Aging of inner ear structures and central vestibular representations

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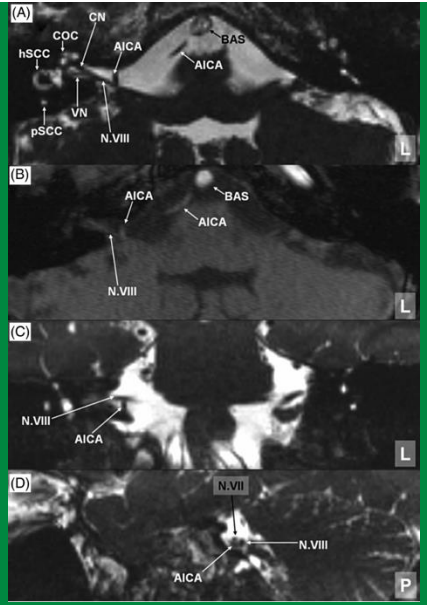
Role of neuroimaging for peripheral vestibular disorders

RESEARCH PAPER

MRI and neurophysiology in vestibular paroxysmia: contradiction and correlation

Christoph Best,[1,2] Joachim Gawehn,[3] Heidrun H Krämer,[4] Frank Thömke,[2] Tugba Ibis,[2] Wibke Müller-Forell,[3] Marianne Dieterich[5,6,7]



Curr Radiol Rep (2020) 8:25
https://doi.org/10.1007/s40134-020-00365-z

ENT IMAGING (L JACOBI-POSTMA, SECTION EDITOR)

State of the Art Imaging in Menière's Disease. Tips and Tricks for Protocol and Interpretation

Lisa M. H. de Pont[1,2] · Josephine M. van Steekelenburg[1] · Berit M. Verbist[2] · Mark A. van Buchem[2] · Henk M. Blom[3] · Sebastiaan Hammer[1]

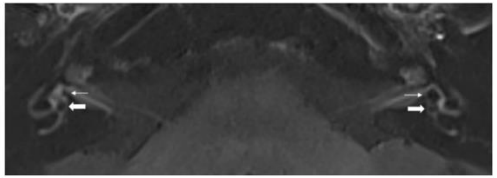


Fig. 2 Axial 4 h-delayed Gd-enhanced 3D-FLAIR MRI through the inferior part of the vestibule in a 53-year-old patient diagnosed with left-sided definite Menière's disease, according to the 2015 Bárány criteria. On the symptomatic side, the saccule (thin arrow) appears larger than the utricle (thick arrow), but not confluent, consistent with mild vestibular hydrops (low-grade saccular hydrops). Compare with a normal saccule on the right. There is no evidence of cochlear hydrops

Acta Otorhinolaryngol Ital. 2018 Aug;38(4):369–376. doi: 10.14639/0392-100X-1986

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MR imaging of endolymphatic hydrops in Ménière's disease: not all that glitters is gold

G Conte [1], F M Lo Russo [2], S F Calloni [2,✉], C Sina [1], S Barozzi [3], F Di Berardino [3,4], E Scola [1], G Palumbo [1], D Zanetti [4], F M Triulzi [1,5]

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Overview

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- Background & Research Question
- The inner ear pipeline (flow chart)
- Geodesic template building process
- Lessons from our ocular morphometrics pipeline
- Results - Template / Laterality / Gender
- Results - Aging of inner ear structures
- Results - Aging of the VIII. cranial nerve
- Results - Aging of central vestibular presentations
- Summary
- Outlook

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Template-building

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Template building

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https://github.com/ANTsX/ANTs

```
inputPath=${PWD}/
outputPath=${PWD}/TemplateMultivariateSyN_NormAvg/

export ANTSPATH=/mnt/c/users/tangge/ANTS/install/bin/

${ANTSPATH}/antsMultivariateTemplateConstruction2.sh \
  -a 1 \
  -d 3 \
  -o ${outputPath}T_ \
  -i 5 \
  -g 0.25 \
  -j 4 \
  -c 2 \
  -k 1 \
  -w 1 \
  -f 8x4x2x1\
  -s 4x2x1x0 \
  -q 100x70x50x40 \
  -n 0 \
  -l 1 \
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  -m CC[4] \
  -t SyN \
  sub*.nii.gz
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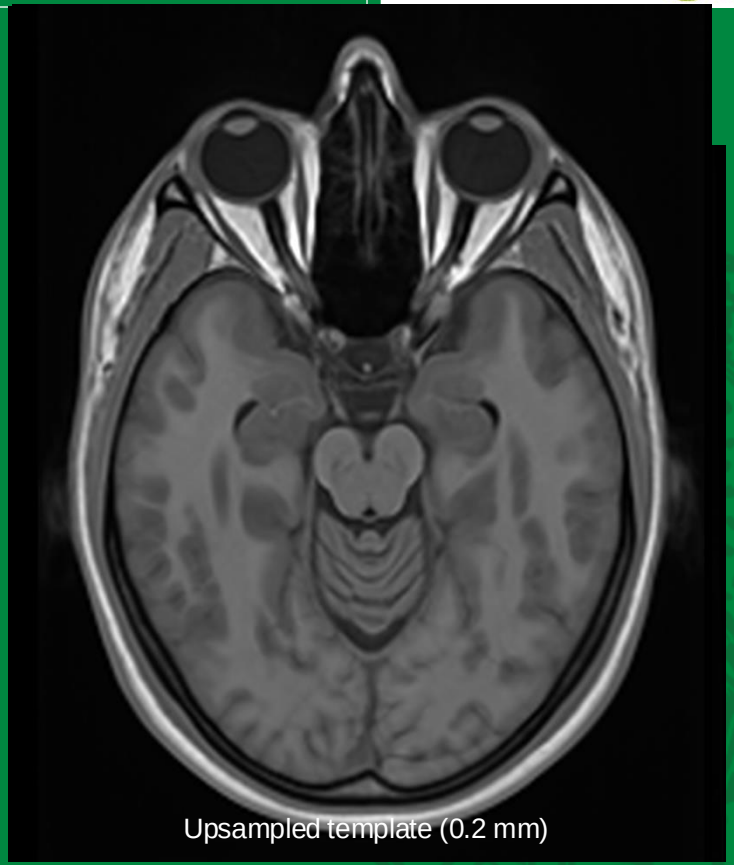

Upsampled template (0.2 mm)

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Template-building for the human inner ear

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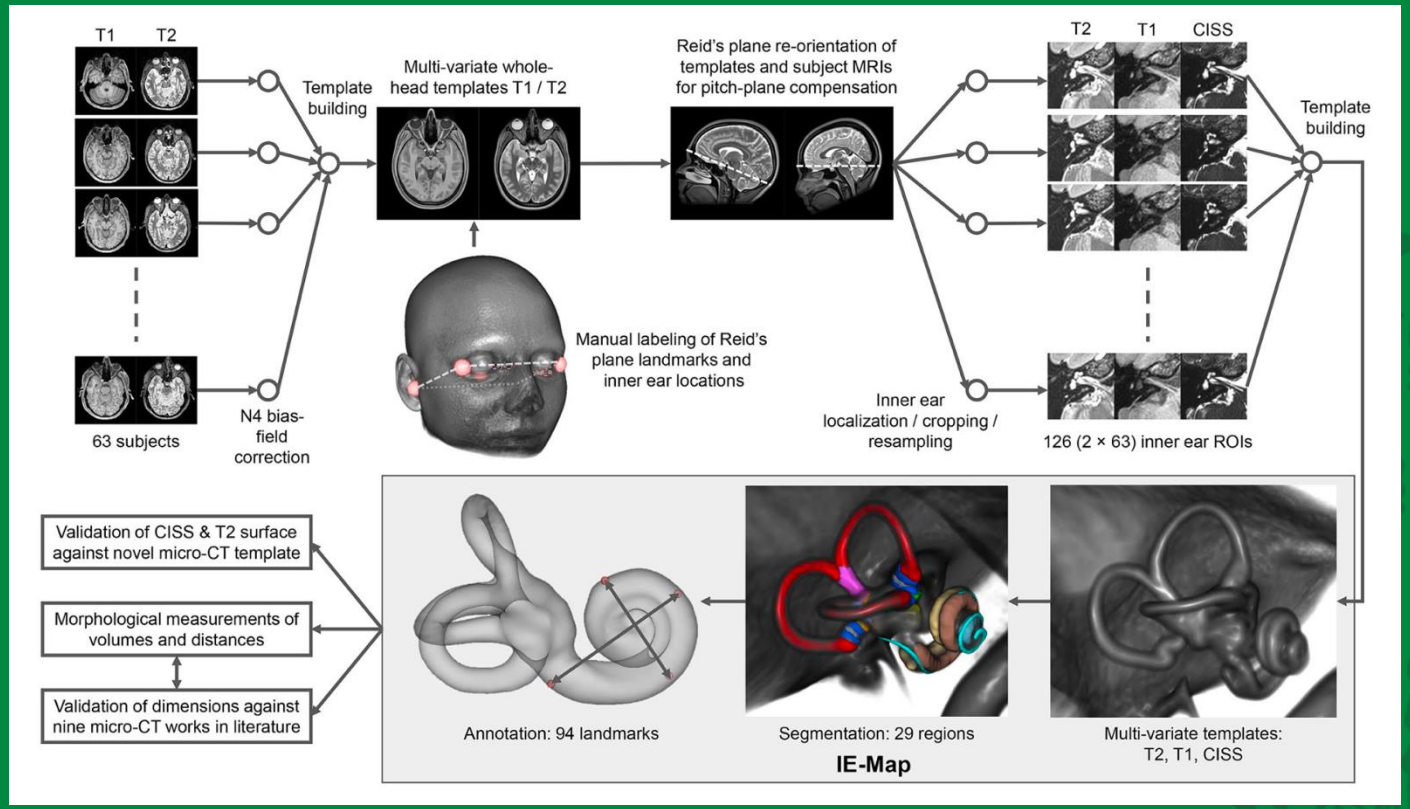

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Template-building for the human inner ear

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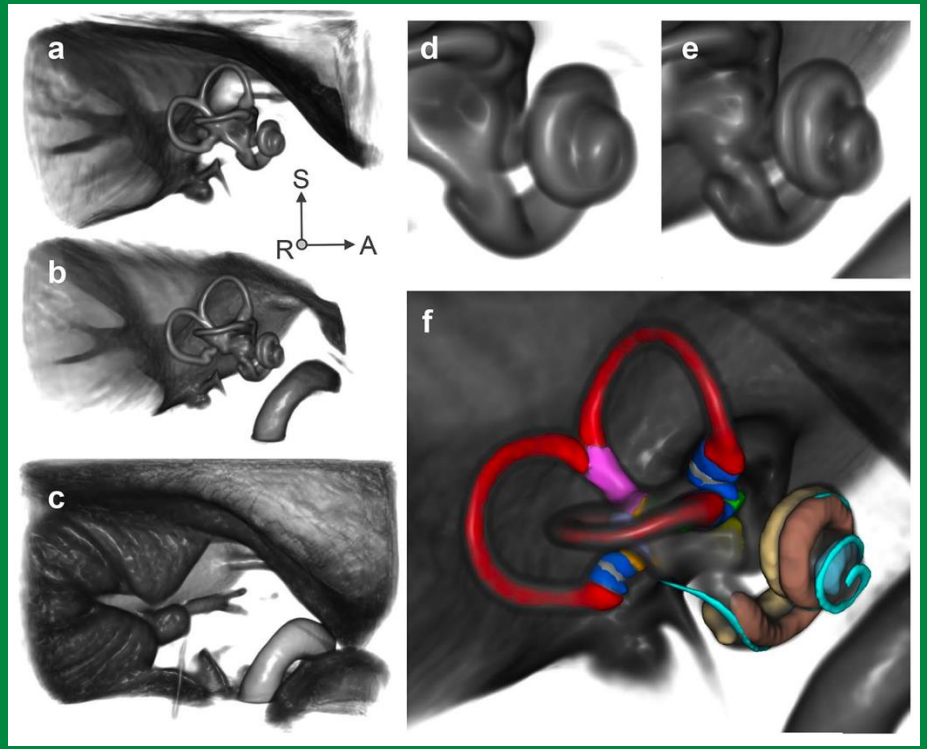

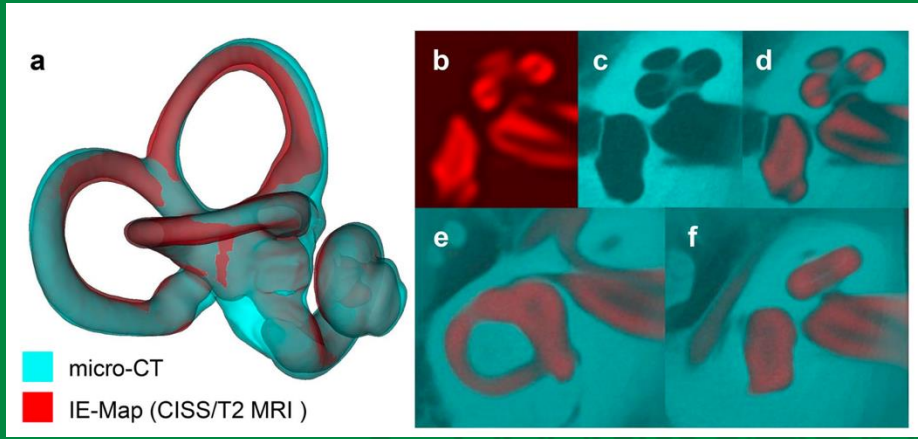

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Laterality effects?

Template-building

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Laterality – lessons from ocular morphometrics

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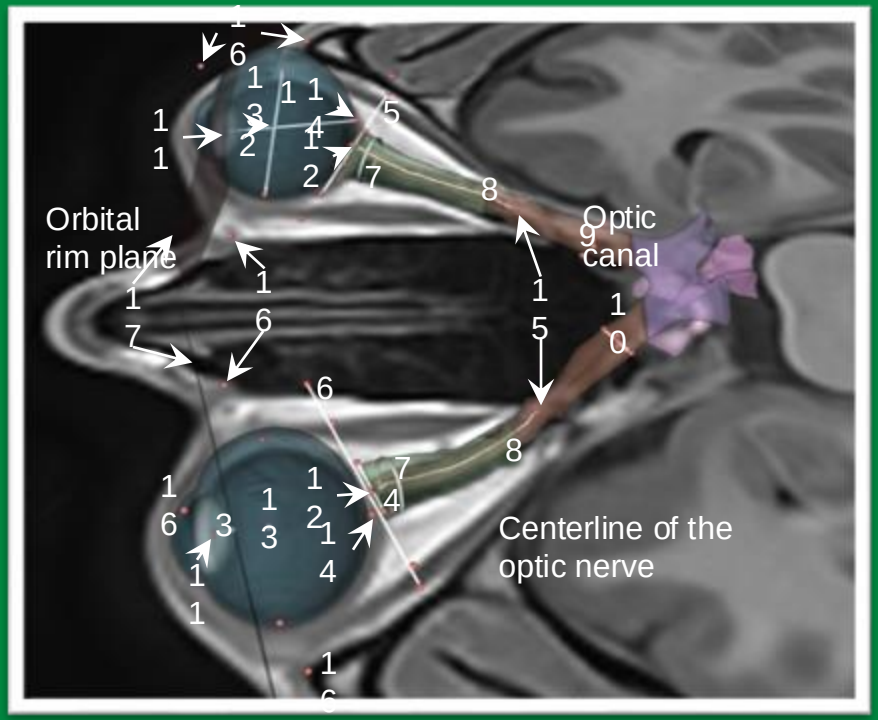

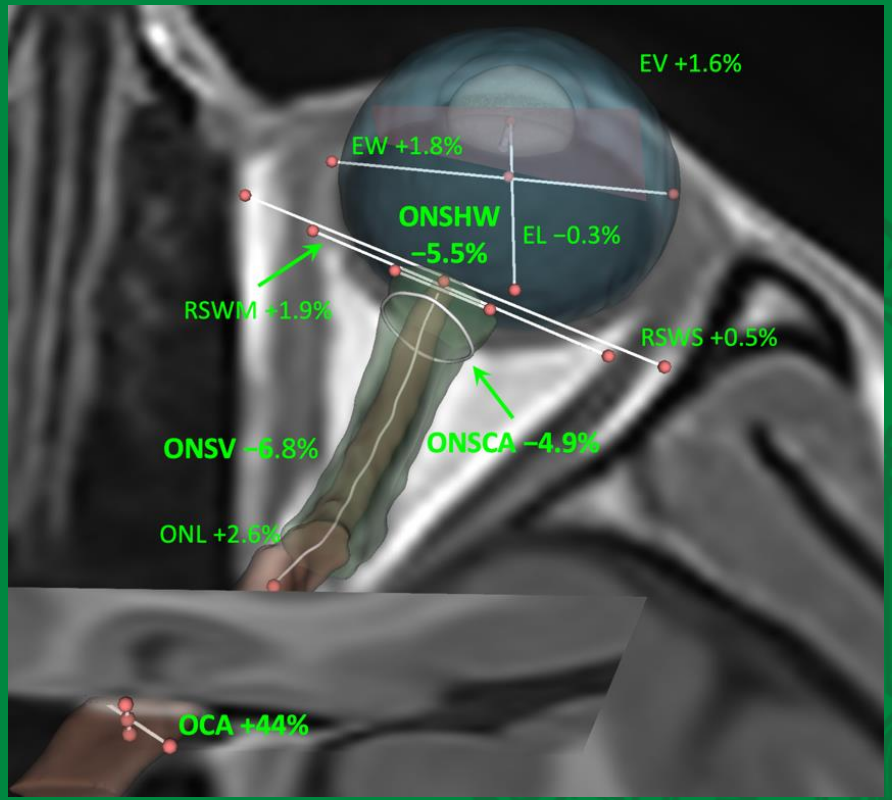

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~~Laterality effects~~

Template-building

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Sex differences ?

~~Laterality effects~~

Template-building

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Total intracranial volume (aka head size)

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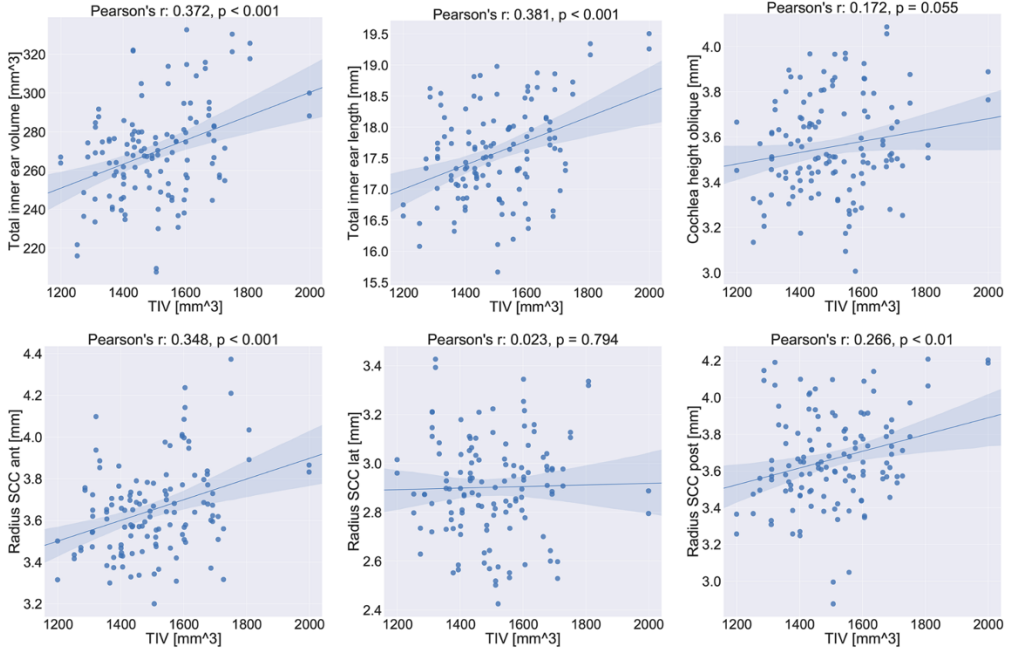

Figure 3. Correlation plots for inner ear measurements with total intracranial volume (TIV). Linear correlation values (Pearson's r) and corresponding *p*-values are indicated in the subplot titles. The 95% confidence interval for the regression estimate is drawn as a translucent band around the regression line. Total inner ear volume and length, as well as the radii of the anterior and posterior semicircular canals (SCC) are linearly correlated with head size. The oblique cochlea height might well be while the radius of the lateral SCC appears to not be correlated at all with TIV. The results indicate the importance of TIV for future quantitative assessments between cohorts. (Figure panels created with seaborn v0.11.0 https://seaborn.pydata.org/).

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~~Sex differences~~

~~Laterality effects~~

Template-building

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Aging

~~Sex differences~~

~~Laterality effects~~

Template-building

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Study Design

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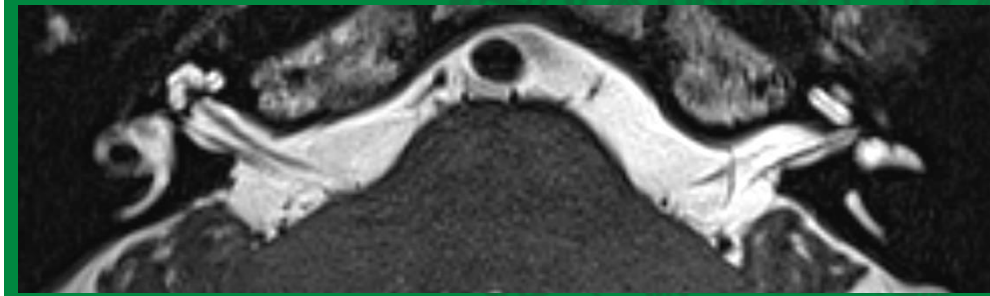
- 88 healthy subjects (71 LMU, 17 Antwerp) 2019-2022
- 20-80 years old, gender-balanced
- Siemens Prisma 3T with 64ch head&neck coil (LMU), 32ch head coil (Antwerp)

Sequenz	Slice thick-ness [mm]	Repetition time [msec]	Echo time [msec]	Inversion time [msec]	Flip angle [deg]	Bandwith [Hz/Px]
T2w	0,75	3200	560	/	120	625
T1w	0,75	2060	2,17	1040	12	230
FLAIR	1	5000	393	1800	120	780
3D-CISS	0,4	9,33	4,33	/	70	400
T2-SPACE	0,4	1300	132	/	100	280



T2-SPACE > CISS

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Study Design

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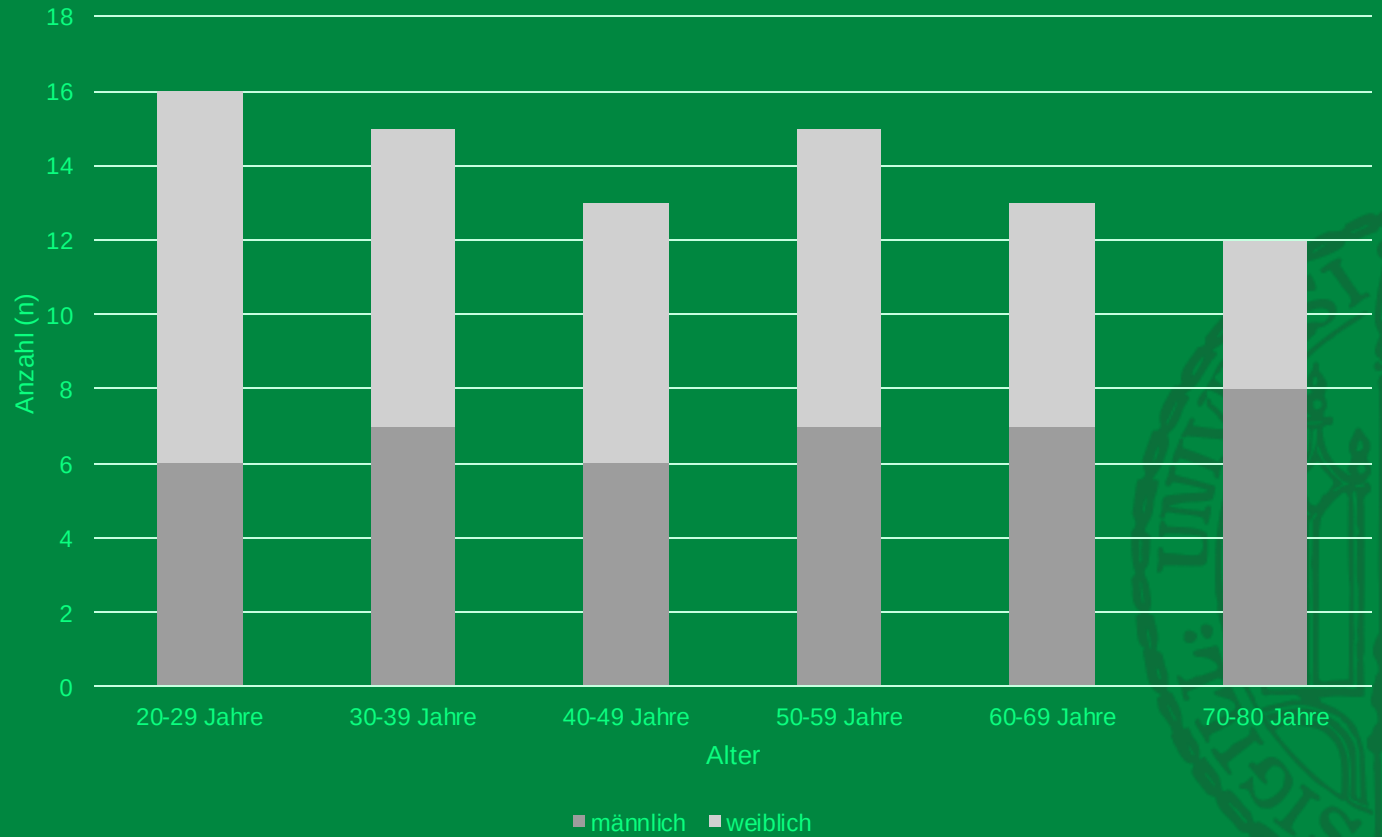
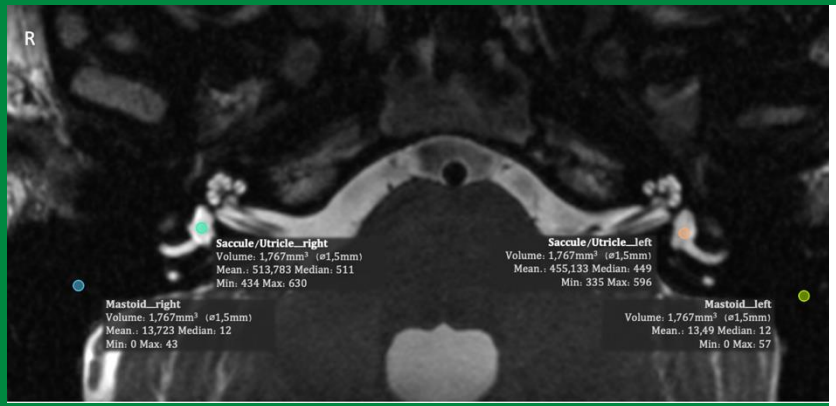
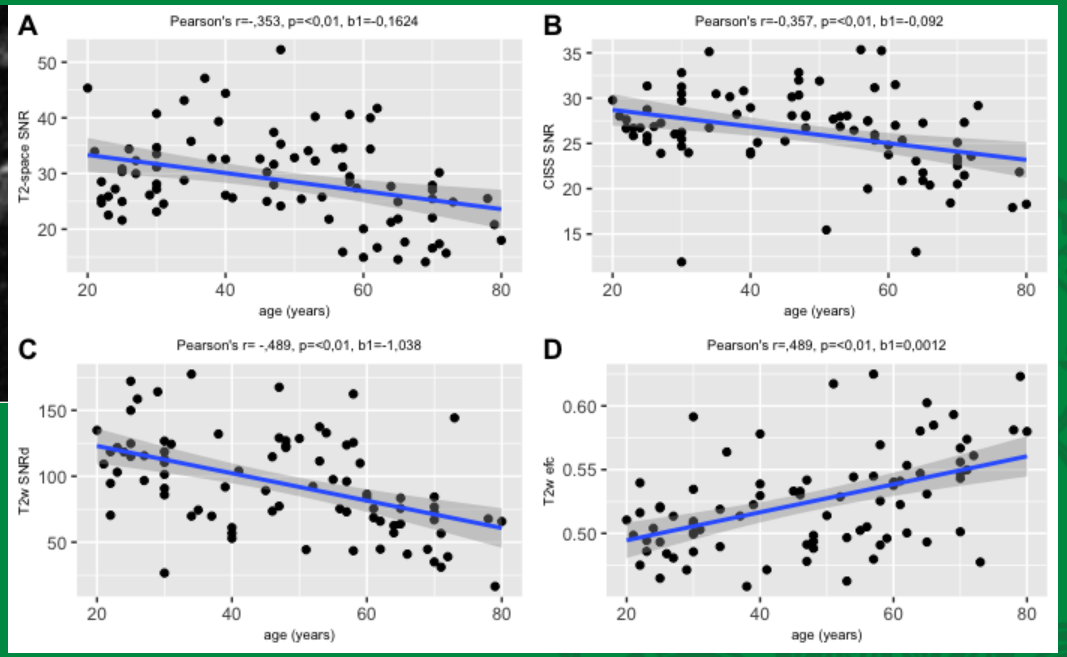


Results – Aging effects on signal quality



Significant correlation of age with signal-to-noise ratio and entropy-focused-criterion over sequences. Most likely the consequence of increased head motion.



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Results – Coil effects on signal quality

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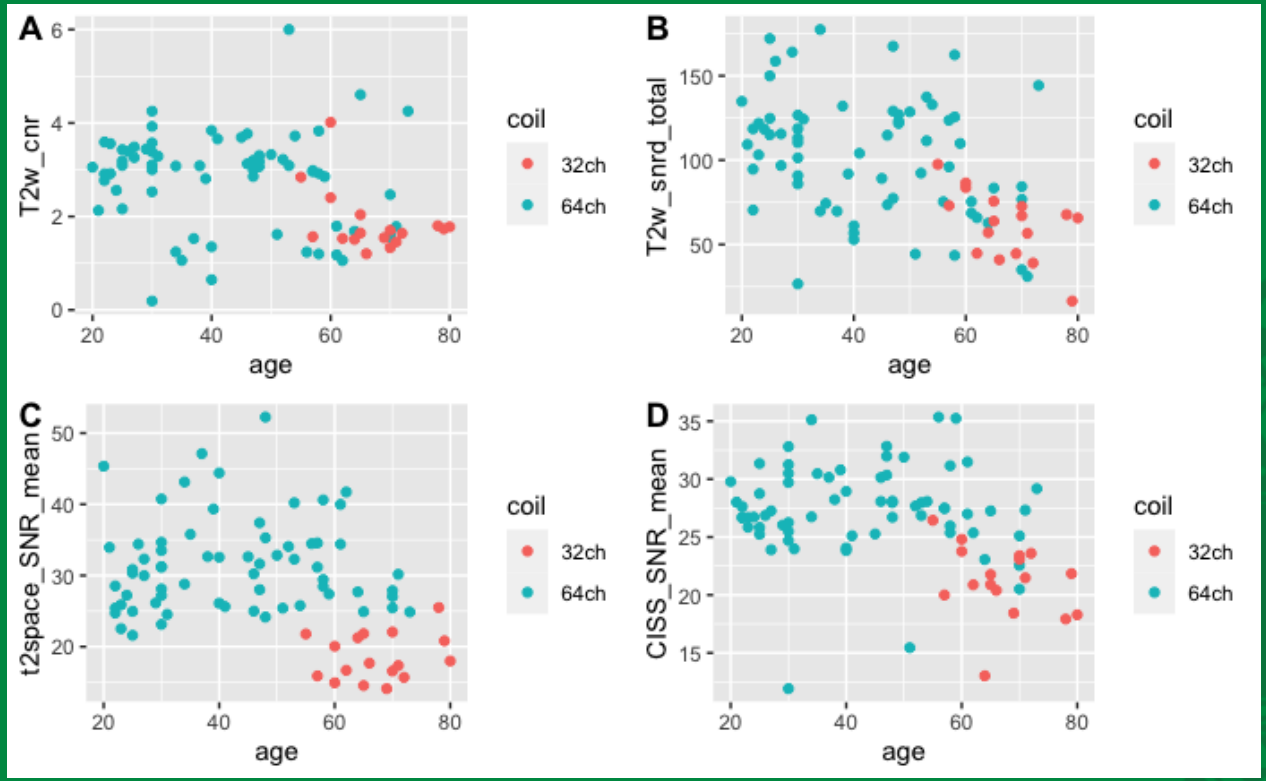
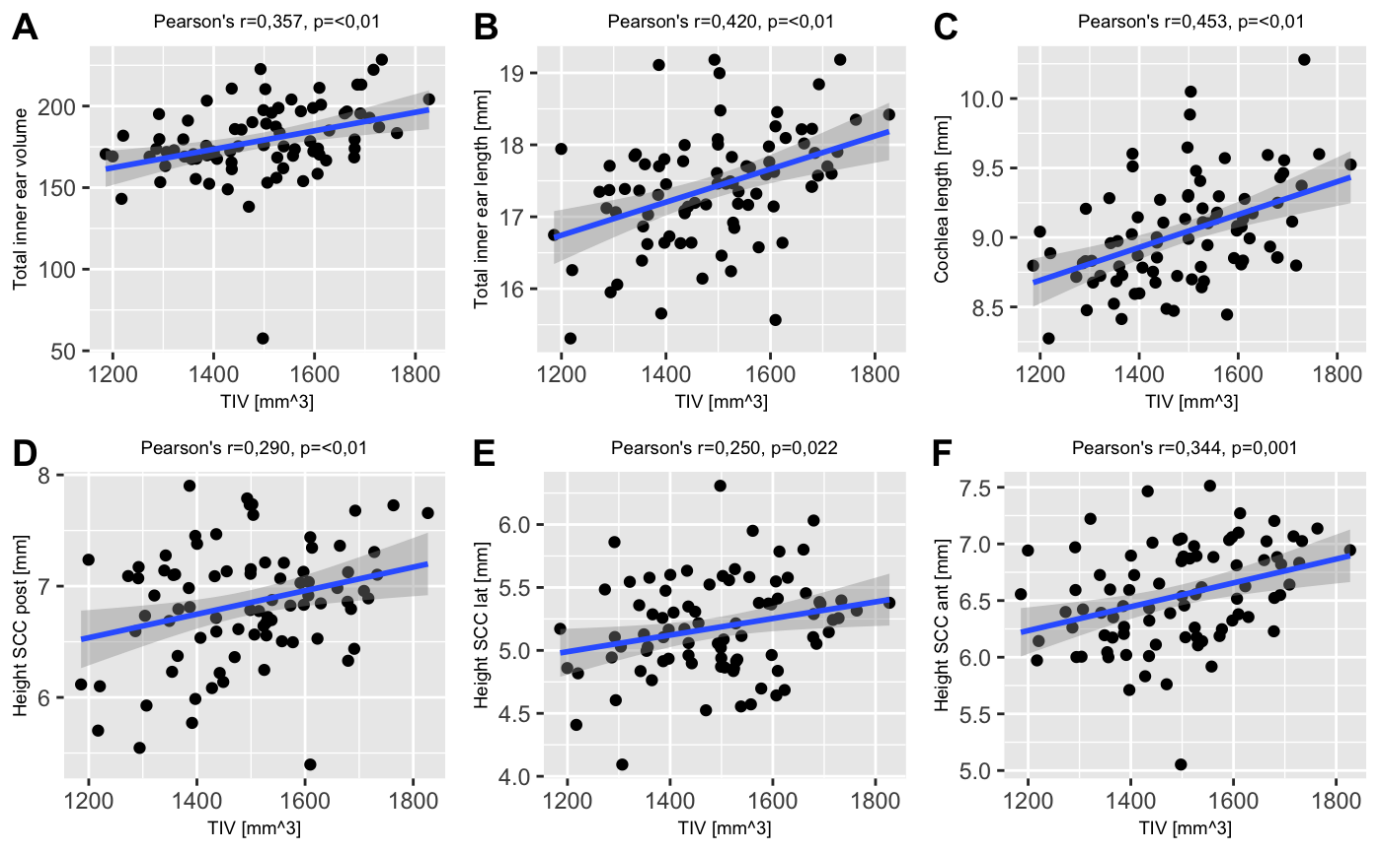


Results – Replication of TIV as confounder



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Results – No effect of age on inner ear volumetrics

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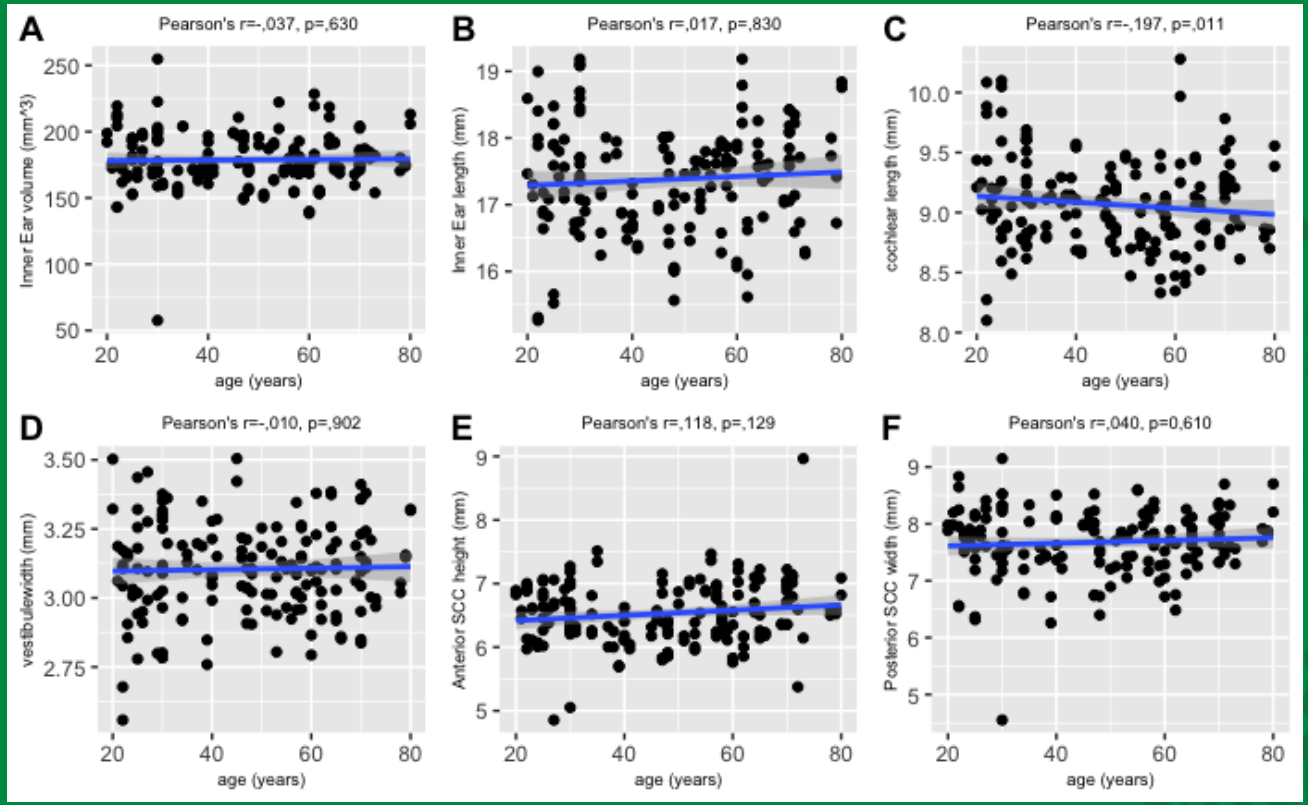

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Results – Aging VIII. cranial nerve

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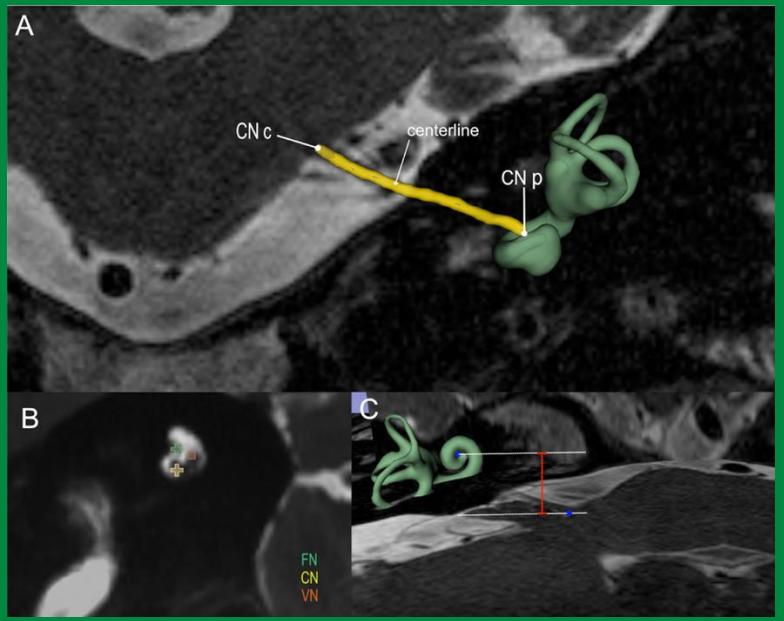

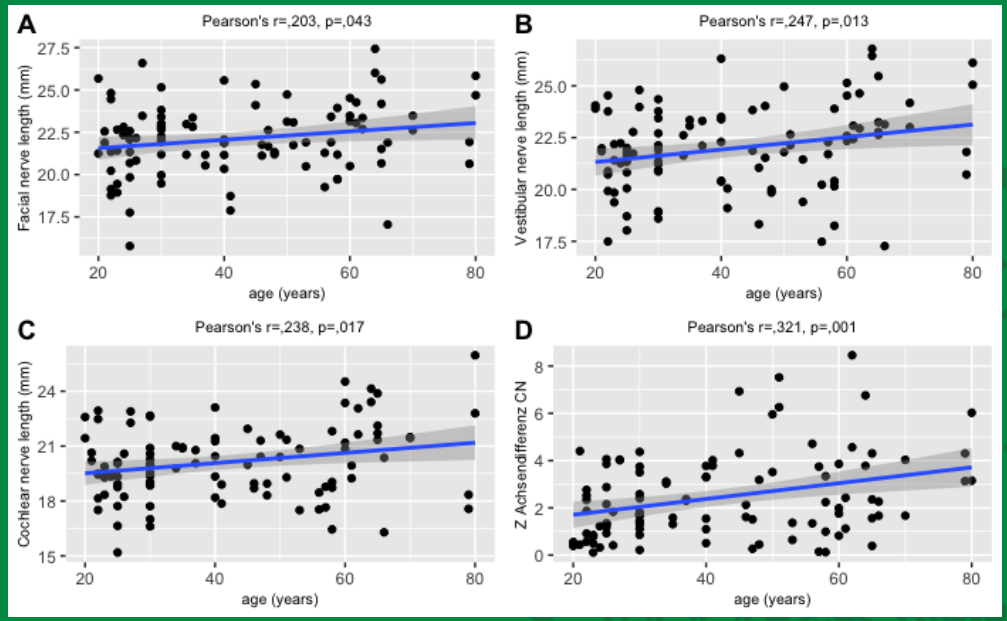

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Results - Aging effects on central vestibular representations

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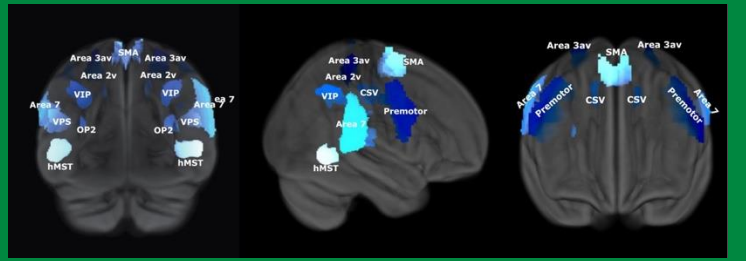
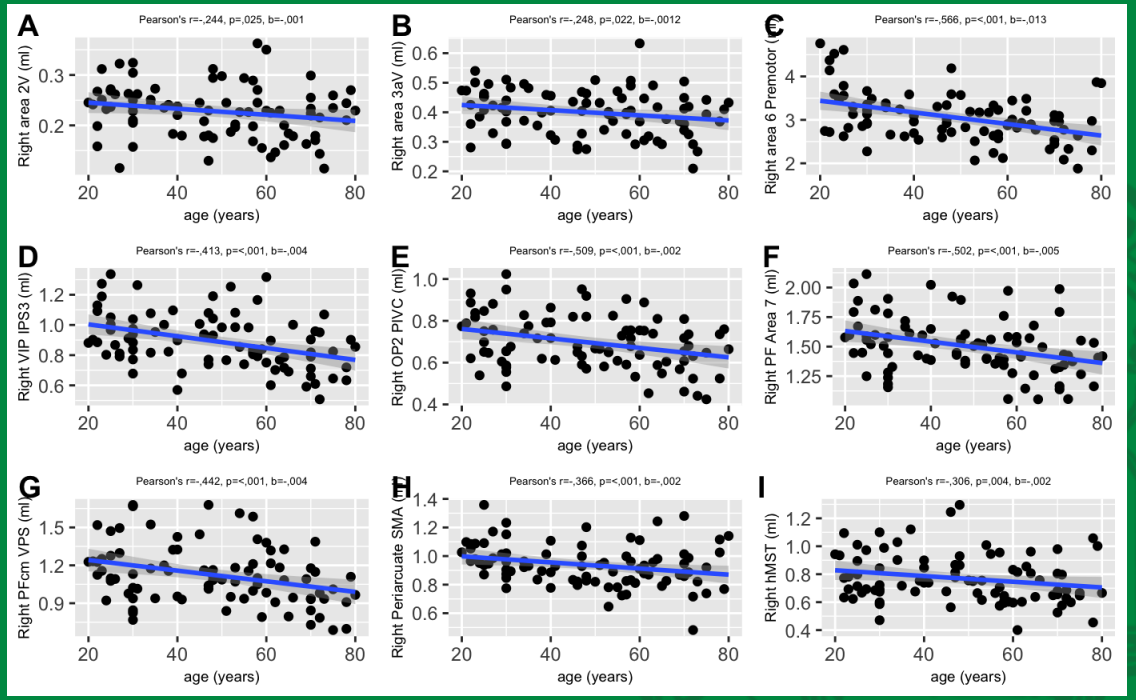


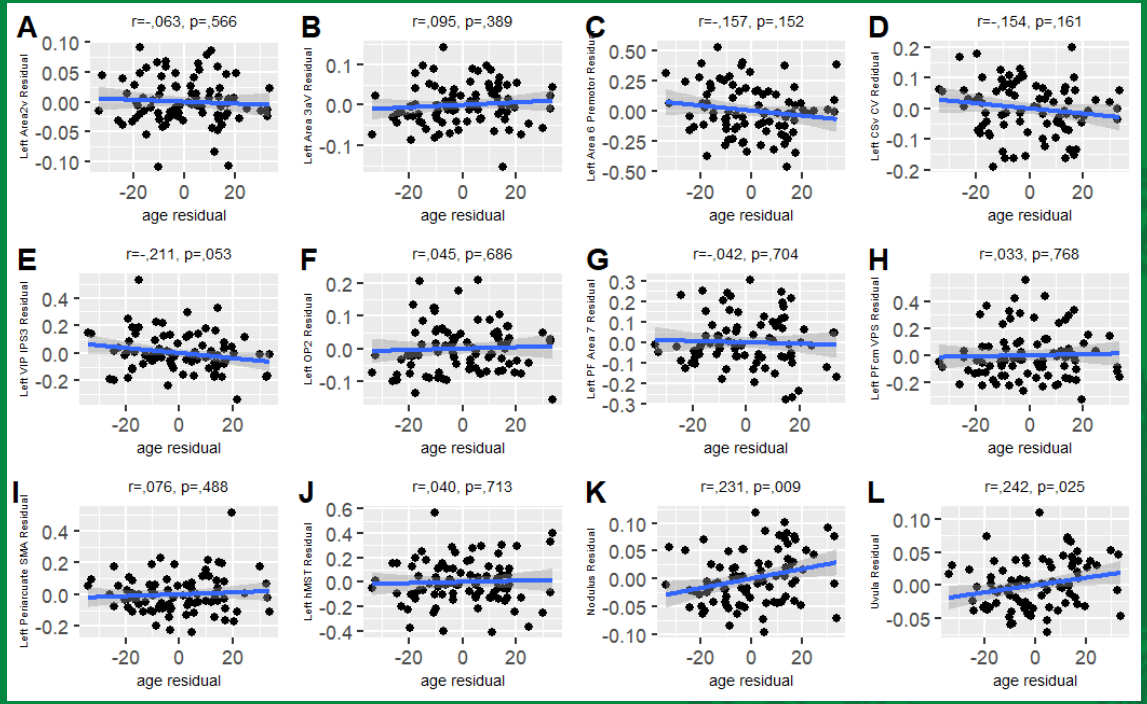
Raiser T. et al. NeuroImage 2020

Cortical vestibular representations decline in volume with age. This aligns with the cerebral grey matter reduction.



Results - Aging effects on central vestibular representations

If you control for general grey matter volume loss with age then cerebellar regions (A-F = central vestibular ROIs of the left hemisphere, K = nodule, L = uvula) actually increase in volume with age.



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~~Aging~~

~~Sex differences~~

~~Laterality effects~~

Template-building

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Summary

- Inner ear morphometrics show no effect for age
- Need to control for coil characteristics across sites
- The 8th cranial nerve lengthens with age but shows no change in geometrics (tourtuosity/torsion) as the brainstem seems to descends
- Cortical vestibular representations decrease in volume in alignment with global grey matter reduction
- Cerebellar regions on the other hand seem to increase in absolute and relative volume

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Tissue characterization

~~Aging~~

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Template-building

Outlook

- Research going forward with one multi-modal human inner ear template (T1/T2/CISS) for adults
- Characterization of soft tissue parameters (DWI spectrum, MPM, Echo Mapping, CEST, QSM)
- Test applicability of 4D-Flow in inner ear imaging
- Tackle identification of peripheral vestibular disorders 2025

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Number and volume of white matter hyperintensities with age or BMI

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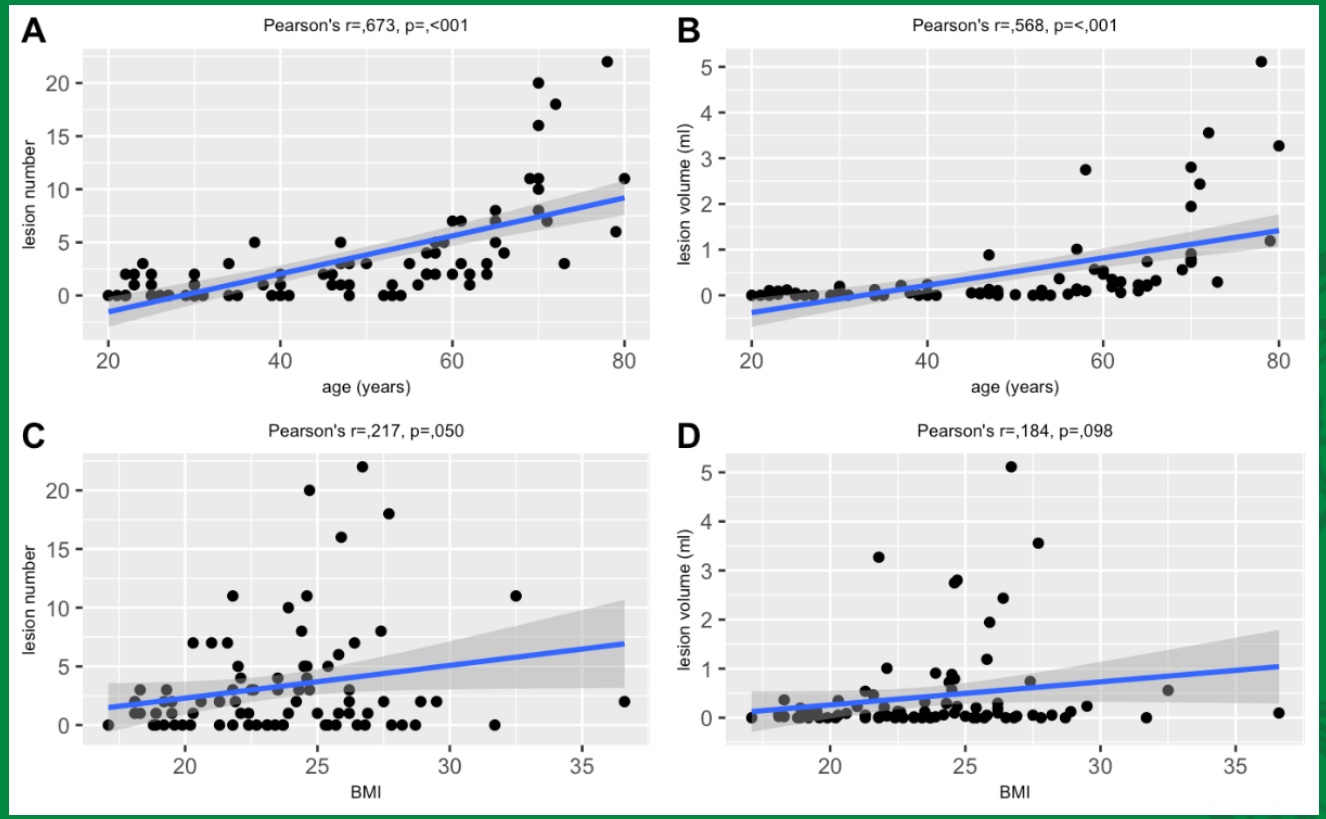

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DHI, VSS, GPAQ and Motion sickness with age

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