Automated slice-specific z-shimming for fMRI of the human spinal cord

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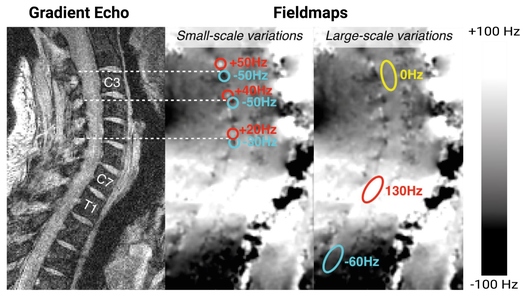
Introduction

- Spinal cord fMRI is challenging due to the cord's small diameter and the strong influence of physiological noise of cardiac and respiratory sources.
- Another significant problem for spinal fMRI arises from prominent signal drop-outs that are caused by magnetic field inhomogeneities.

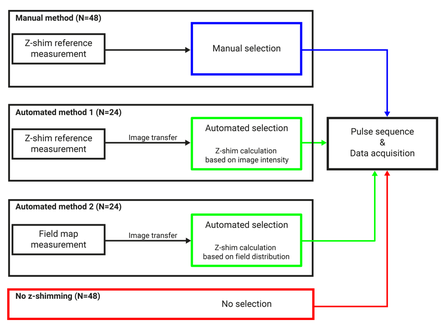


Adapted from Cohen-Adad, 2017

- We previously utilized slice-specific z-shimming to mitigate these susceptibility-induced signal drop-outs (Finsterbusch et al., 2012).
- While successful, this approach has the practical drawbacks that it i) is time-consuming, ii) requires special experience, and iii) relies on subjective assessment.
- In this project, we aimed to overcome these drawbacks by developing two automated slice-specific z-shim approaches.

Methods

- 48 participants were measured on a 3T MRI system (Siemens Prisma) equipped with a 64-channel head-and-neck coil and a spine array.
- For each participant, we obtained data with three different gradient-echo EPI acquisitions:
  1. with z-shim gradient compensation based on manual selection (as in Finsterbusch et al., 2012)
  2. with z-shim gradient compensation based on automated selection
  3. without z-shim gradient compensation

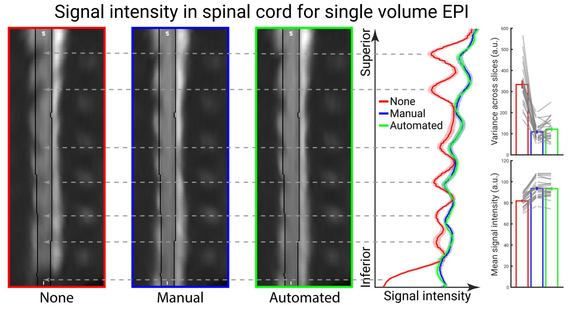


Results

1

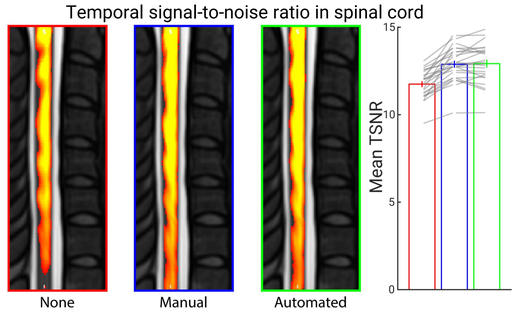
Automated method 1: z-shim reference based selection

Signal intensity in spinal cord for single volume EPI



None Manual Automated

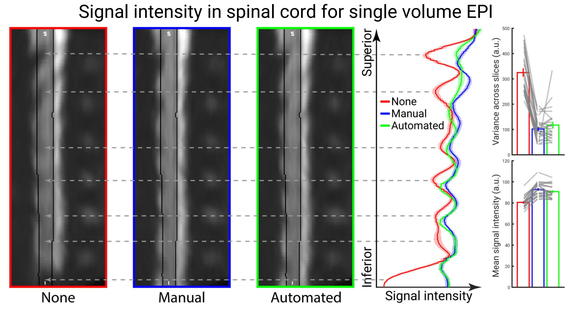
Temporal signal-to-noise ratio in spinal cord



	% signal increase	% reduction in variability	% tSNR increase
Automated vs None	14	64	10
Manual vs None	14	67	10

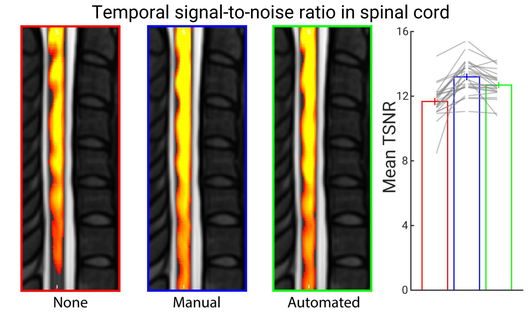
Automated method 2: field map based selection

Signal intensity in spinal cord for single volume EPI



None Manual Automated

Temporal signal-to-noise ratio in spinal cord

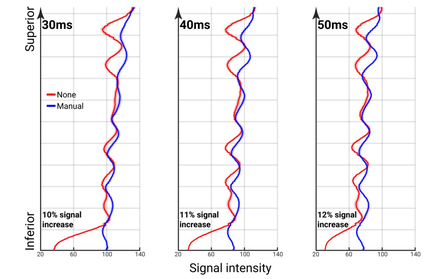


	% signal increase	% reduction in variability	% tSNR increase
Automated vs None	13	64	9
Manual vs None	15	69	13

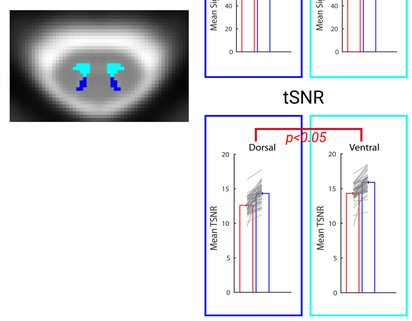
2

Effect of z-shimming over different echo times

Single volume EPI



Effect of z-shimming in gray matter



Discussion

- We successfully developed two approaches for automatically determining slice-specific z-shims. The approach based on the z-shim reference scan achieved a nearly identical performance compared to the standard approach based on manual selection (Finsterbusch et al., 2012).
- This automated z-shim approach could benefit spinal cord fMRI in two ways: i) saving time by eliminating the need to manually select the optimal z-shim value for each slice, and ii) increasing the reproducibility of spinal cord fMRI by eliminating the subjective component of the selection, thus holding promise for longitudinal studies.
- The field map based selection approach was successful in recovering signal, but performed slightly worse than the manual approach. We are currently investigating the reason for this discrepancy, as this approach could be beneficial for also obtaining slice-specific x- and y-shims without the need to acquire separate reference scans.
- We also demonstrated that the beneficial effect of z-shimming is clearly present across different echo times and that it is more pronounced in the dorsal than the ventral horn, thus highlighting the importance of z-shimming for fMRI studies focussed on pain processing in the spinal cord.
- In the future, it will be interesting to assess the direct benefits of slice-specific z-shimming for task-based and resting-state spinal fMRI and we are currently investigating the latter point with this data-set.

References

Cohen-Adad, J. (2017). Functional Magnetic Resonance Imaging of the Spinal Cord: Current Status and Future Developments. *Seminars in Ultrasound, CT and MRI*, 38(2), 176–186.
Finsterbusch, J., Eippert, F., & Büchel, C. (2012). Single, slice-specific z-shim gradient pulses improve T2*-weighted imaging of the spinal cord. *NeuroImage*, 59(3), 2307–2315.