Open-source preprocessing pipelines control for motion in multi-shell developmental diffusion-weighted imaging data

Emily M. Heffernan, Michael L. Mack, Margaret L. Schlichting

Department of Psychology, University of Toronto

Introduction

Diffusion-weighted imaging (DWI) presents the possibility to characterize white matter in vivo and across development

DWI data are highly susceptible to motion artifacts that may inflate or obscure white matter changes, particularly in populations with higher in-scanner motion.[1]

Choice of pipeline can also impact measures derived from DWI[2,3]

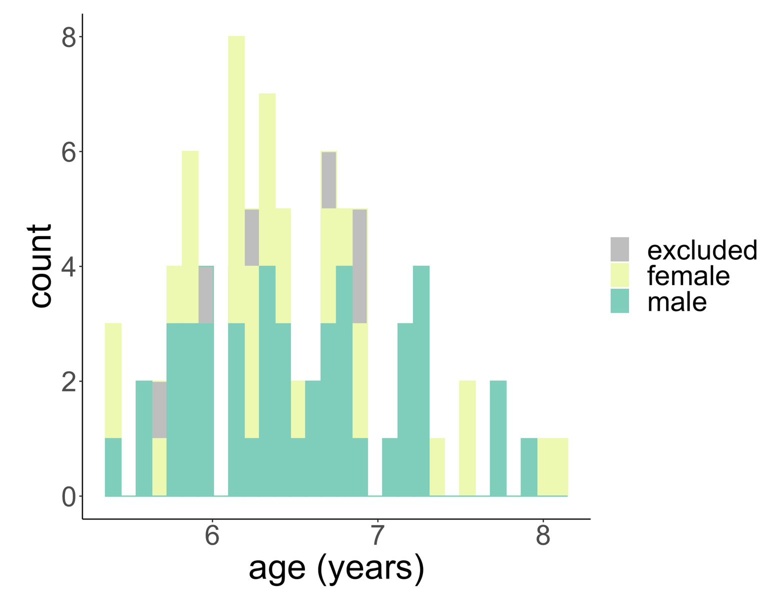
Recent advances, such as multi-shell image acquisition and preprocessing techniques, may reduce motion confounds in DWI[2,4]

Here we explore to what extent open-source preprocessing pipelines correct for motion in a pediatric cohort

Methods

Developmental data (T1 and multi-shell diffusion) from MASiVar[5] were used for these analyses

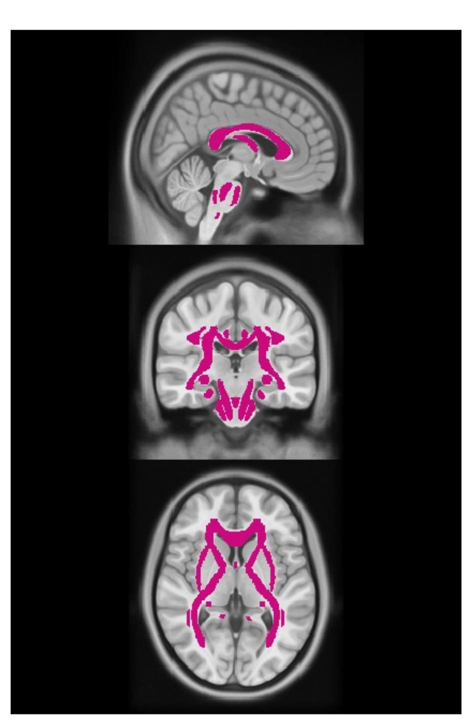
83 participants aged 5–8 years (mean 6.48, SD 0.63, 35 female, 48 male). Six were excluded for high motion (mean relative root mean square displacement [RMS] > 1.2).



Motion metrics of mean absolute RMS and mean relative RMS (in b = 0 shells) and temporal signal to noise ratio (TSNR; in b = 2,000 shells) were computed for each subject.[6]

All data were processed using both the PreQual[7] and QSI Prep[8] pipelines (with default settings)

Mean multi-shell diffusion metrics (mean diffusivity [MD], radial diffusivity [RD], axial diffusivity [AD], and fractional anisotropy [FA]) were then calculated using MRtrix[9] in white matter tracts defined by the JHU ICBM white matter atlas[10]



The JHU white matter atlas[10]

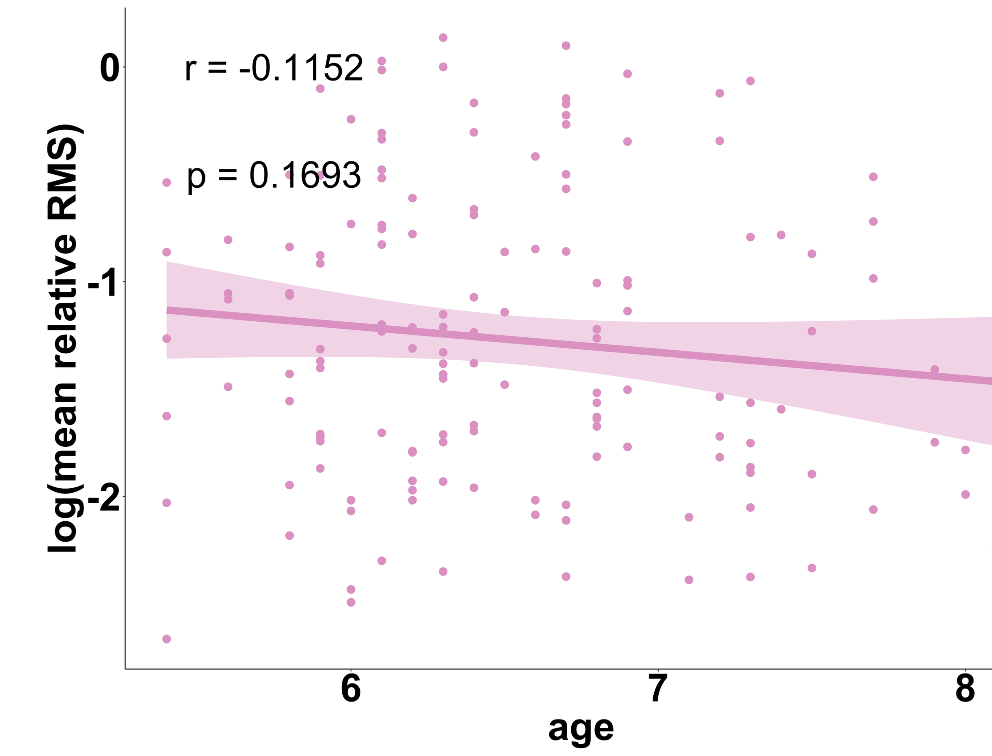
Preprocessing Stage	PreQual	QSI Prep
MP-PCA denoising	✓	✓
Patch2self denoising		✓
Gibbs unringing	✓	✓
N4 B1 bias field correction	✓	✓
b=0-scaled Intensity normalization		✓
Eddy motion correction	✓	✓
TOPUP distortion correction	✓	✓
GRE fieldmap EPI distortion correction		✓
T1w-based normalization		✓
Computation of DWI metrics	✓	

Partially adapted from https://qsiprep.readthedocs.io/en/latest/comparisons.html

Results

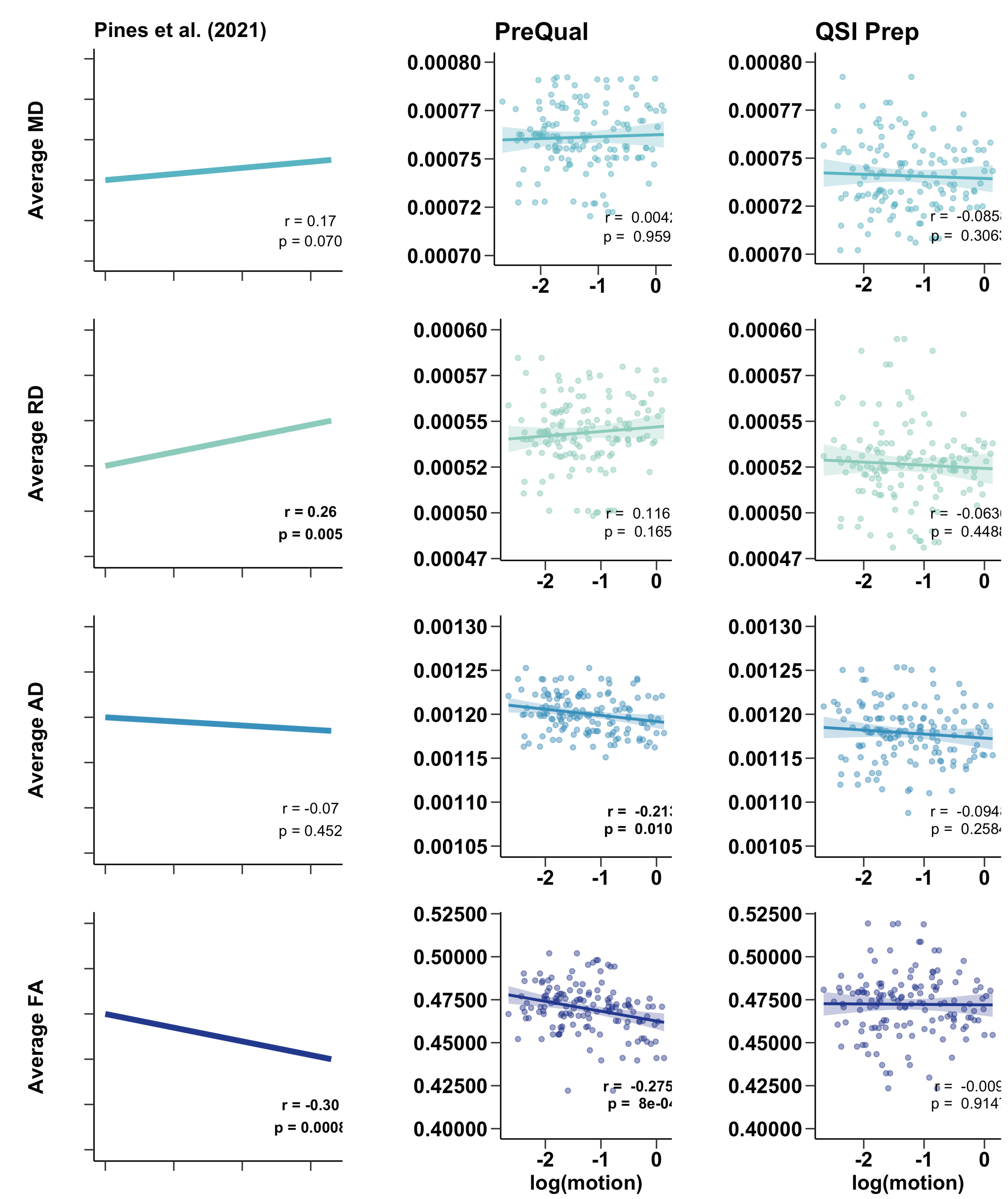
Mean relative RMS and mean absolute RMS decreased with age (NS); TSNR increased

Diffusion metrics calculated across pipelines moderately to strongly correlated (all r > 0.58, all p << 0.0001



After controlling for age and sex using a generalized additive model (GAM) approach outlined in [1], DWI data processed using QSI Prep showed no motion correlation.

AD and FA data processed with PreQual showed modest correlation comparable to Pines et al. (2021)[4]

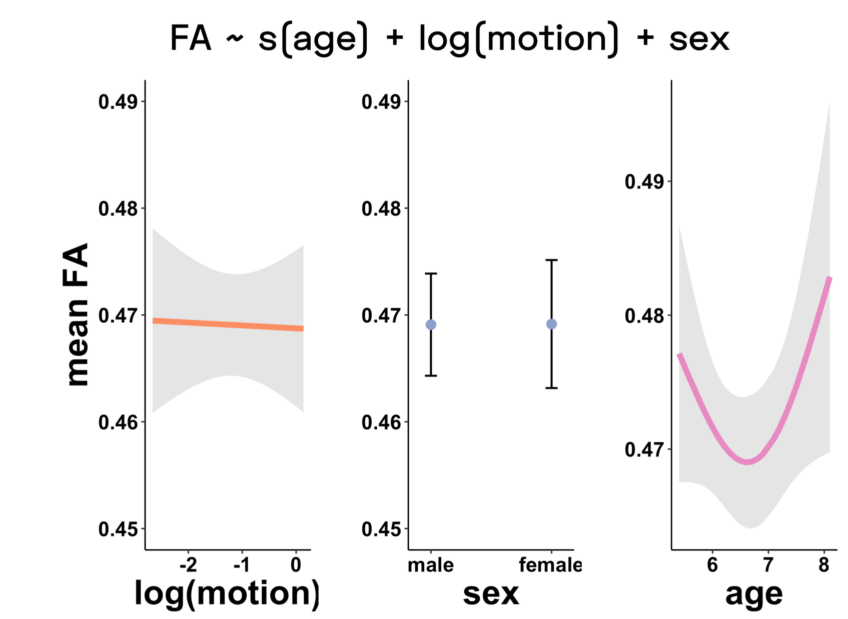


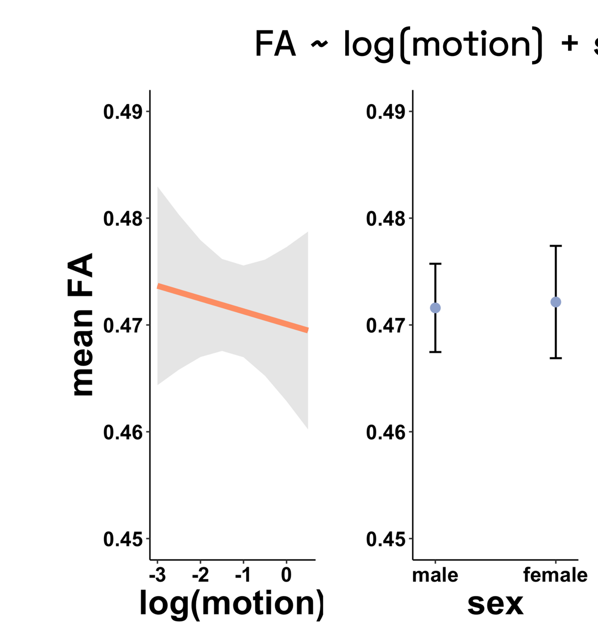
QSI Prep slightly increases sensitivity to aging effects

Two GAMs were fit to the data from each pipeline, with and without age as a smooth term and with sex and motion as linear terms

Including age as a regressor modestly improved model fit for FA data processed with QSI Prep

No changes were found across models fit to PreQual data





Conclusions

Open-source preprocessing pipelines, in particular QSI Prep, show promise in eliminating motion confounds in DWI data

Even after preprocessing, residual motion may impact diffusion-derived metrics

Changes in preprocessing pipeline may impact sensitivity to effects of age

Researchers are urged to quantify and report motion and correlations between motion and metrics of interest

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