2026 JULY 19–22
VANCOUVER, BC
JOINT AAPM | COMP MEETING

Impact of Polynomial Detrending on Weisskoff Analysis for Radius of Decorrelation Estimation

Henry Szu-Meng Chen, PhD[1], Judd M. Storrs, PhD[2], Fan-Chi F. Su, PhD[3], Jie Deng, PhD[3], Ali Golestani, PhD[4], Kevin T. Grizzard, PhD[5], Brian A. Taylor, PhD[6], Trevor J. Andrews, PhD[7] and Ho-Ling Anthony Liu, PhD[6], (1) University of Colorado Anschutz, Aurora, CO, (2) Nationwide Children's Hospital, Columbus, OH, (3) UT Southwestern Medical Center, Dallas, TX, (4) Arthur J. E. Child Comprehensive Cancer Centre, Calgary, AB, Canada, (5) Columbia University Irving Medical Center, New York, NY, (6) UT MD Anderson Cancer Center, Houston, TX, (7) Washington University at St Louis, St. Louis, MO

CONCLUSIONS and TL;DR

Detrending has a major impact on Weisskoff analysis and RDC values (larger RDC means better temporal stability). We show that:

- Without detrending
  - Largest deviation from ideal curve in Weisskoff analysis
  - Lowest RDC
  - Reflects greater temporal autocorrelation from low-frequency signal from hardware instability
  - Single metric quality assessment
- With quadratic detrending
  - Better agreement with the ideal curve in Weisskoff analysis
  - Higher RDC
  - Consistent with conventional fMRI preprocessing
  - Needs separate drift analysis for complete quality assessment

Our work suggests that it is prudent to select the same detrending strategy for consistent monitoring and interpretation of fMRI QC.

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INTRODUCTION

Weisskoff analysis[1] assesses temporal stability of echo-planar imaging (EPI) in functional MRI (fMRI) by comparing how the temporal coefficient of variation (CoV) scales with increasing ROI size relative to the ideal behavior expected for uncorrelated and identically distributed noise, which for square N × N voxel ROI is

$$CoV(N) \propto \frac{1}{\sqrt{N}}.$$

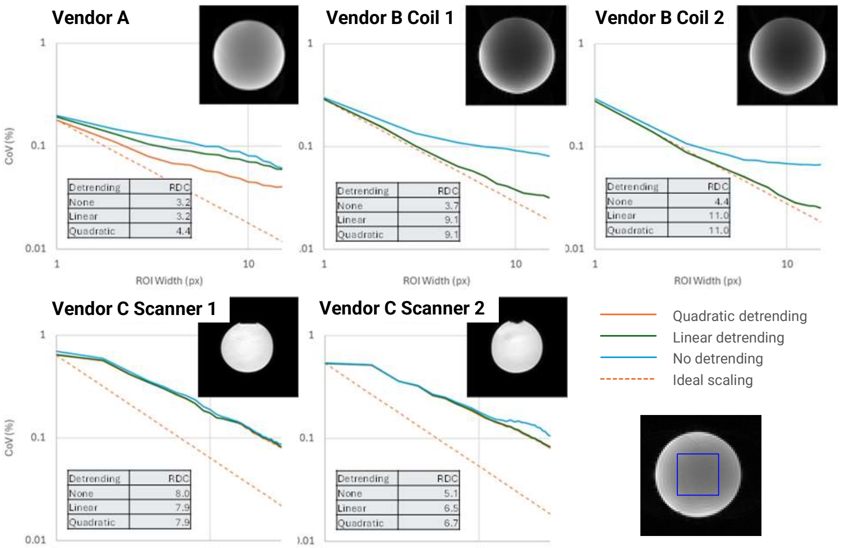
Deviation from this curve indicates unwanted intervoxel correlation from system instabilities.

A later extension introduced the radius of decorrelation (RDC), defined as

$$RDC = \frac{CoV(1)}{CoV(N_{max})},$$

which quantifies the ROI size at which voxel independence is lost[2]. The approach adopted quadratic detrending for its CoV calculation without explicit justification.

In this study, we evaluated how detrending choices influence Weisskoff analysis and derived RDC values.



Example of $N_{max} \times N_{max}$ square ROI centered in the central slice.

Figure 1. Weisskoff analysis and RDC results for hardware combinations using different detrending strategies. Note that ideal scaling appears only with quadratic detrending but can be aligned to other curves by vertically shifting the curve so its starting CoV matches the data's initial CoV. Insets show the uniform phantom used for each scan. Bottom right shows an example ROI for CoV calculation.

METHODS AND MATERIALS

1. Gradient echo EPI time series were acquired using site specific fMRI QC protocols with uniform phantoms on
   - Vendor A 3T diagnostic
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2. Temporal CoV was calculated using centered square N × N ROI from N = 1 to N_{max} equaling 56 mm in the central slice with
   - No detrending
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3. Weisskoff analysis with RDC calculation was performed using these CoVs to quantify the effects of detrending

RESULTS

Detrending choice substantially changes RDC

- No detrending
  - Larges deviation from ideal scaling
  - Smallest RDC
- Linear detrending
  - Reduced deviation from ideal scaling
  - Improved (*i.e.*, larger) RDC
- Quadratic detrending
  - Similar to linear detrending
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- Results support observations that Vendor C scanner 1 seems to have better stability than scanner 2 (scanner 1 has higher RDC)

DISCUSSION

- Increase in RDC is consistent with removal of low-frequency signal components associated with slowly varying hardware instabilities (*i.e.*, gradient heating), which increase the apparent decorrelation distance
- These slowly low-frequency components are typically removed during standard fMRI preprocessing
- Without detrending yields a single, easy-to-track metric that captures all temporal fluctuations, making it useful for longitudinal hardware performance monitoring
  - Conflates hardware drift with other sources of correlated temporal noise
- Including polynomial detrending is consistent with conventional fMRI preprocessing pipelines and improves agreement with ideal Weisskoff scaling
  - May be an outdate proxy for confounds in modern fMRI data processing and should be complemented with separate drift analysis for more complete quality control assessment

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Purpose: Weisskoff analysis assesses temporal stability in functional MRI by comparing how the temporal coefficient of variation (CoV) scales with ROI size relative to ideal uncorrelated noise (e.g. ideal scaling) to assess unwanted intervoxel correlation. Later extension introduced the use of radius of decorrelation (RDC), which measures the size of ROI at which statistical independence of the voxel is lost; however, this approach adopted quadratic detrending in calculating the CoV without explicit justification. Our study evaluated how detrending choices alter Weisskoff analysis, including RDC, and how they influence their use in routine QC.

Methods: Weisskoff analysis with RDC calculation was performed on gradient echo EPI time series acquired on 4 scanners from 3 vendors using uniform phantoms. For each dataset, the temporal CoV were computed without detrending, with linear detrending, and with quadratic detrending, The resulting Weisskoff analysis plots and RDCs were used to quantify the effects of detrending.

Results: Across platforms and coil configurations, Weisskoff analysis without detrending consistently yielded the largest deviation from the ideal scaling and the smallest RDC, followed by linear, then quadratic detrending, with linear and quadratic often similar. This ordering is consistent with removal of low frequency components that reflect slowly varying hardware instabilities, such as gradient heating, thereby increasing the apparent decorrelation radius.

Conclusion: Detrending choice substantially changes RDC and affects the interpretation of temporal stability. Omitting detrending yields a single, easy to track parameter that encompass all temporal fluctuations, which is useful for longitudinal hardware monitoring, but conflates hardware drifts with other correlated noise sources. Polynomial detrending aligns with common fMRI preprocessing pipelines; however, it may be an outdated proxy for confounds relative to modern fMRI data processing and needs to be used with a separate drift analysis for a more complete QC. Our work provides guidance on selecting and interpreting detrending strategies for fMRI QC.

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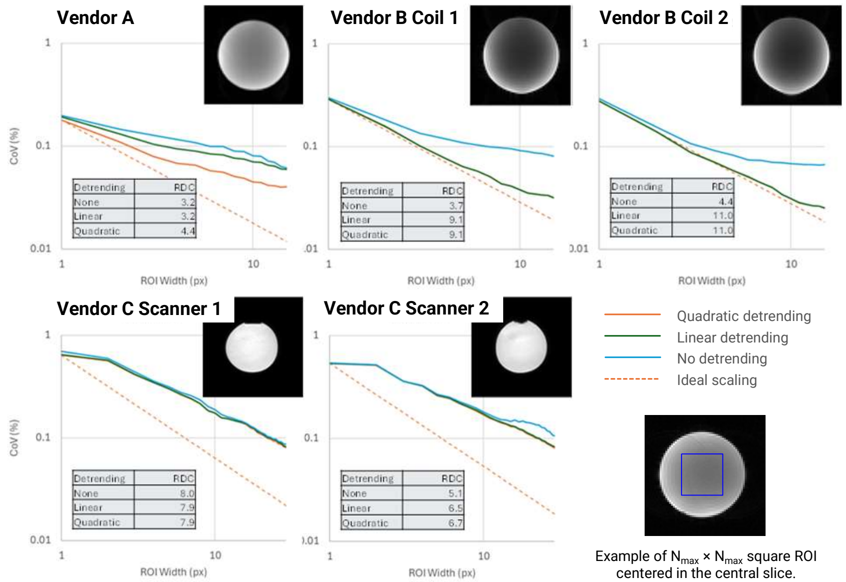

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DISCUSSION

- Increase in RDC is consistent with removal of low-frequency signal components associated with slowly varying hardware instabilities (*i.e.*, gradient heating), which increase the apparent decorrelation distance
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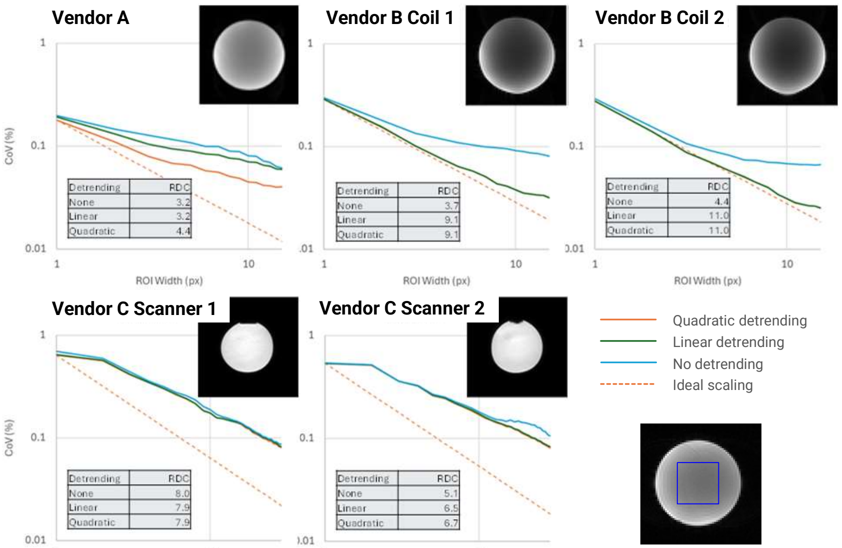

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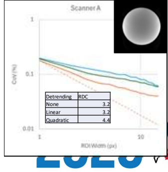

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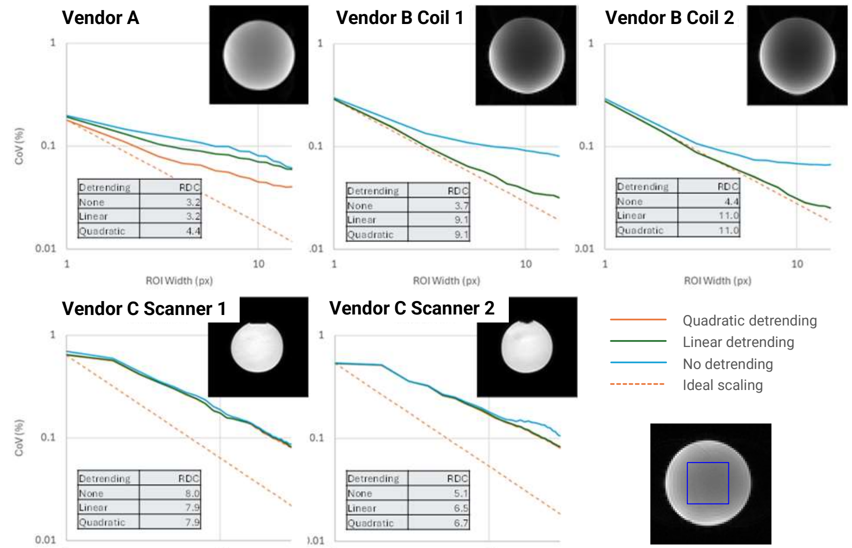

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Discussion

- The results are consistent with the removal of low-frequency signal components associated with slowly varying hardware instabilities (*i.e.*, gradient heating), which increase the apparent decorrelation distance.
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- The results validates the observation that Vendor C scanner 1 seems to have better fMRI performance that Vendor C scanner 2 (scanner 1 has higher RDC)

Conclusion

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