ILLUMINATING BRAIN HEALTH

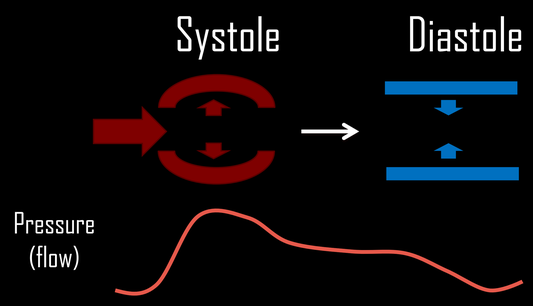
Using Diffusive Optical Imaging to Study Vascular Health and Reactivity

Benjamin Zimmerman, Chin Hong Tan, Kathy A. Low, Nils Schneider-Garces,
Timothy B. Weng, Mark A. Fletcher, Edward L. Maclin, Gabriele Gratton & Monica Fabiani

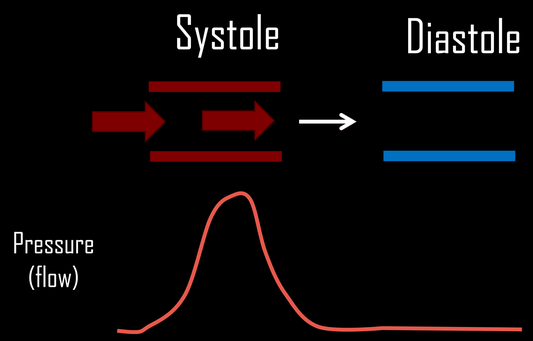
Beckman Institute, University of Illinois at Urbana-Champaign

Aerobic fitness has been related to the level of cognitive decline that occurs with normal aging. Some of this relationship may be explained by vascular health in the brain, including arterial elasticity. We have been studying a novel method to measure arterial elasticity non-invasively in the brain by quantifying the length and shape of the pulse wave, which can be measured using optical methods. Furthermore, we have been relating this measure to the shape and timing of the hemodynamic response to breath-holding, a measure of vascular reactivity. Here we show the relationship between this measure of elasticity and vascular reactivity, and discuss mechanisms by which vascular health may impact cognitive fitness.

Physiology



HEALTHY elastic arteries expand during systole of the pulse and contract during diastole leading to longer and more gradual blood flow.



UNHEALTHY inelastic arteries cannot expand as the pulse wave moves through, leading to short and sharp bursts of blood flow.

Methods

Participants: 55 older adults aged 55 to 87.

Breath holding task: Participants performed 6 end-expiratory breath holds for 18s in order to induce hypercapnia within a magnetic resonance scanner.

References

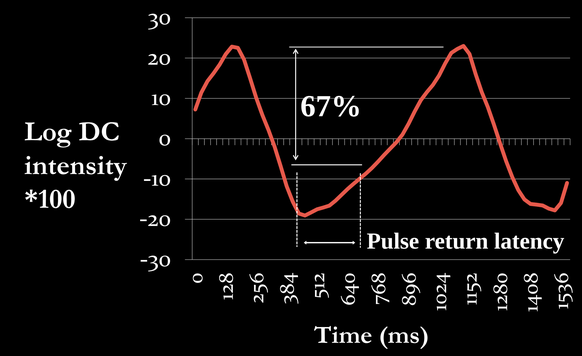
Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature Reviews Neuroscience, 9*(1), 58–65.

Izzo, J. L., Jr, & Shykoff, B. E. (2001). Arterial stiffness: clinical relevance, measurement, and treatment. *Reviews in cardiovascular medicine, 2*(1), 29–34, 37–40.

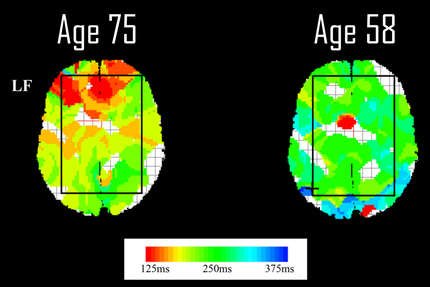
Salthouse, T. A. (2010). Selective review of cognitive aging. *Journal of the International neuropsychological Society, 16*(5), 754.

Quantifying Brain Elasticity

Elasticity measurement: The latency of the pulse return is calculated. Shorter pulse return times correspond to greater arterial stiffness. Latency differences due to blood pressure are controlled by dividing the resulting latency measure by the pulse pressure.

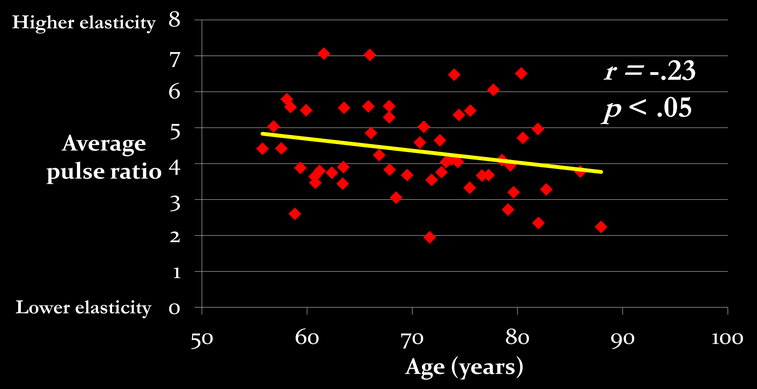


Optical pulse recordings were time-locked to the R-wave of the EKG. Localization was achieved by co-registering each participant's full-head optical montage with their structural magnetic resonance image (MRI).



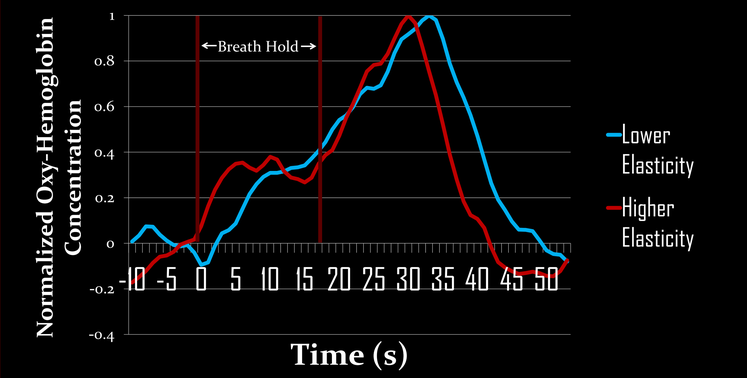
Pulse return latency maps of an older and younger participant. Warmer colours are representative of less arterial elasticity. Of note are the regional variations in elasticity across the brain.

RED = Less elastic BLUE = More elastic



Vascular Reactivity and Elasticity

Hemoglobin measurement: Absolute concentrations of oxy- and deoxy-hemoglobin are calculated by a frequency-domain OxiplexTS tissue oxymeter. Near infra-red light is emitted by fibers on the forehead at two wavelengths modulated at a radio frequency. The light is collected by a detector from four known distances. Absolute absorption and scattering coefficients are determined and used to derive hemoglobin concentrations.



**p<.01, reaction defined as first reaching 30% of peak. **p<.01, recovery defined as returning to 20% of the peak.

Average change in tissue oxy-hemoglobin during the breath holding task for participants with lower and higher arterial elasticity as determined by median split. Higher elasticity predicts a faster reaction and a faster recovery.

Discussion

- Diffusive optical methods can be used to derive measurements of arterial elasticity in the brain.
- Participants with more elastic arteries produce quicker changes in oxy-hemoglobin concentration during hypercapnia. This vascular reactivity may help cognitive processing.
- Future investigation will seek to determine if these measurements are predictive of longitudinal declines in cognition, and specifically whether or not regional measures will differ in their predicative power.

This project was supported by a grant NIH 1 RC1 AG035927 Z ARRA to Monica Fabiani and an NSF IGERT fellowship (0903622) to B. Zimmerman.