Layer-specific myeloarchitecture of human S1 hand area in younger and older adults at 7T-MRI

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Introduction

- The sense of touch is fundamental to our perception of reality. Critically, **with advancing age, tactile abilities adapt**.
- Lately, healthy **aging** has been **linked to cortical myelin plasticity** (Callaghan 2014, Grydeland 2018), but little is known on how this relates to functional cortex architecture (e.g. body topography) and tactile behavior.
- It has been suggested that **layer-specific** variation in **myelin reflects functional specializations** of the local cortical architecture (Nieuwenhuys 2013). However, **prior** in-vivo **studies** on age-related myeloarchitecture mainly **described** the **cortex as** a **two-dimensional sheath**.
- Recent advances in magnetic resonance imaging at 7 Tesla (**7T-MRI**) offer the possibility **to study layer-specific myeloarchitecture** in humans **in-vivo** (Kuehn 2017).
- The present study investigated how:

H1 myeloarchitecture of the human primary somatosensory cortex (S1) hand area varies with respect to cortical layers, finger topography and age,

H2 variation in layer-specific S1 myelin relates to variation in resting-state connectivity.

H3 variation in layer-specific S1 myelin relates to variation in tactile behavior.

Methods

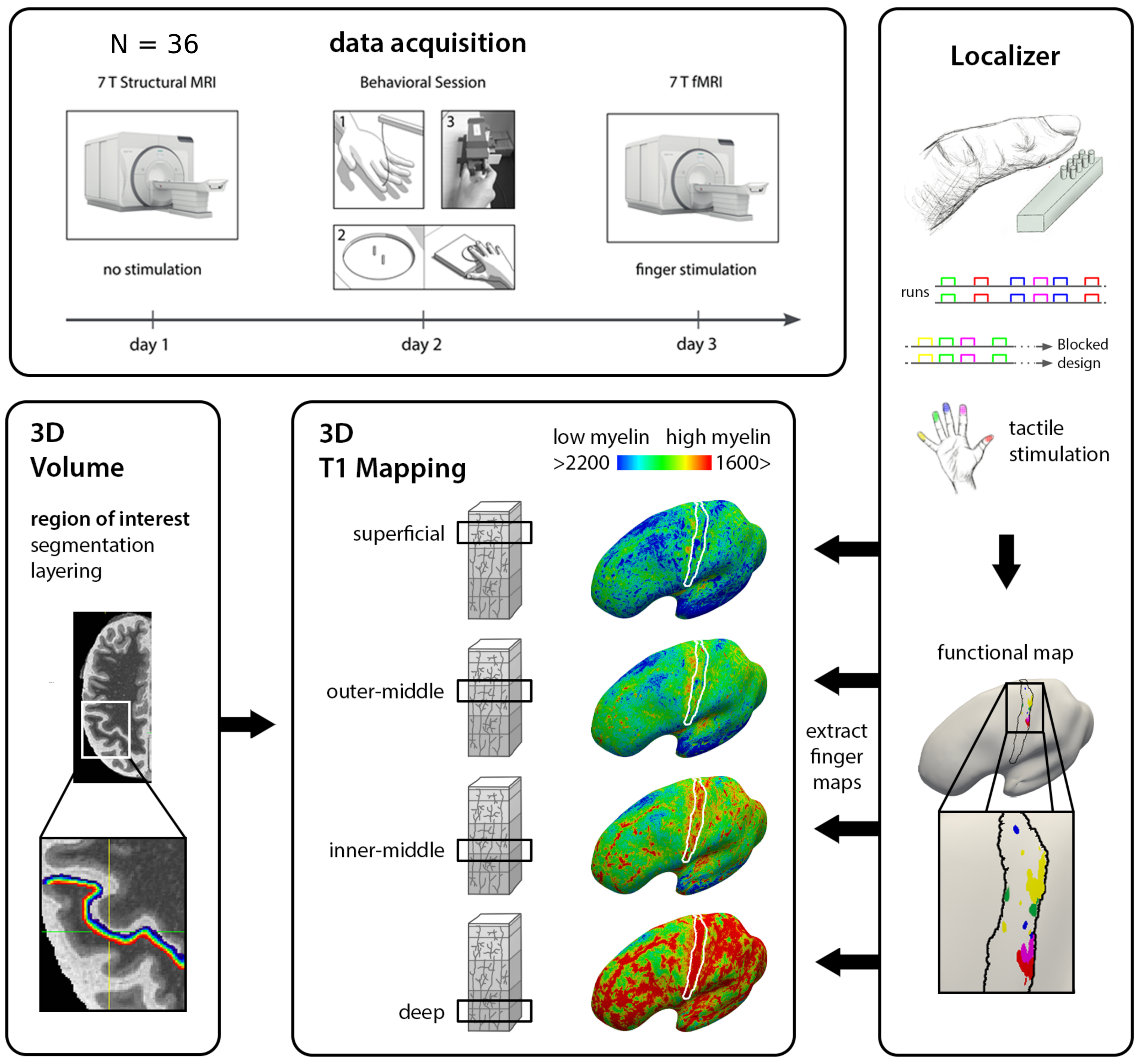
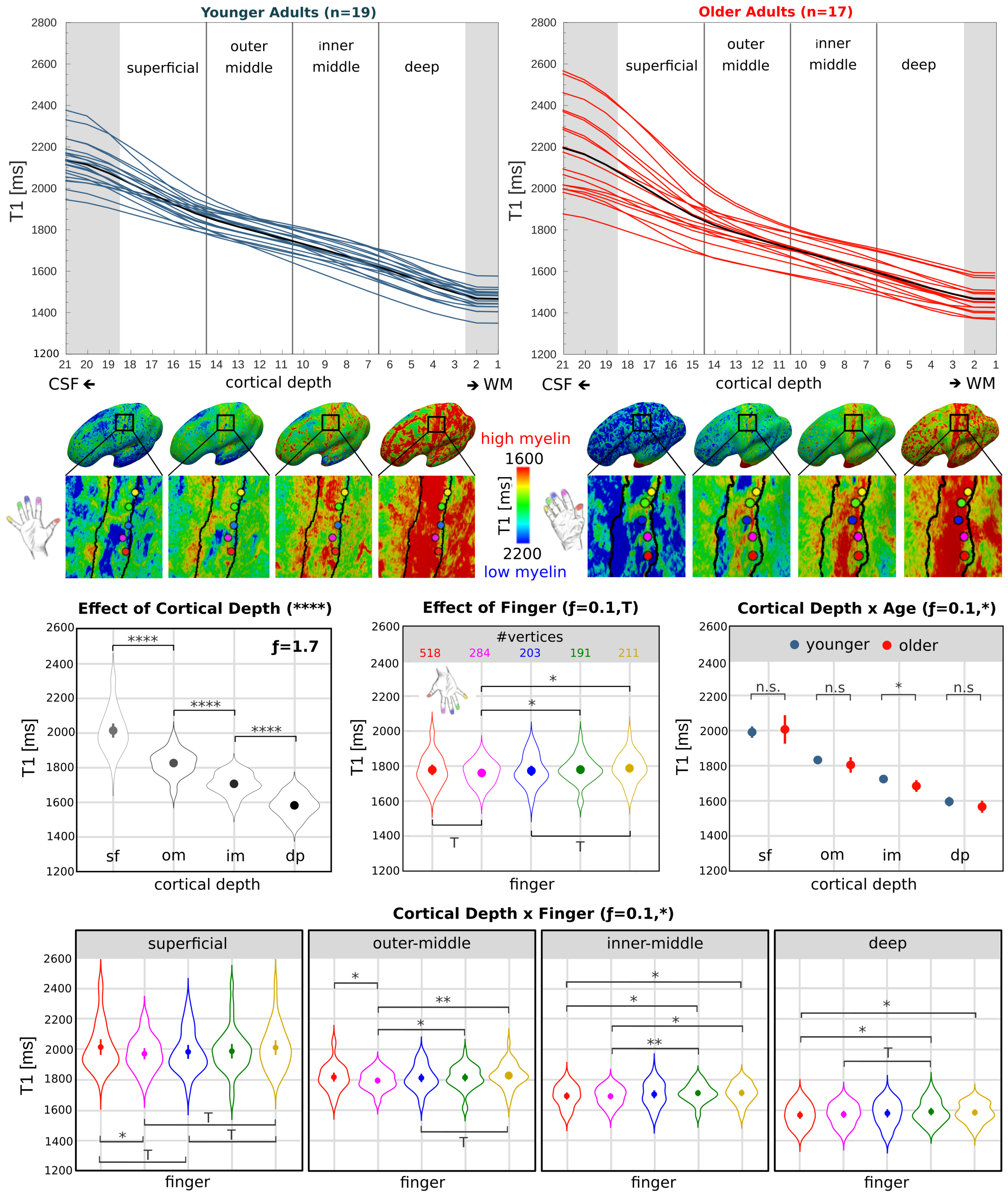


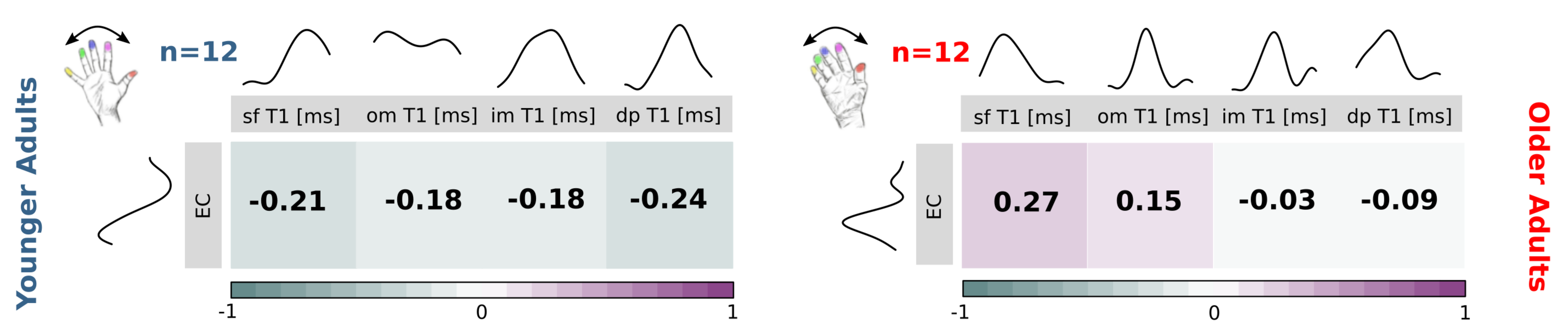
Figure 1. General procedure and extraction of cortical quantitative T1 (qT1) maps. 7T-MRI data of 36 healthy, right-handed volunteers (n=19 younger adults: mean age = 25 +/- 3 years; n=17 older adults: mean age = 71 +/- 4 years) were acquired at a Siemens MAGNETOM scanner (day 1: MP2RAGE, 0.5 mm isotropic; day 3: EPI, 1.0 mm isotropic). Tactile behavior was tested in 3 different tasks: (1) detection, (2) discrimination, (3) precision. Intra-cortical qT1 values, used as myelin proxy (Stueber 2014), were estimated from the region of interest using the equivolume model (Waehnert 2014) implemented in the CBS Tools. Extracted values were averaged into 4 cortical depths (superficial, outer-middle, inner-middle, deep) and mapped onto the inflated surfaces. Vibro-tactile stimulation applied to the fingertips of the right hand during functional scanning (blocked design, 5 seconds stimulation duration) was used to locate the hand area in contralateral S1. qT1 values are given in milliseconds. Please note that lower qT1 values indicate higher myelin levels (colored in red).

Results

A Cortical T1 Profiles of Left S1 Hand Area in Younger and Older Adults



B Structure-Connectivity Correlation (Kendall's Tau)



C Structure-Behavior Correlation (Kendall's Tau)

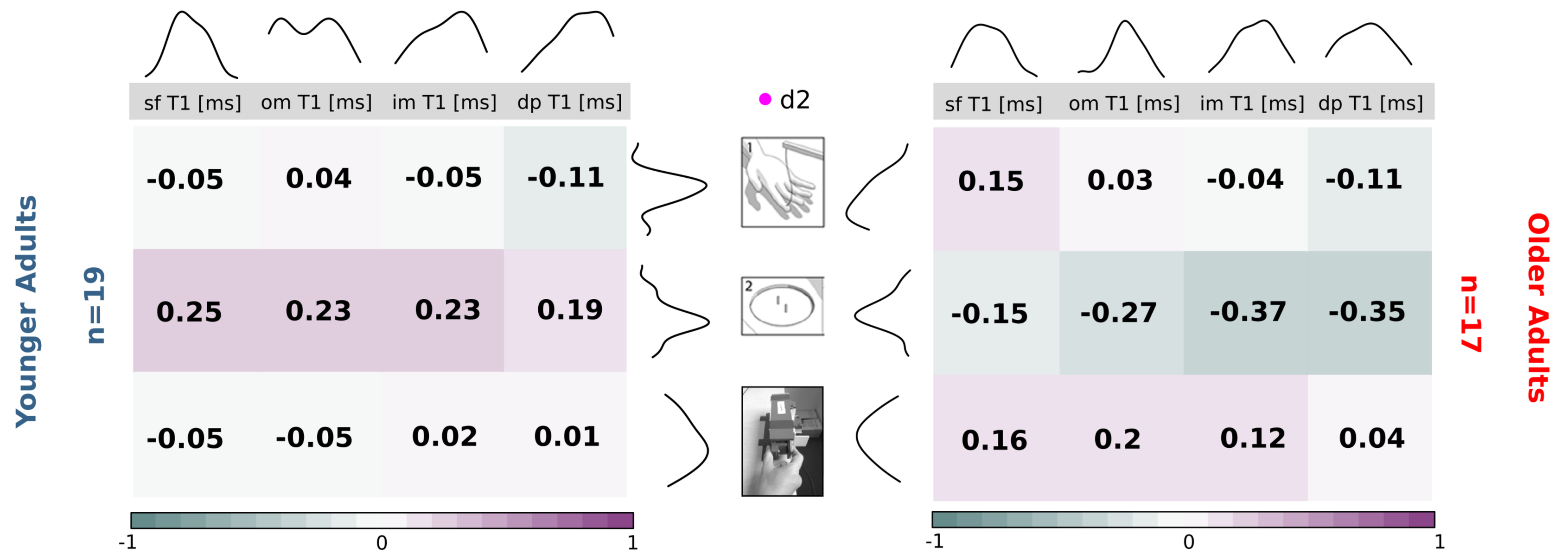


Figure 2. qT1 profiles and statistical results. **(A)** Layer-dependent distribution with increasing myelin levels (decreasing qT1 values) from superficial to deep layers (group mean in black color). The 3 most superficial and the 2 deepest layers (grey color) were excluded. Intra-cortical qT1 values (milliseconds) were averaged into 4 cortical depths (superficial: sf, outer-middle: om, inner-middle: im, deep: dp). Activation peaks of localizer were plotted to qT1 maps (second row). There was a significant main effect of cortical depth with $p < .0001$ (****), a trend towards a main effect of finger mainly driven by d2 with $p < .05$ (*), $p < 0.1$ (T), a significant interaction between cortical depth and age group with lower qT1 values at inner-middle cortical depth in older compared to younger adults with $p < .05$ (*) and a significant interaction between cortical depth and finger mainly driven by thumb and index finger with $p < .01$ (**), $p < .05$ (*), $p < 0.1$ (T). Effect size given as Cohen's ƒ (small: 0.1, medium: 0.25, large: 0.4). **(B)** Structure-connectivity correlation between layer-dependent qT1 and Eigenvector Centrality (EC, rectified linear unit correlation, Lohmann 2018) in younger and older adults averaged across fingers. Correlation coefficients given as Kendall's Tau. Negative correlations colored in shades of turquoise, positive correlations colored in shades of purple. **(C)** Structure-behavior correlation between layer-dependent qT1 extracted from d2 area and tactile index finger performance (detection, discrimination, precision). Correlation coefficients given as Kendall's Tau.

Discussion

H1 Layer-specific qT1 mapping in younger and older adults suggests myeloarchitecture of S1 hand area is inhomogeneous and varies with respect to finger topography and age dependent on cortical depth. We found increased myelin levels in inner-middle layers in older compared to younger adults. Index finger maps were more myelinated in middle layers, thumb maps in deeper layers, appearing to have a special role, most likely being preserved in older age.

H2 A significant link between resting-state connectivity and layer-specific qT1 was missing. However, strongest correlations were found in superficial and deep layers known to be involved in inter-regional communication.

H3 Strongest correlations were found for spatial discrimination and deep qT1 in older adults, however, a significant link was missing. Including QSM as iron proxy, pRF maps (Liu 2021) and behavioral marker of all five fingers may clarify the link between cortical myelin and tactile behavior.

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