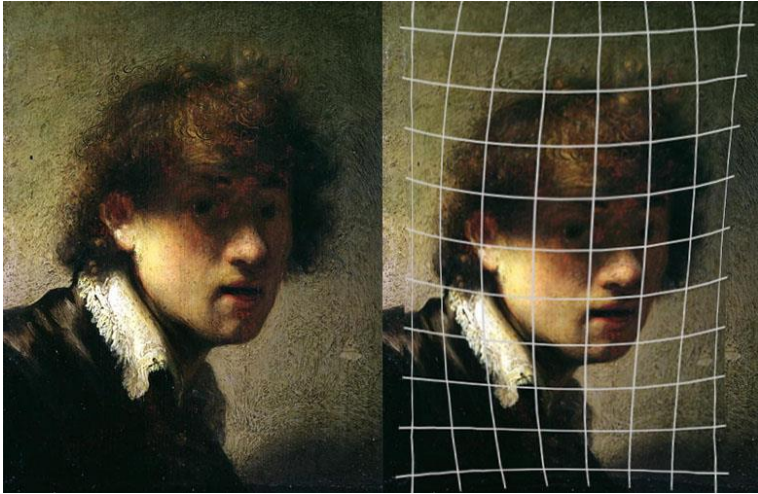


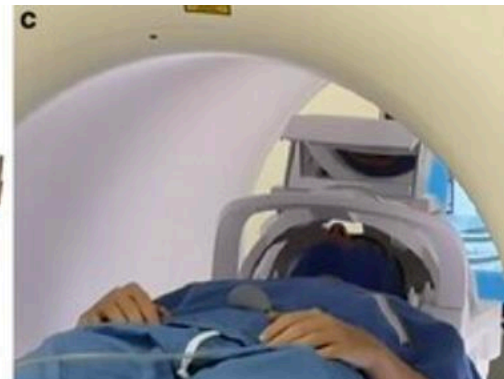
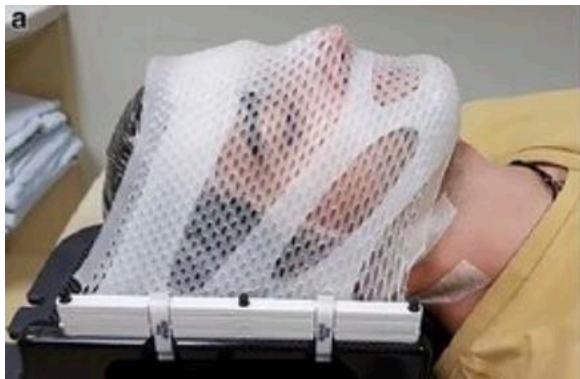
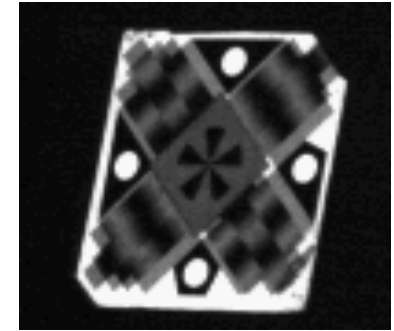
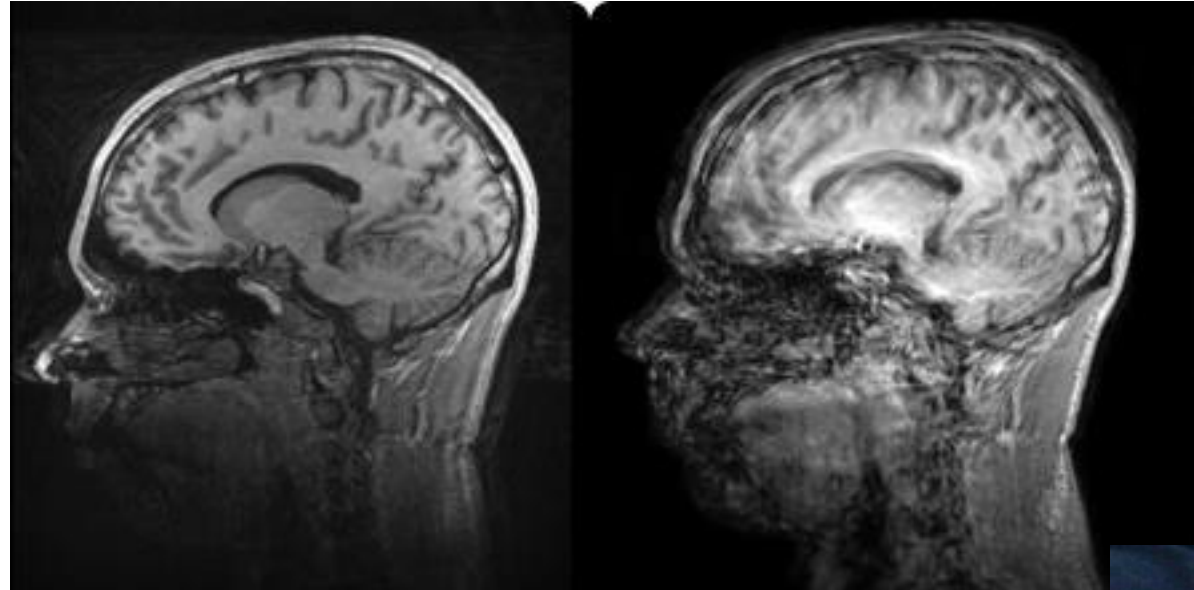
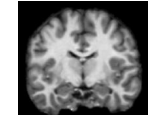


Nonlinear Warp Fields as a Source of Physiological Information in fMRI

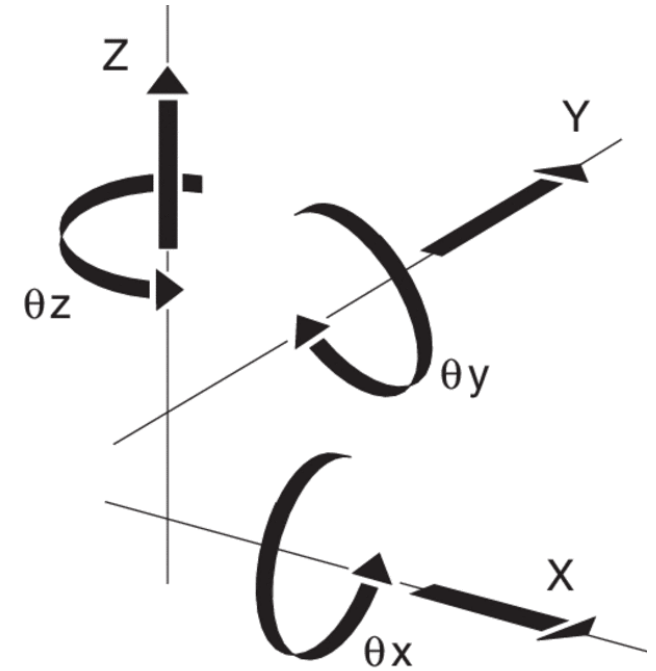
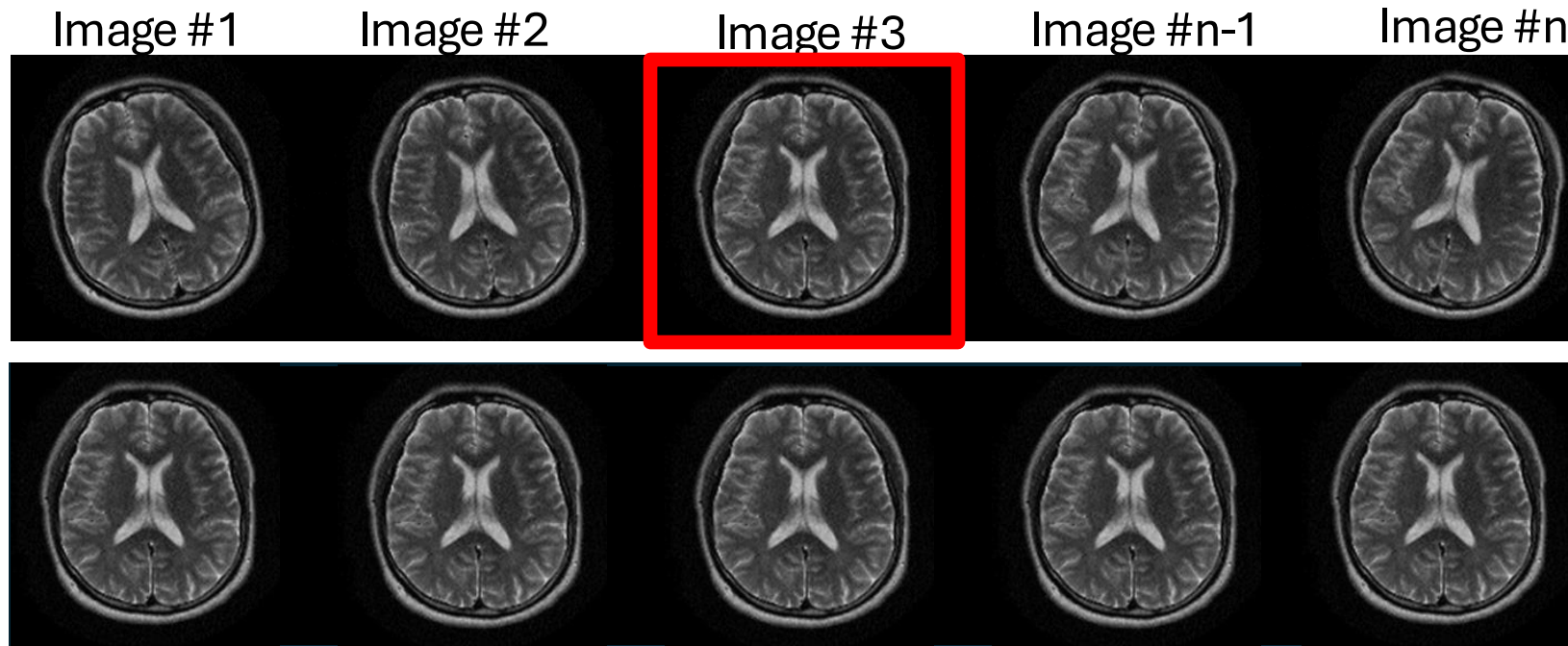
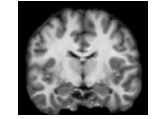
05/22/26 Burak Akin



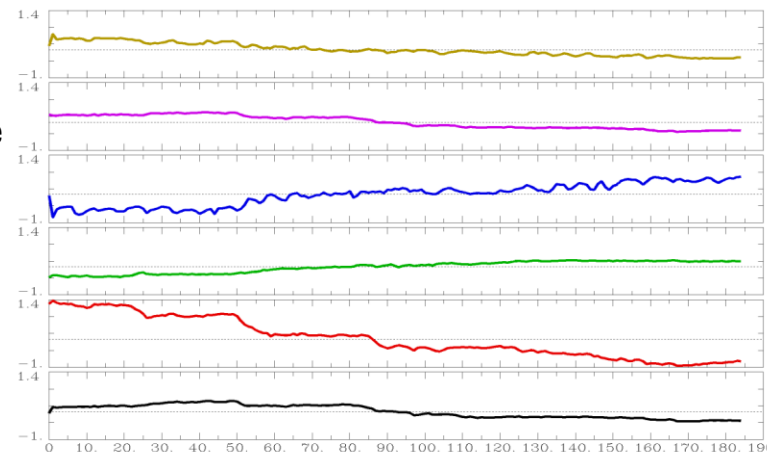
Motion in MRI



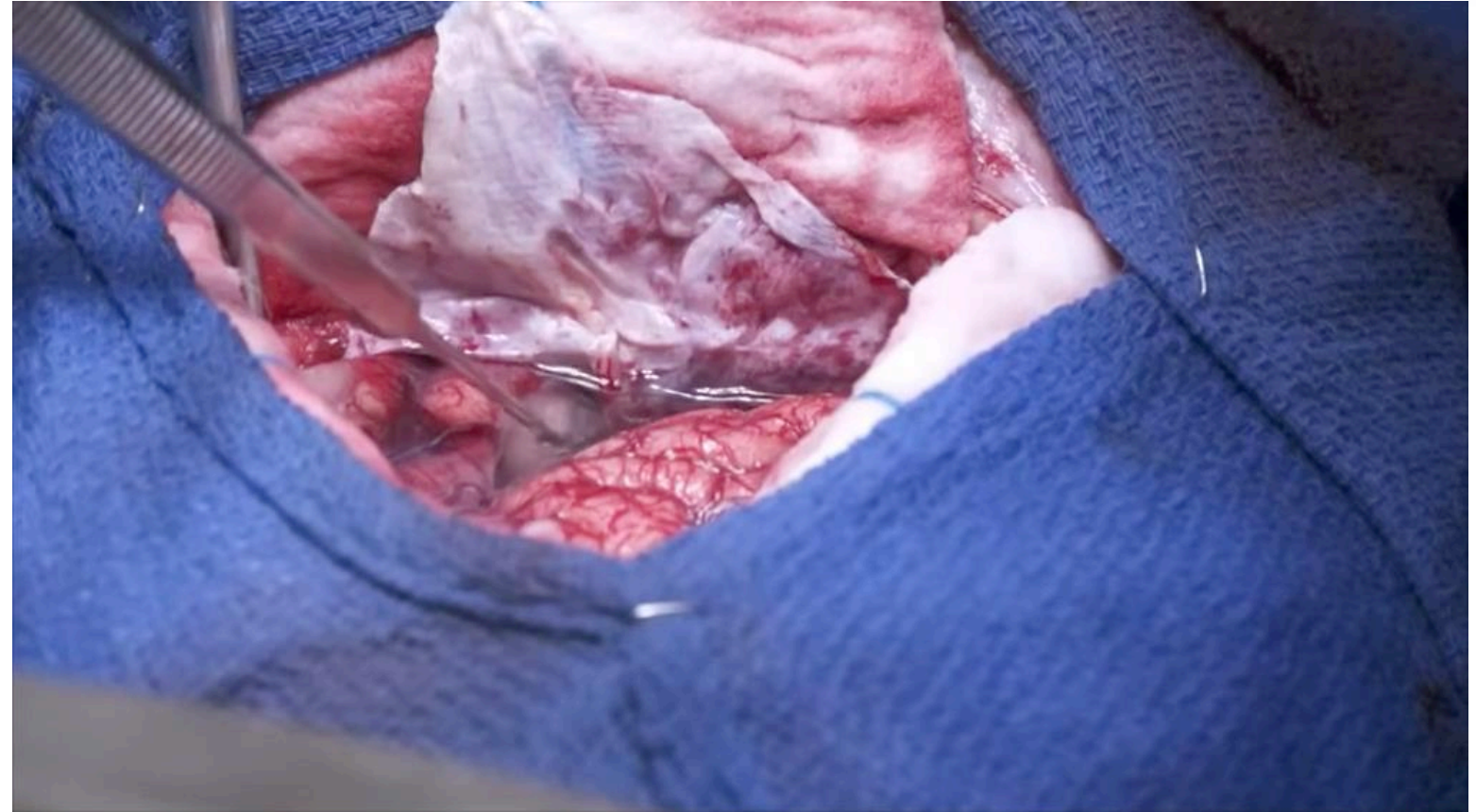
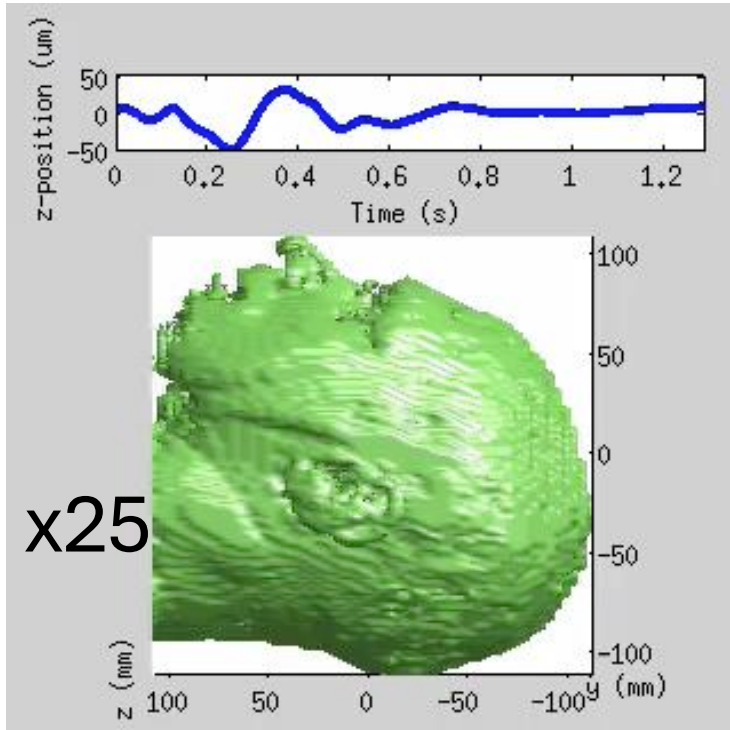
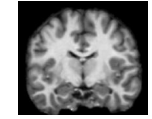
Rigid body motion correction



```
3dvolreg -verbose \ -zpad 1 \ -base  
pb01.sub01.r01.tshift+orig'[0]' \ -1Dfile  
dfile.sub01.r01.1D \ -prefix  
pb02.sub01.r01.volreg \ -cubic \  
pb01.sub01.r01.tshift+orig
```

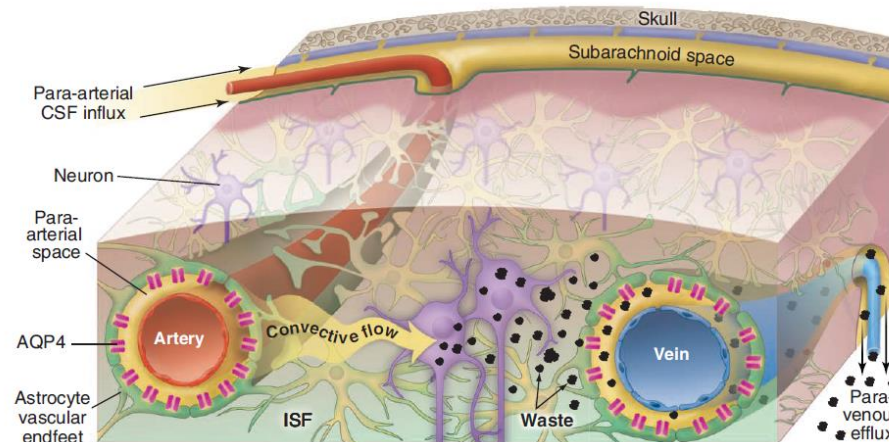
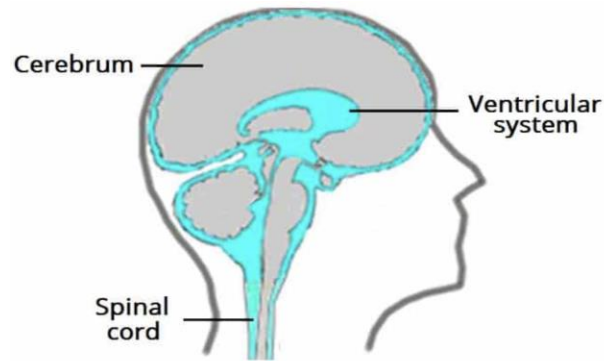
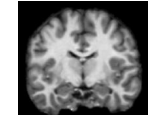


Sources of Motion



Craniotomy @ Northwestern Medicine

Sources of Motion



Go with the flow. Convective glymphatic fluxes of CSF and ISF propel the waste products of neuron metabolism into the paravenous space, from which they are directed into lymphatic vessels and ultimately return to the general circulation for clearance by the kidney and liver.

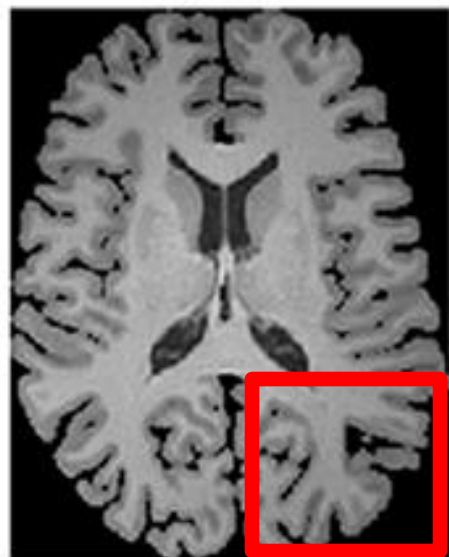
Lymphatic draining system of the brain tissue, so called glymphatic system

Arterial pulsations propulse water through aquaporin channels

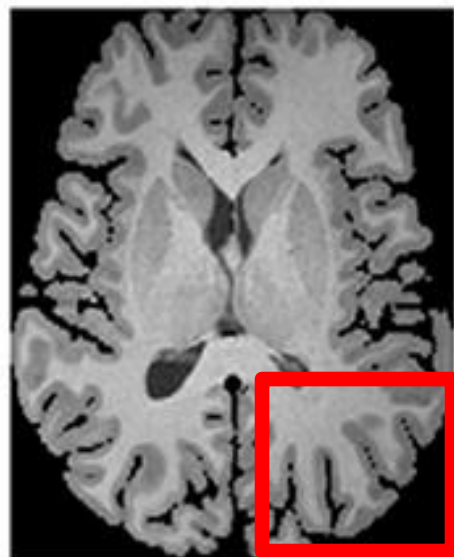
An intercellular “glymphatic” pathway clears cell waste from the brain and may reveal new targets for treating neurodegenerative diseases.

Garbage truck of the brain. Nedergaard M Science. 2013

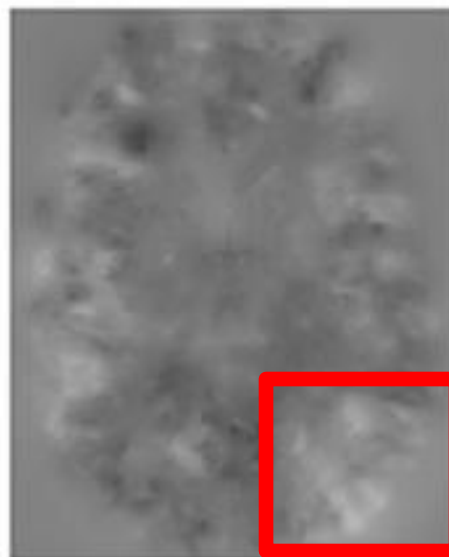
Non-linear registration



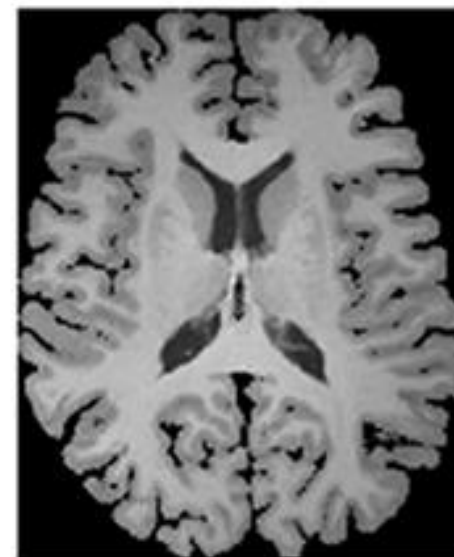
Fixed



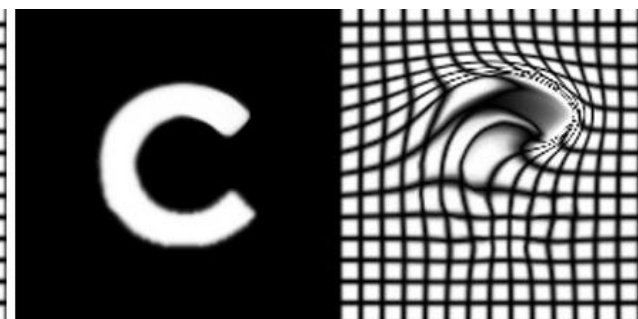
Moving



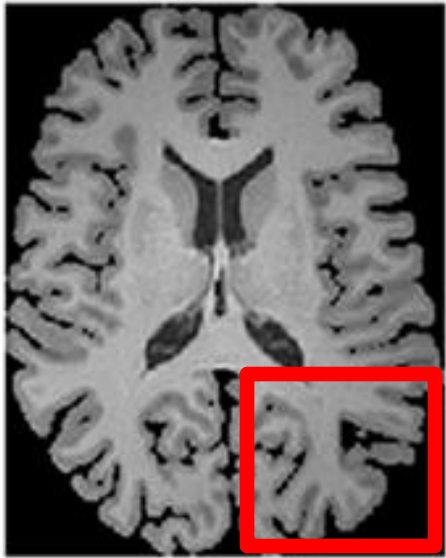
Deformation



Warped



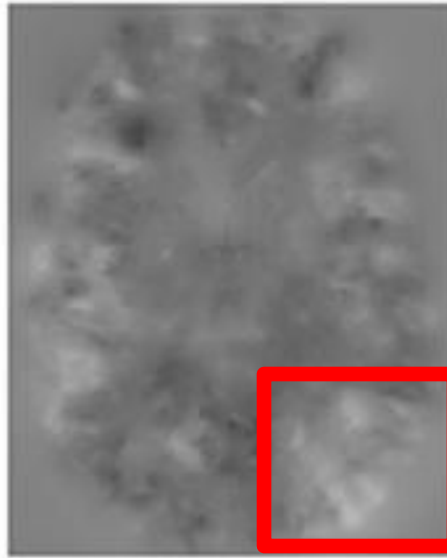
Non-linear registration



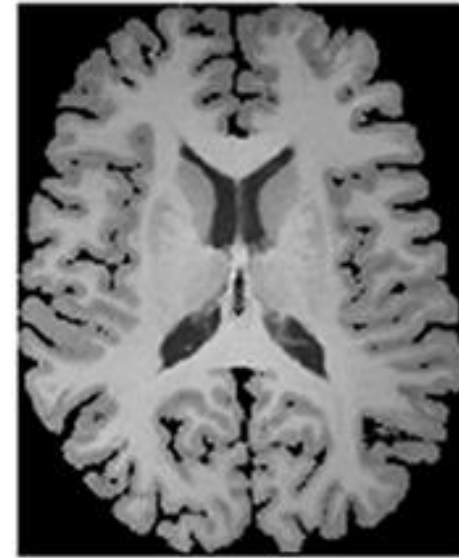
Fixed



Moving



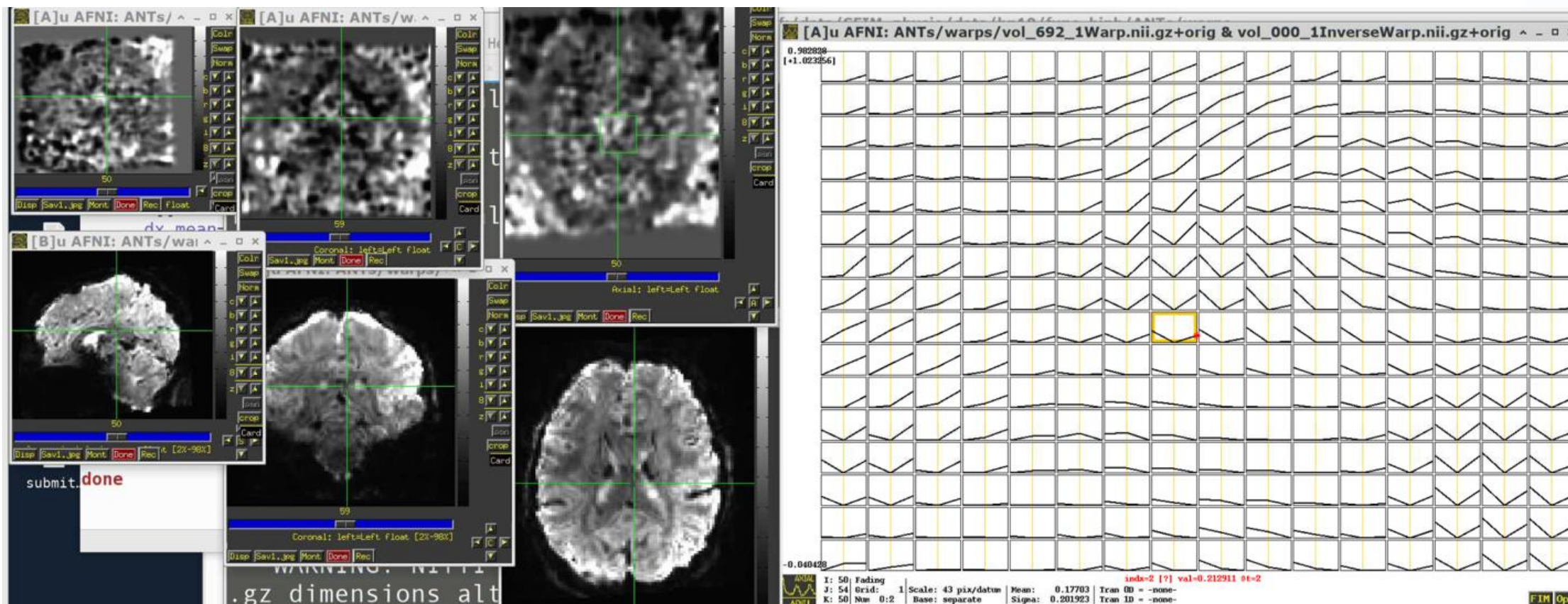
Deformation



Warped

```
antsRegistration \  
  --dimensionality 3 \  
  --float 1 \  
  --collapse-output-transforms 1 \  
  --output [ "${OUTDIR}/warps/vol_${v}_", "$OUTWARP", 0 ] \  
  --interpolation Linear \  
  --winsorize-image-intensities [0.01,0.99] \  
  --use-histogram-matching 0 \  
  --initial-moving-transform [ "$REF", "$MOV", 1 ] \  
  --transform SyN[0.03,2,0] \  
  --metric CC["$REF","$MOV",1,2] \  
  --convergence [10x5,1e-5,5] \  
  --shrink-factors 2x2 \  
  --smoothing-sigmas 1x1vox
```

Image registration (T2* fMRI images)

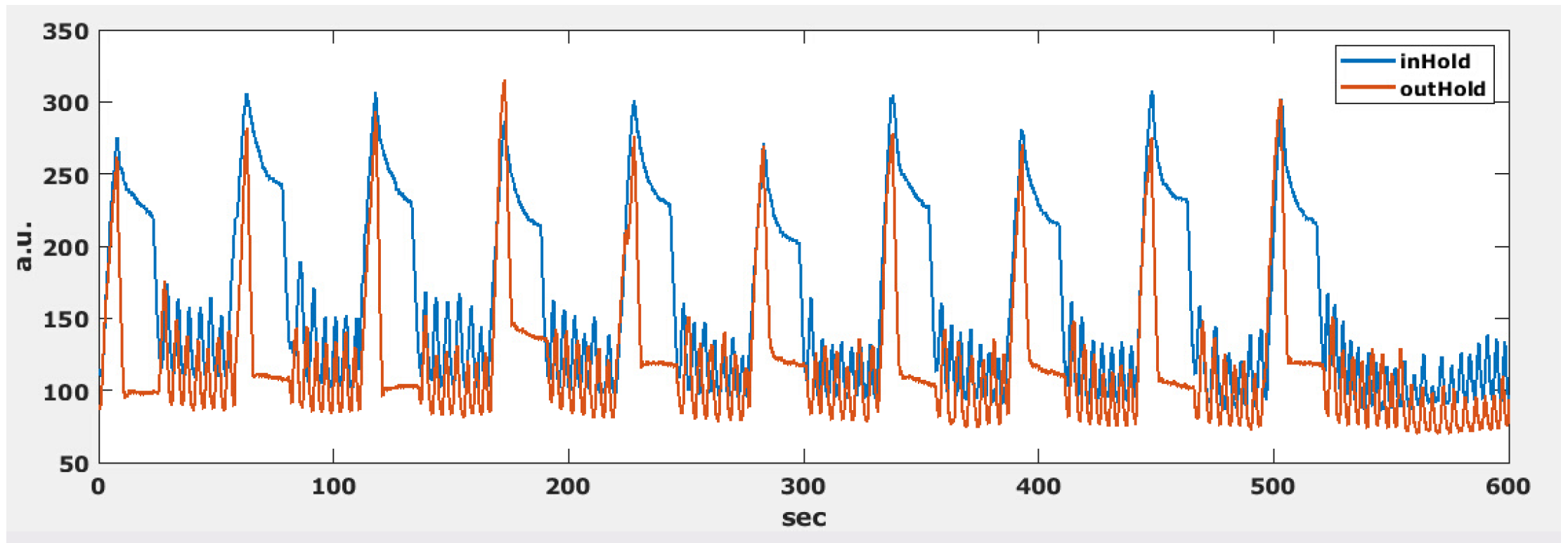
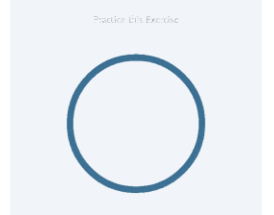


$$\text{Magnitude} = \sqrt{dx^2 + dy^2 + dz^2}$$

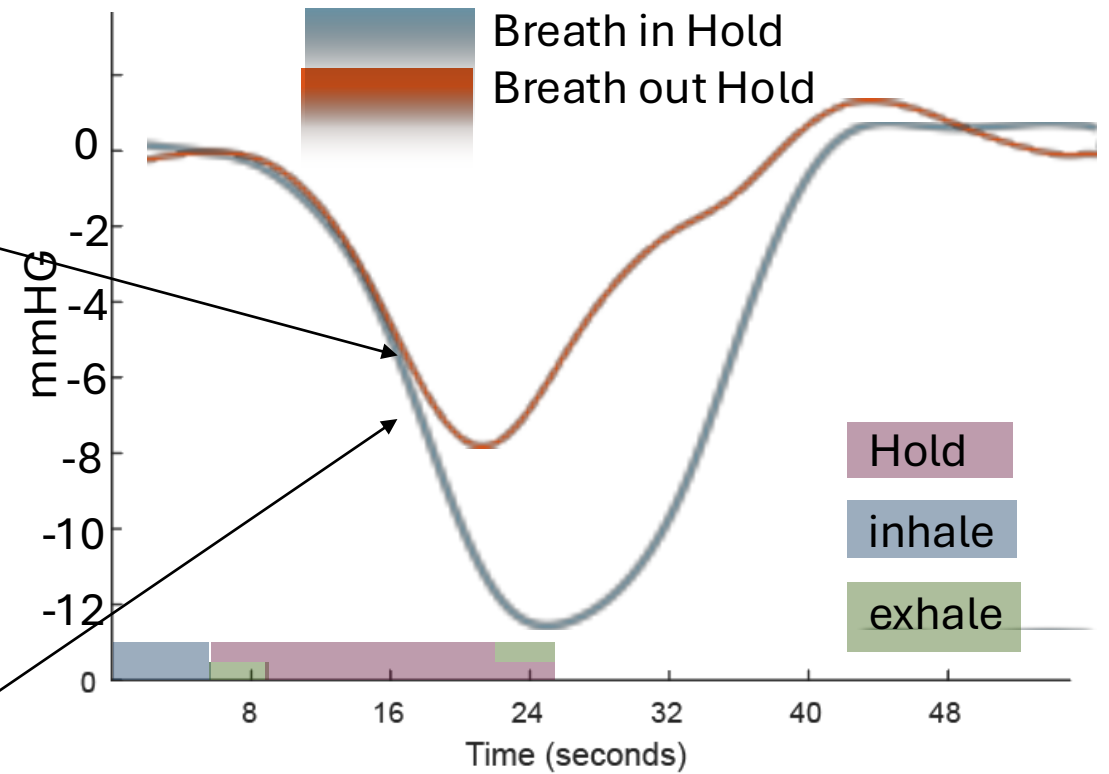
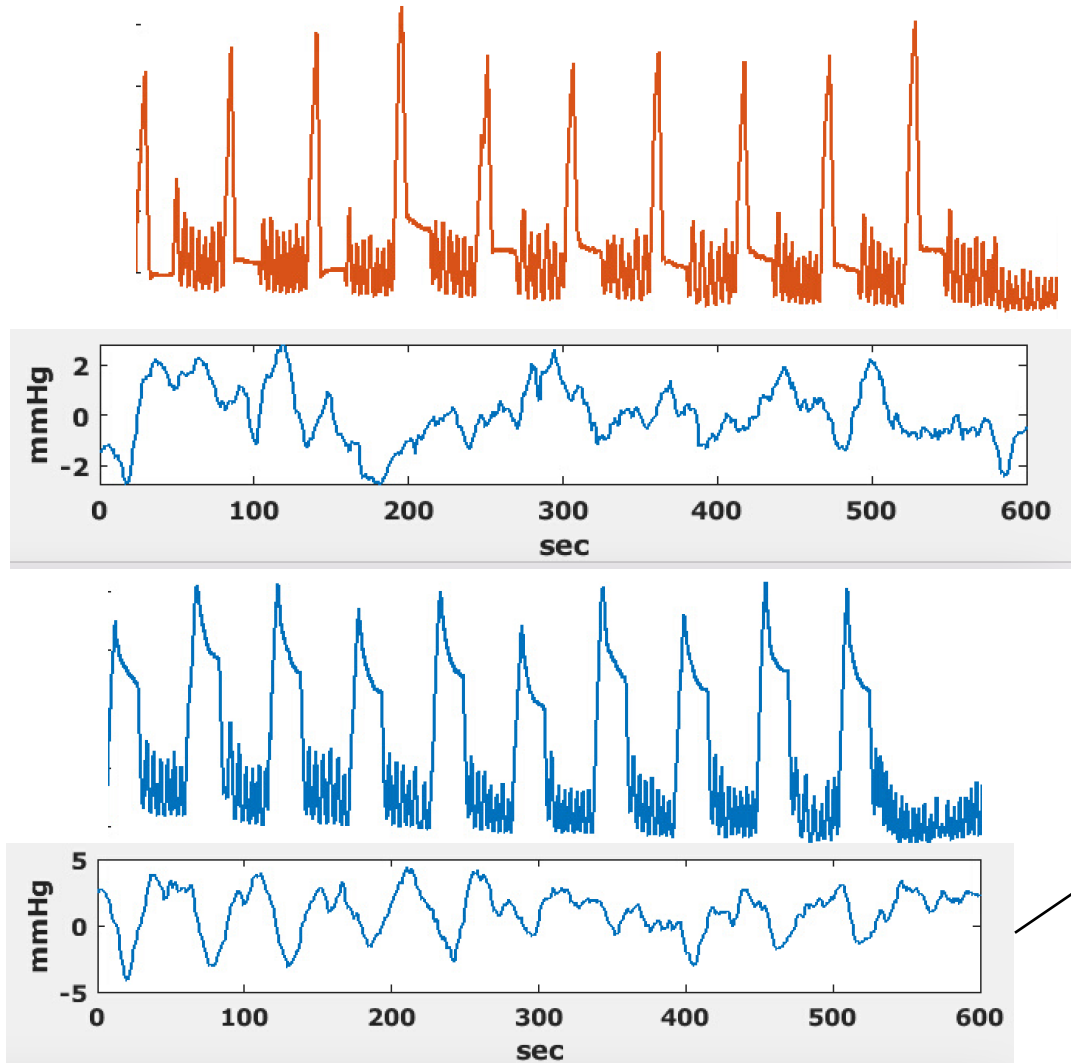
$$\theta = \arccos \left(\frac{dz}{\sqrt{dx^2 + dy^2 + dz^2}} \right)$$

Breath Holding tasks

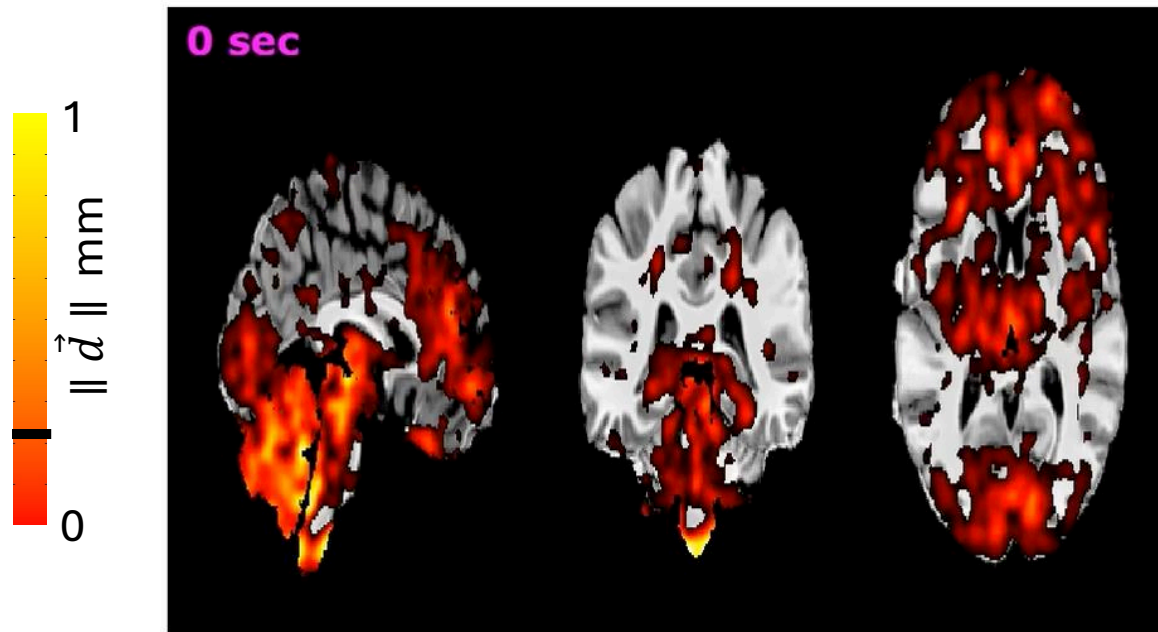
- Respiration volume changes during two task scans



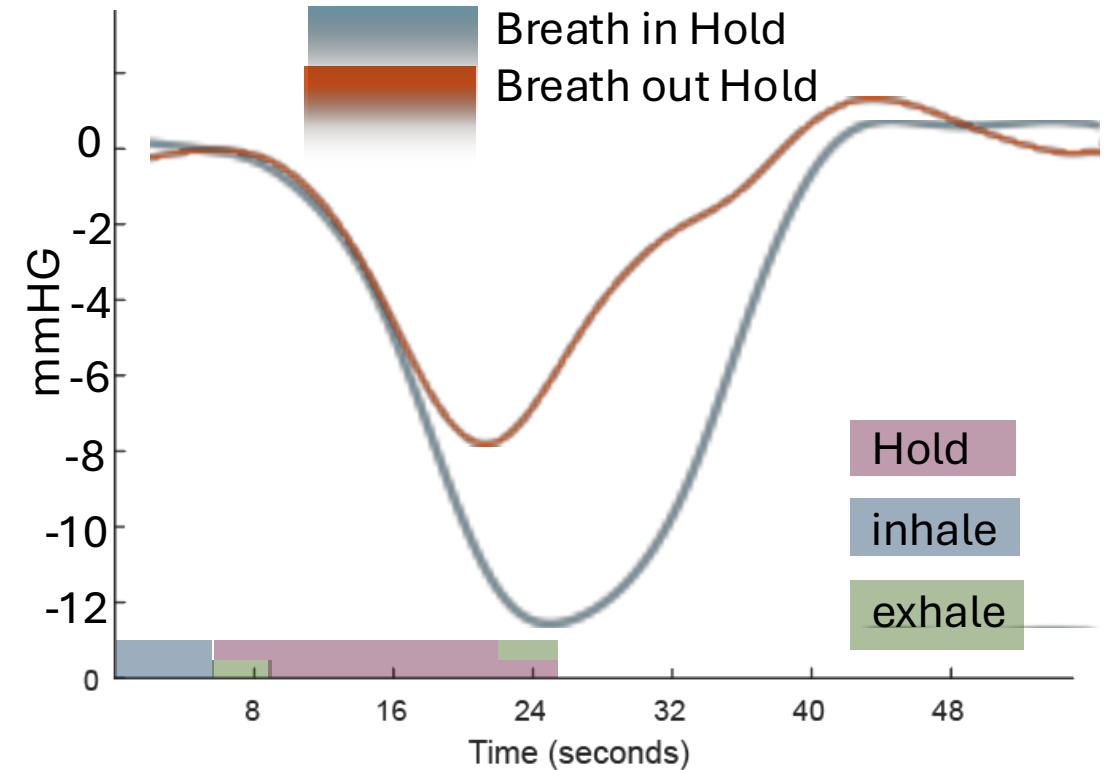
Trial Related Averaging MAP



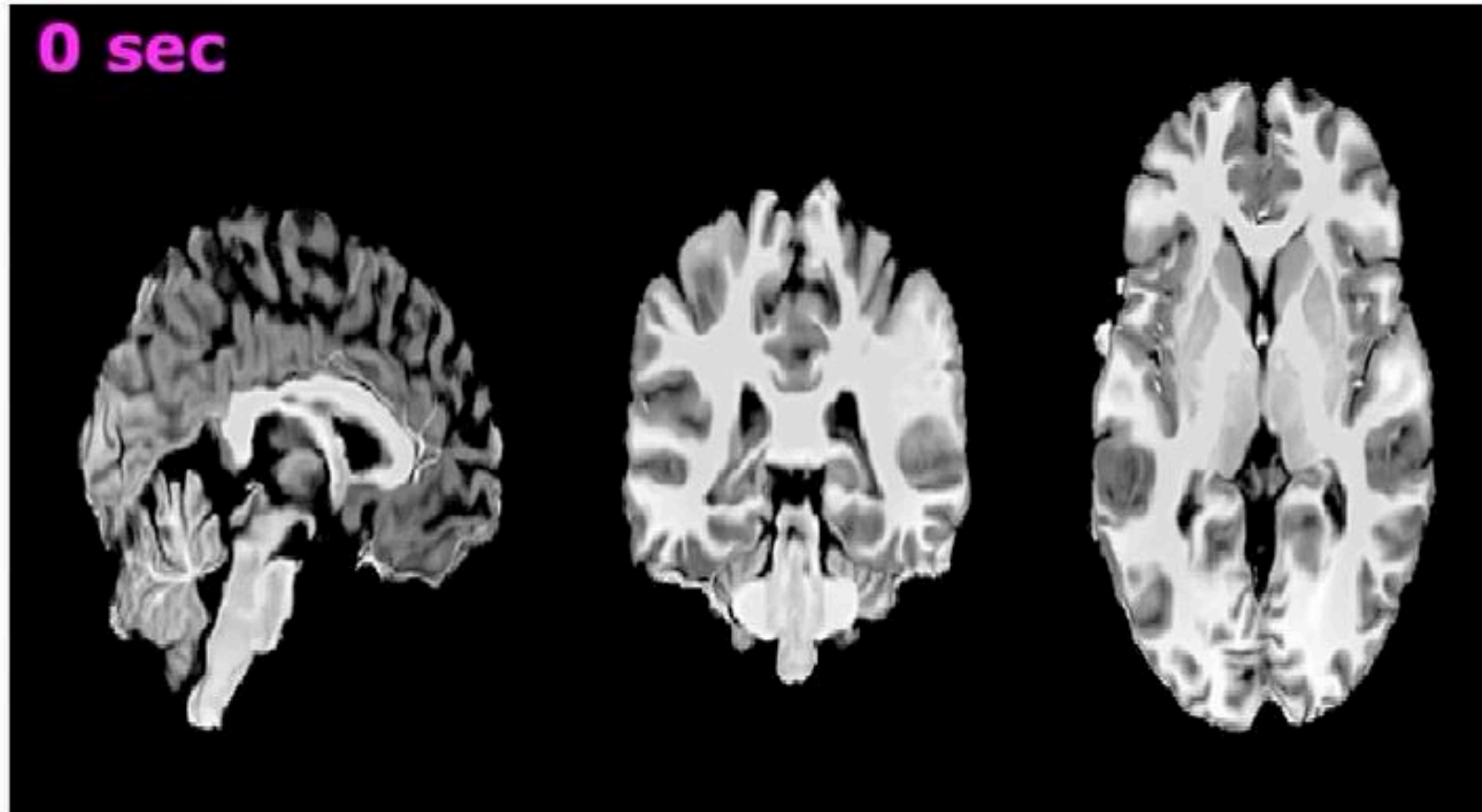
Task related displacement at physiological compartments



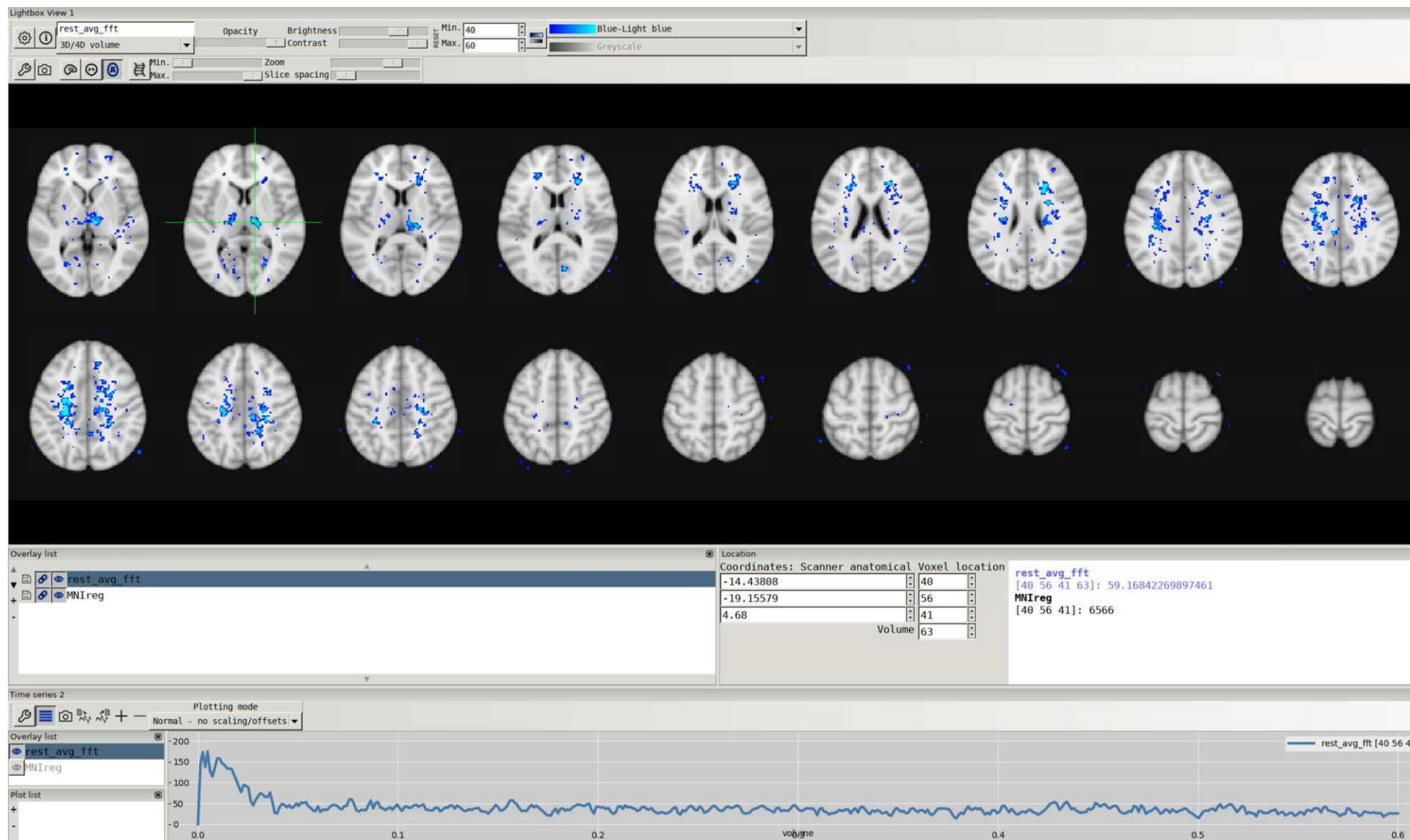
$$\|\vec{d}\| = \sqrt{(\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2}$$



Task related displacement applied on T1 Anatomical x50



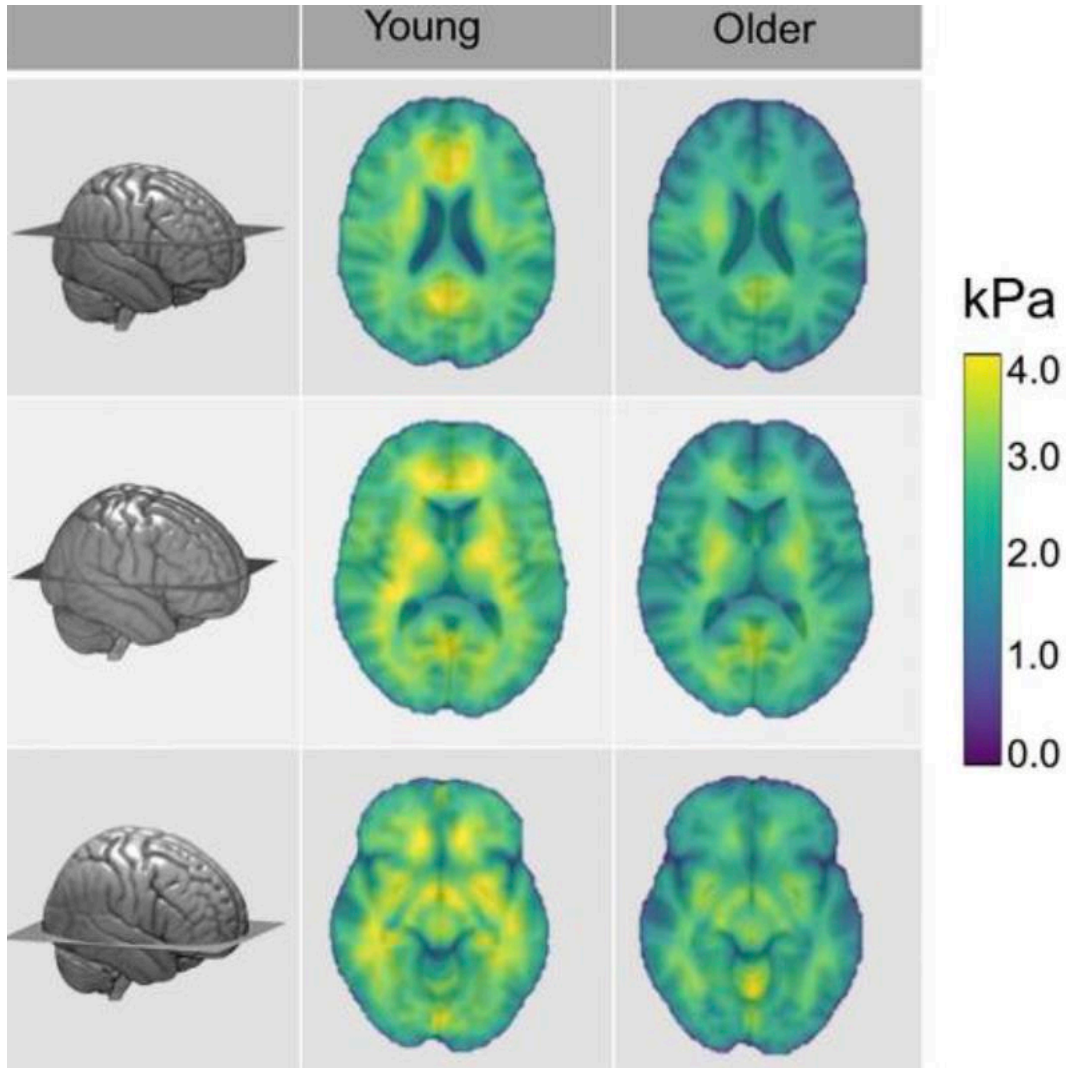
Resting state – Warp field displacements



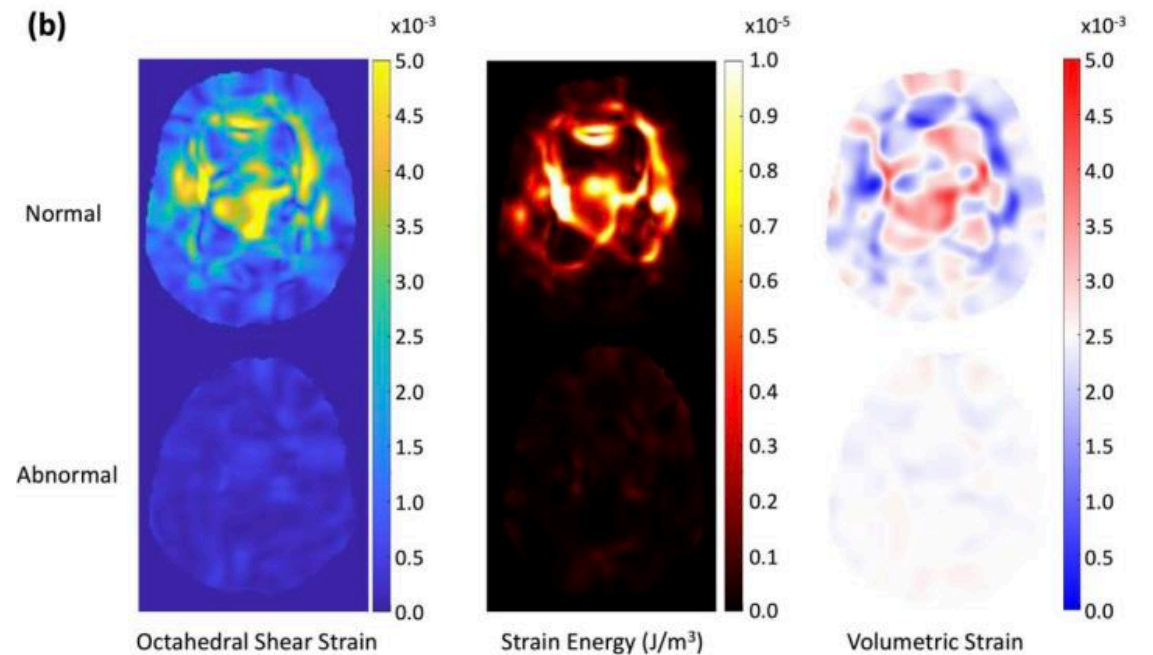
Breathing– Warp field displacements



Brain Stiffness, MR-Elastography

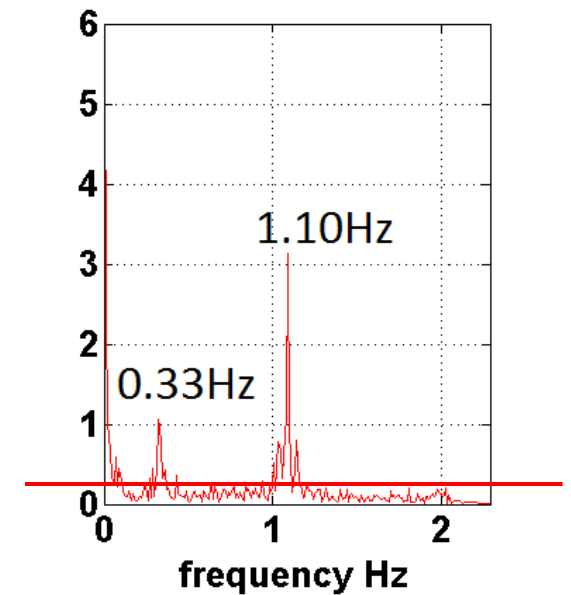
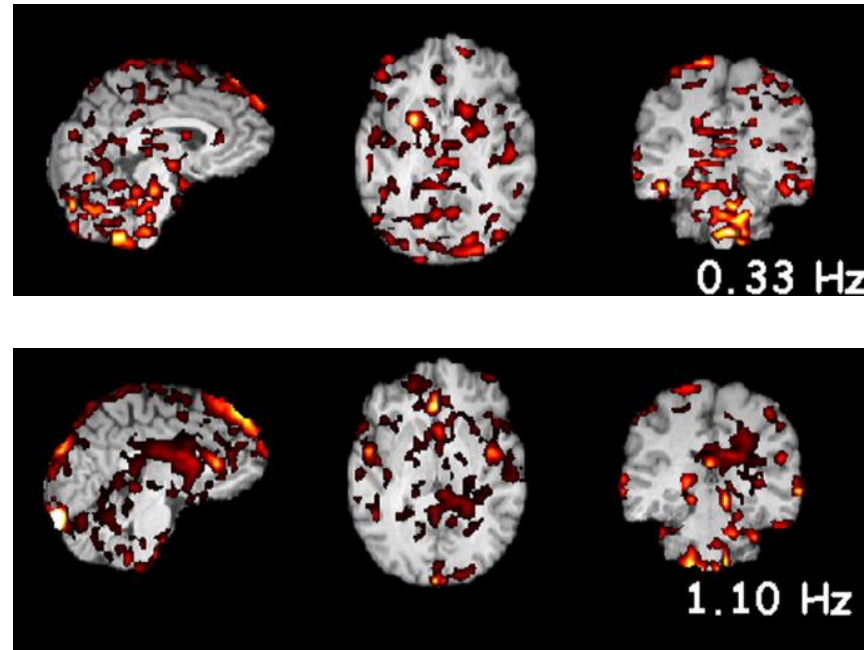
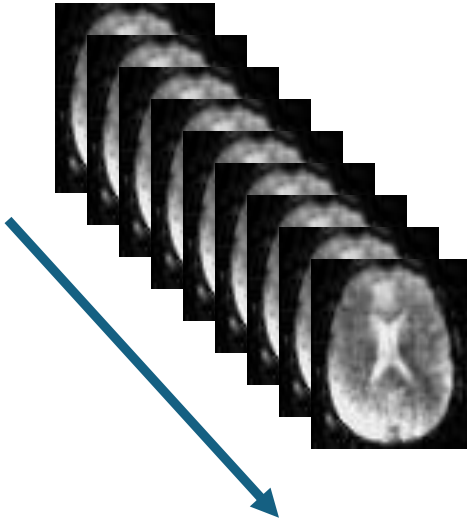


bSSFP - Insights from 3D q-aMRI



Ultra fast fMRI TR=100ms at Resting state

- Non-linear warping every 100ms



Combining External measures

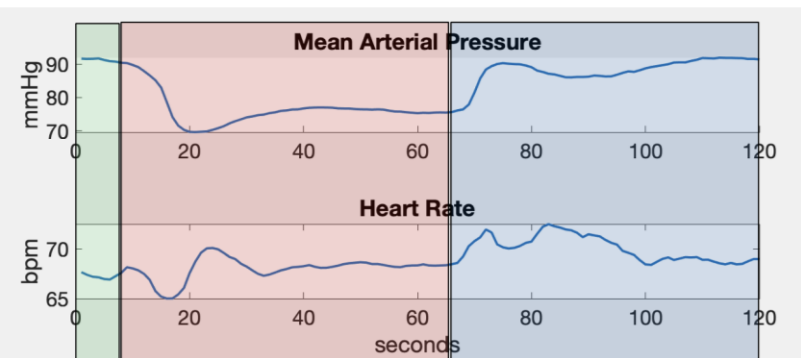
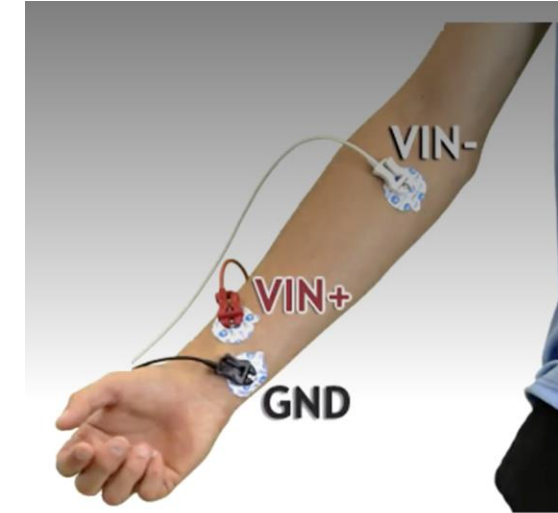
Blood Pressure Monitor (Caretaker)



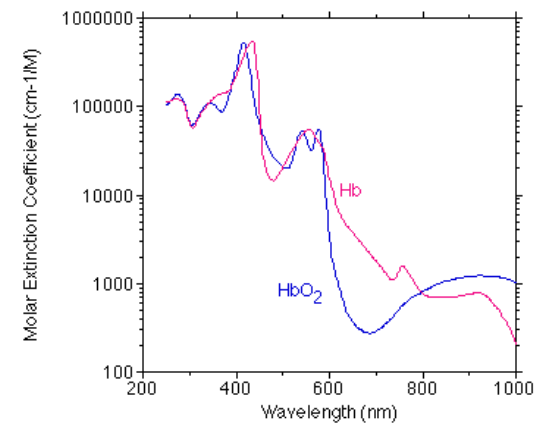
NIRS finger probe (Artinis)



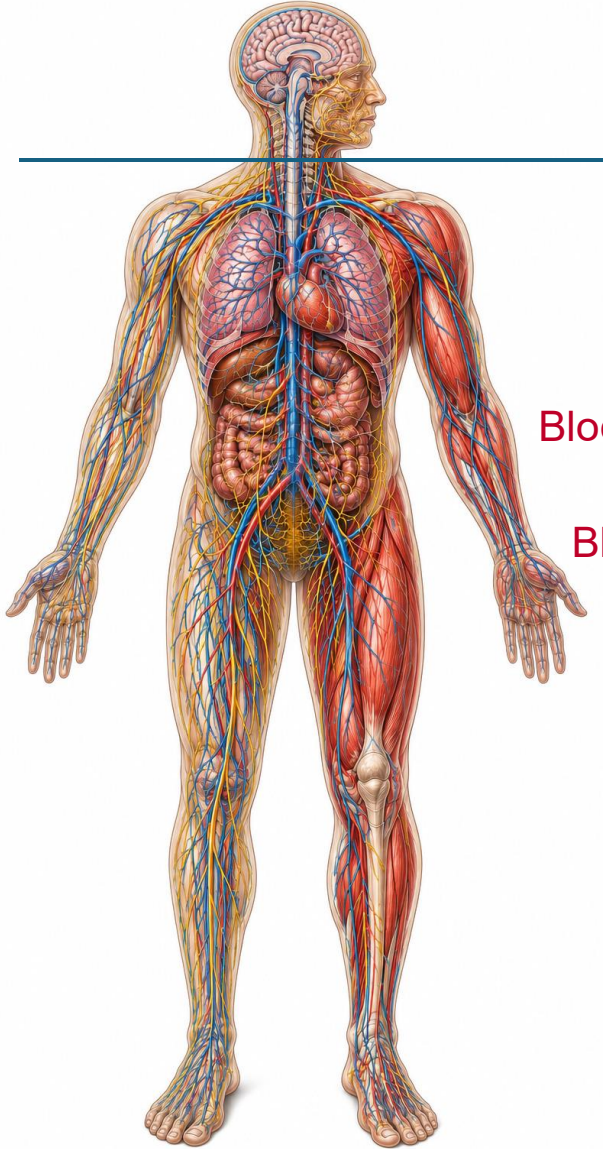
EMG monitor



inhale
hold
release



Peripheral Measures



Blood Pressure

Blood Volume

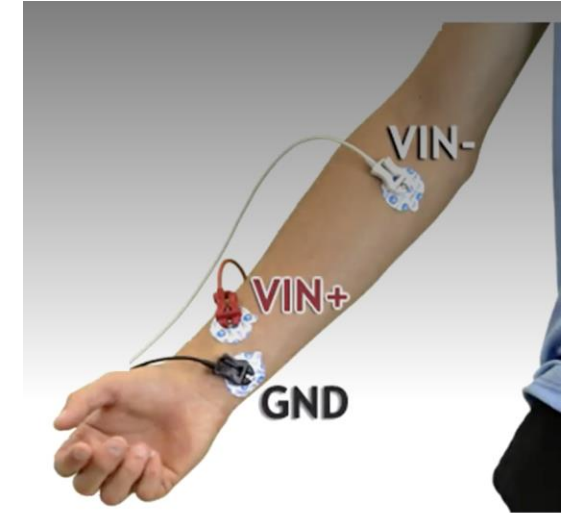
Muscle tone

Vascular tone

NIRS finger probe (Artinis)



EMG monitor

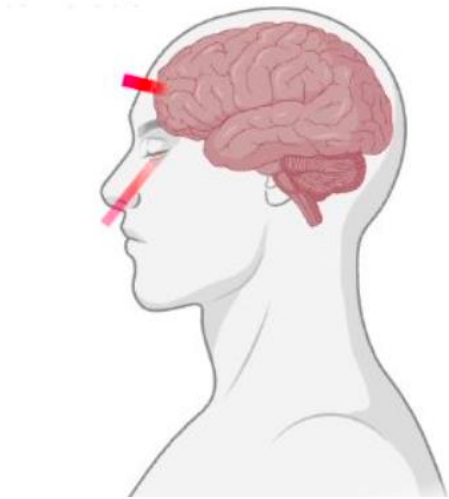


Blood Pressure Monitor (Caretaker)

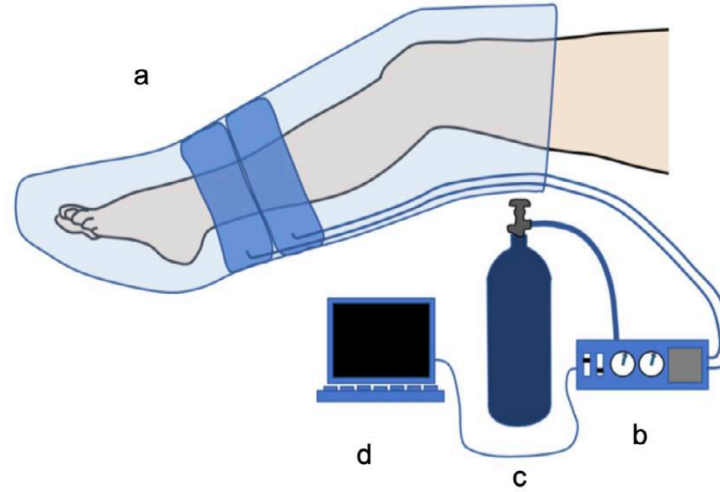


External stimulation 93M protocol

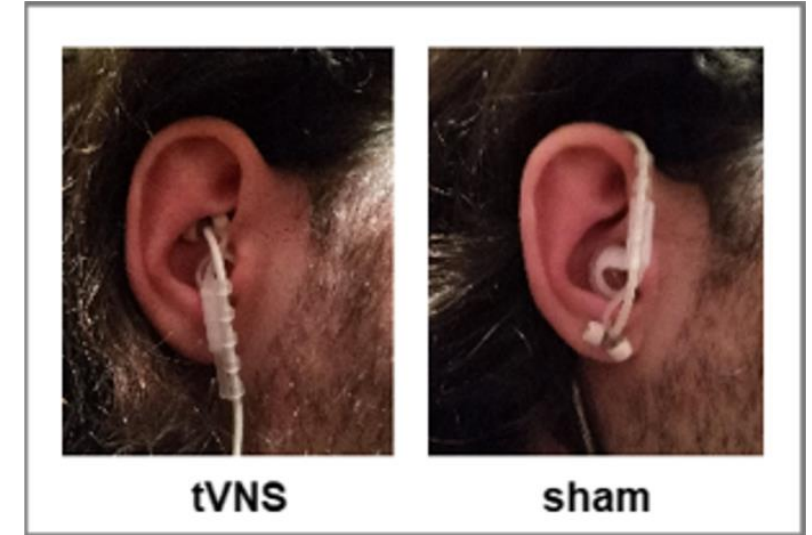
Light Stimulation



Pressure Cuff



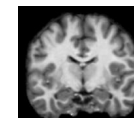
Vagal nerve stimulator(tVNS)



Obst et al., 2021



Thanks to colleagues...



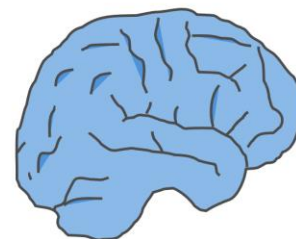
Tyler



Stephanie



Dan



Any questions ?



Peter



Javier



Catherine



Sharif



"OK, Mrs. Dunn. We'll slide you in there, scan your brain, and see if we can find out why you've been having these spells of claustrophobia."