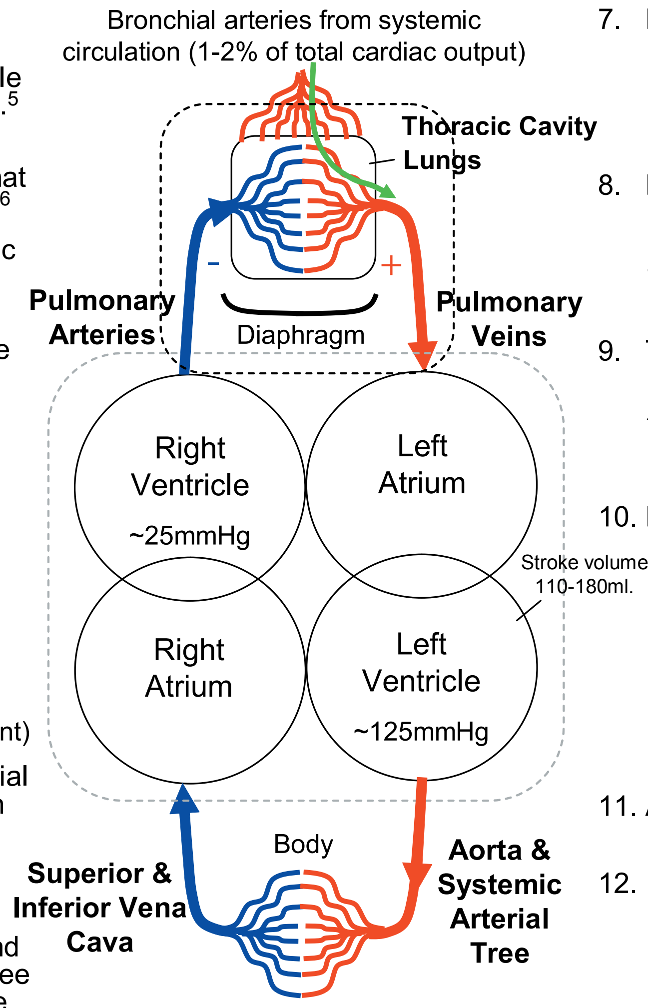
Appendix

Resonant Cardiopulmonary Operation – A Theory

1. The pulmonary circulatory system holds 9% of body blood volume or about 450ml. However, it is capable of holding 2X its "normal" capacity.[5]
2. The pulmonary arterial tree has a very large compliance, equaling that of the entire systemic arterial tree.[6]
3. A function of the lungs and thoracic cavity is to serve as a reservoir supplying blood to the left atrium.
4. During inhalation thoracic pressure becomes negative (a vacuum). Negative pressure increases with the extent of inhalation.[7]
5. Pulmonary blood vessels expand, storing blood, thereby reducing blood flow to the left atrium.[8]
6. Consistent with RSA, heart rate increases (yet output decreases). This increase serves 2 purposes:

   a) It ushers blood to the lungs via the right side of the heart during inhalation (low pressure environment)

   b) It limits the fall in systemic arterial pressure. (Left side of heart – high pressure environment.)
7. Arteries constrict coincident with increasing heart rate.
8. The net effect is that blood flow and pressure in the systemic arterial tree falls but is maintained within viable limits. *We know this as the rising edge of the HRV cycle.*



7. During exhalation thoracic pressure reverses, i.e. it becomes positive. The degree of positive pressure depends on the extent of exhalation.
8. Pulmonary vessels shrink, evacuating blood from the lungs, delivering increased blood flow to the left side of the heart under relatively positive pressure.
9. The heart elevates this pressure resulting in the *Respiratory Arterial Pressure Wave* which propagates through the systemic arterial tree with exhalation.
10. However, consistent with RSA, heart beat rate decreases (yet heart output increases). This decrease also serves 2 purposes:

    a) it slows the flow of blood to the lungs during exhalation.

    b) it limits the rise in systemic arterial pressure
11. Arteries enlarge coincident with decreasing heartbeat rate.
12. The net effect is that blood flow and pressure in the systemic arterial tree rises but is maintained within viable limits.
13. *We know this as the falling edge of the HRV cycle.*

Figure 13 – Cardiopulmonary Resonance- A Theory