# Time course of structural plasticity induced by different types of motor learning

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## Background

- Changes in grey and white matter structure occur in the healthy human brain following motor training (>1 week)[1-4].
- Learning-related plasticity can be detected in short time-scales using DWI through a reduction in mean diffusivity (MD) in task-relevant regions. This MD reduction has been associated with a NMDA-dependent astrocyte hypertrophy, which may be indicative of sites of LTP induction[5,6].
- Motor learning but not mere motor activity is associated with synaptogenesis and with an increase in astrocytic volume[7].

**In this study, we used MD maps to investigate the emergence of early cortical plasticity elicited by a short session of learning in two well-characterized motor learning tasks. We also explore its evolution after motor memory consolidation.**

## Methods

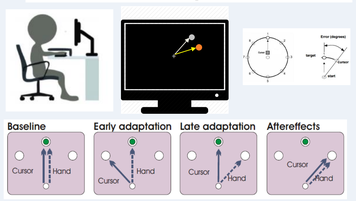
**21 healthy subjects** (11 female, age 23.6±3.1)

### PROTOCOL


**DWI Acquisition** (3:34 min): Multiband-accelerated sequence[8,9] (MB factor 2), Voxel size=2×2×2 mm³, FOV=240x240 mm², 30 gradient directions,b-value = 1000 s/mm², 70 axial slices, TR=5208 ms, TE=89 ms

## Motor learning tasks

### Visuomotor adaptation VMA [13-15]

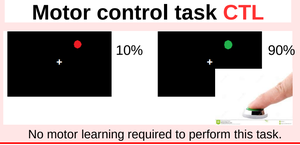



**Adjust our actions to perturbations** by recalibrating motor commands to compensate the error introduced by perturbations

**Cerebellum and posterior parietal cortex (PPC)** are involved in error correction and sensory-motor transformations required to learn this task[13-15]

**Primary motor cortex (M1)** is involved in memory retention in VMA[13-15]

### Motor control task CTL




No motor learning required to perform this task.

### Motor sequence learning MSL [10-12]


**5-element sequence: 4-1-3-2-4**
Self-paced task
60 keypresses per block
25 second rests between blocks

**Acquisition of a new motor skill** with repeated practice of sequential movements

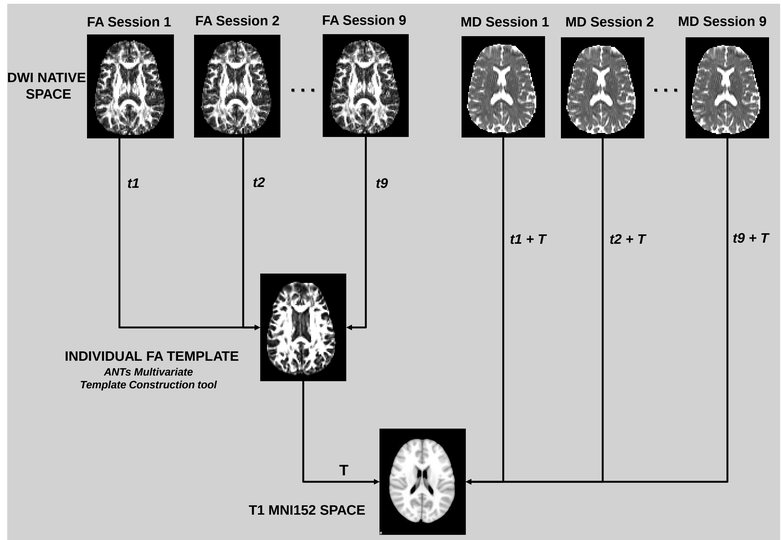
**M1, supplementary motor area (SMA), parietal cortex, cerebellum and hippocampus** are functionally activated during the early learning phase of MSL[10].
Transient acute hippocampal dysfunction has been shown to attenuate fast learning in MSL[11].

**Striatum, Parietal cortex and M1** are involved in the late phase of learning and consolidation. Striatum shows an increase in activity after sleep-dependent consolidation[12].

## DWI processing

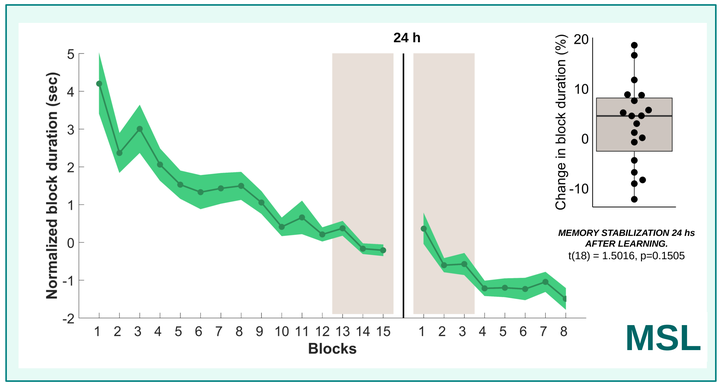
**Dicom to Nifti Conversion** *Dcm2nii* → **Distortion Correction** *FSL's topup+eddy* → **DTI model fit** *FSL's DTIfit* → **MD Normalization[16] to MNI152** *ANTs* → **MD Smoothing** *4mm FWHM*

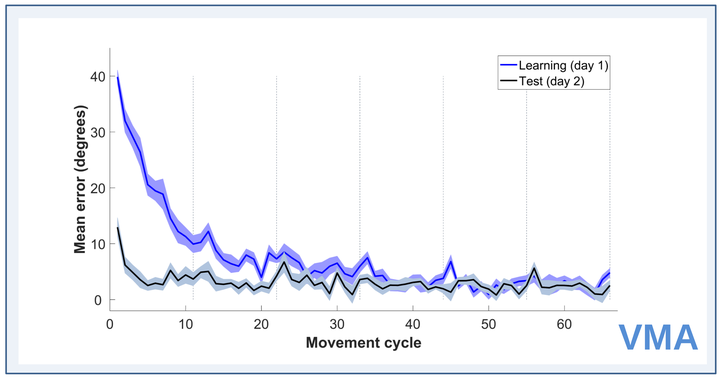
### MD Normalization to MNI152




*t1, t2, …, t9 and T are nonlinear transformations calculated using ANTsRegistration*

## Behavioural results



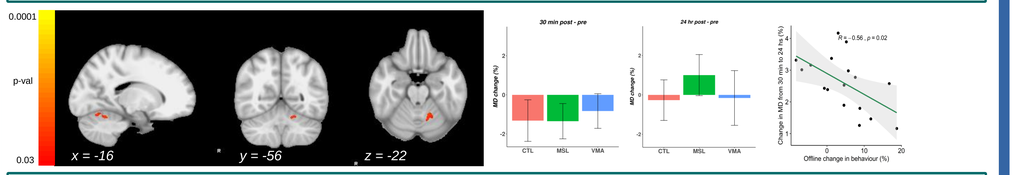




## Mean diffusivity Results

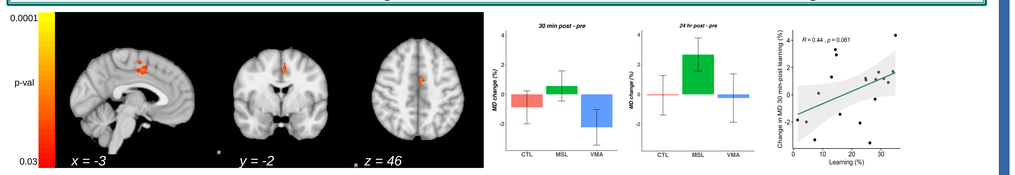
In all cases TFCE-corrected[17] p-values, generated using 10000 permutations in Randomise[18], are shown.
Error bars represent 95% confidence interval of the mean.

**Regional brain changes associated with different types of motor learning**
Effect of session was assessed for each task separately (CTL, VMA and MSL)
Repeated Measures ANOVA 1 factor (session), 3 levels (pre, 30 min-post, 24 hr-post)

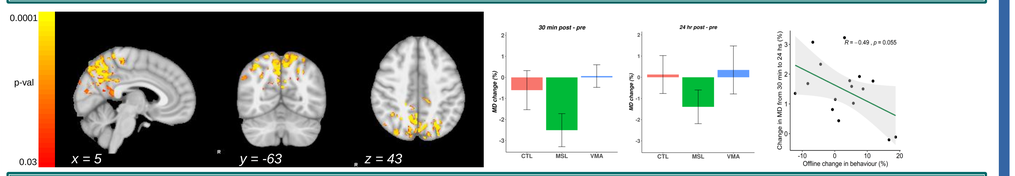
### MSL: Long-term changes in MD in the cerebellum are associated with memory consolidation



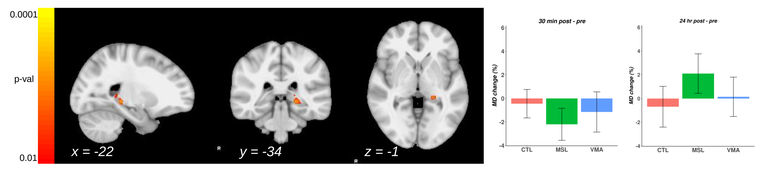

### MSL: Short-term changes in MD in SMA are associated with learning



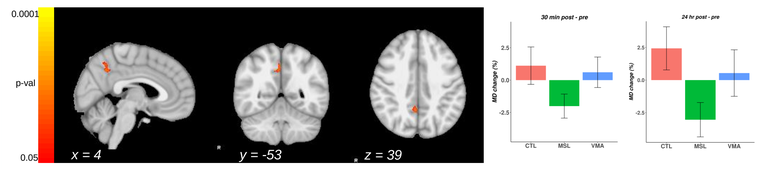

**MSL: Short-term reduction in MD in precuneus cortex and PPC persists at 24 hs**
**Long-term changes in the these regions are associated with memory consolidation**




### MSL: Short-term reduction in MD in hippocampus is reverted after 24 hs




**Task by Session Interaction**
Repeated Measures ANOVA 2 factors (Task, Session), 2 levels Task (CTL, MSL) and 3 levels Session (pre, 30 min-post, 24 hr-post)




## Conclusions

- MSL showed a significant reduction of MD in precuneus and posterior parietal cortex 30 min post-learning which persisted overnight.
- MSL showed a significant decrease in MD in the left hippocampus 30 minutes post-learning. This decrease reverted 24 hs after learning.
- Cortical increase in MD is negatively correlated with consolidation measures but positively correlated with learning measures.
- Our results suggest that acquiring a new motor policy -as in MSL- may involve changes in synaptic efficacy that are stronger than those elicited during VMA.

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LABMAN Latin American Brain Mapping Network · QBIN Quebec Bio-Imaging Network