Reliability of task-based fMRI in the dorsal horn of the human spinal cord

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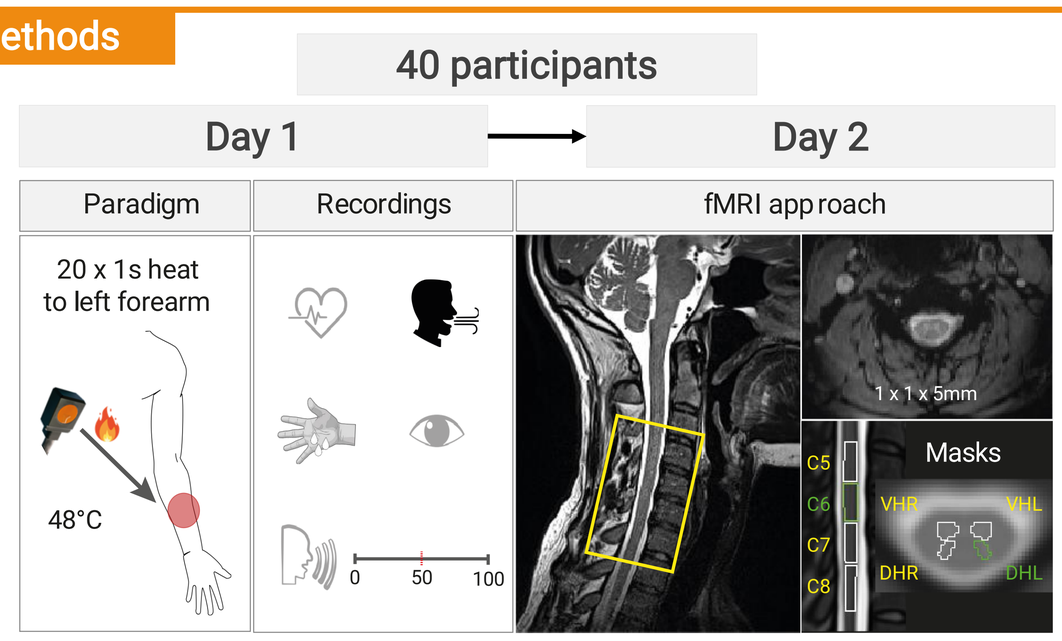
Summary

- Phasic heat stimuli on the forearm evoked BOLD responses in the ipsilateral dorsal horn of spinal segment C6 on both experimental days (though without spatial overlap)
- Test-retest reliability of BOLD responses was poor in the target region, but good in a region including the draining veins

Motivation

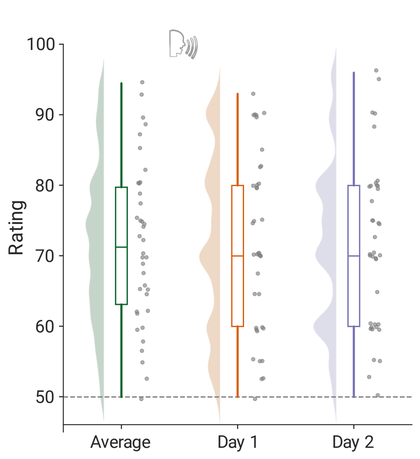
- The spinal cord is the initial processing site within the CNS pain pathway and a core target of descending modulation [1]
- Spinal fMRI is still a relatively young field, facing many challenges such as the small diameter of the cord and the impact of physiological noise [2,3]
- We aimed to probe the limitations of task-based spinal fMRI by investigating the reliability of spinal cord BOLD responses to identical painful stimulation across two consecutive days

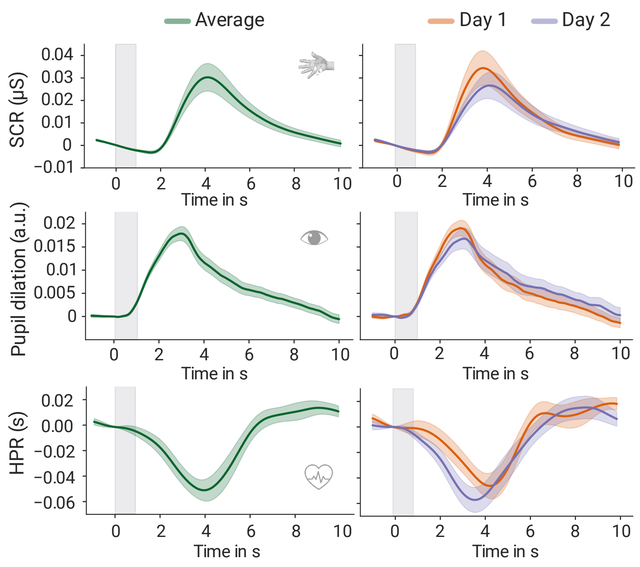
Methods



1 Heat-pain responses across days

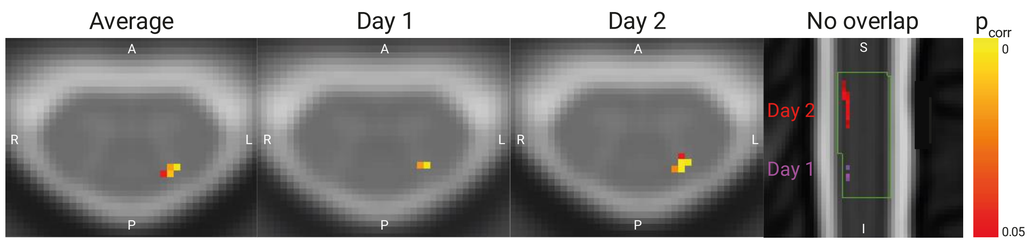
Verbal ratings & physiological responses





Verbal & physiological responses remained similar across days.

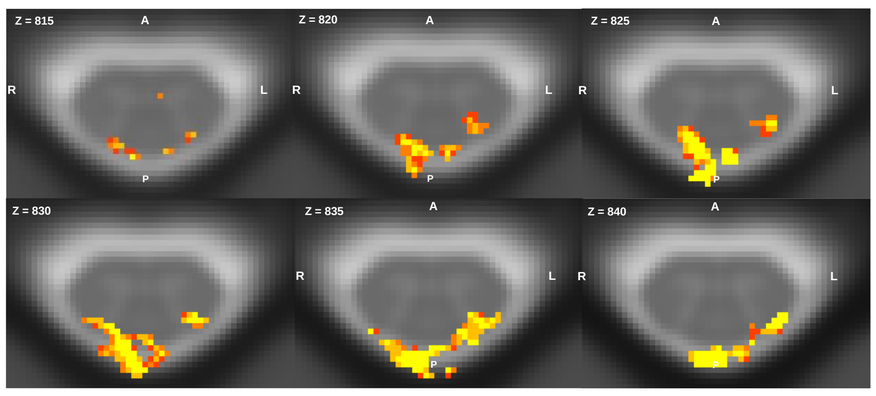
BOLD responses



BOLD responses occurred on both days in the left dorsal horn of segment C6, though without spatial overlap ($p_{corrected} < 0.05$).

2 Spatial specificity of the spinal cord BOLD response

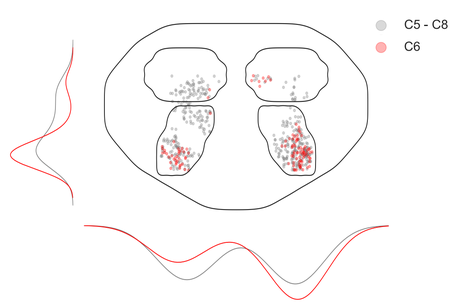
Spatial extent of the BOLD response



Average over both sessions, uncorrected p < 0.001

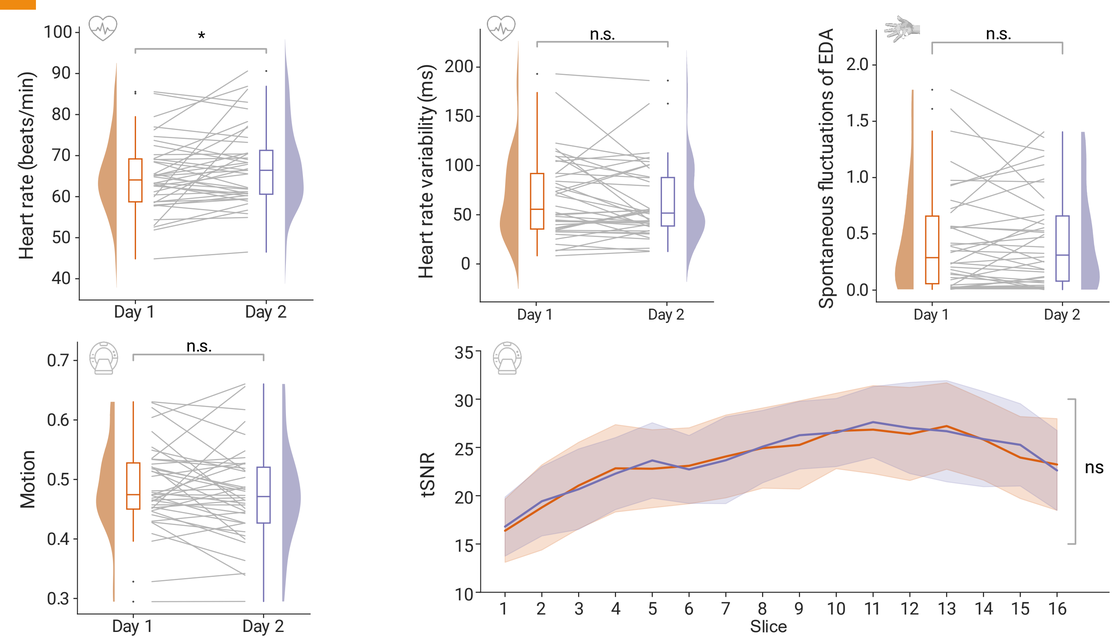
Distribution of active voxels across the gray matter horns

C5	Of 183 active voxels in total:	
	Left: 77.05 %	Dorsal: 88.52 %
C6	Of 116 active voxels in total:	
	Left: 67.24%	Dorsal: 91.40%
C7	Of 131 active voxels in total:	
	Left: 0.76%	Dorsal: 41.98%
C8	Of 3 active voxels in total:	
	Left: 33.33%	Dorsal: 100%



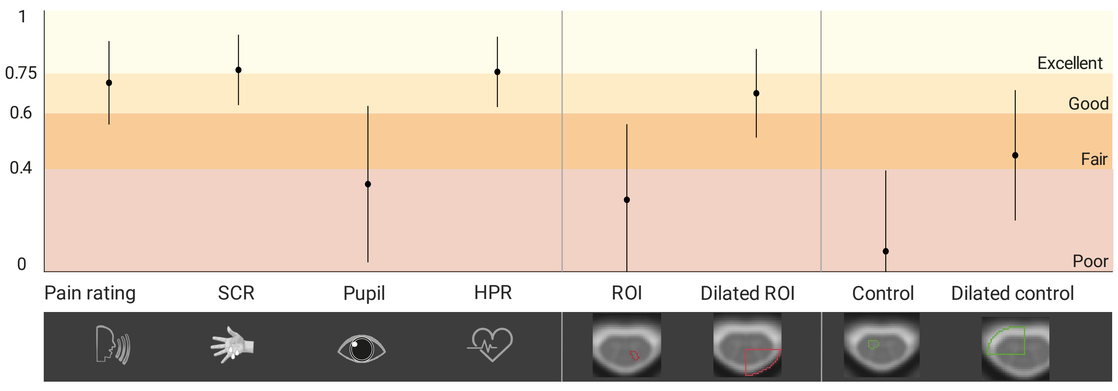
While overall spatial specificity is likely impacted by draining vein signal, pain-induced BOLD responses showed adequate spatial specificity in the gray matter target segment.

3 Physiological state and data quality across days



While heart-rate showed a slight increase from Day 1 to Day 2, none of the other measures indicated significant changes across days.

4 Test-retest reliability



BOLD responses: Average of top 10% of ß scores

Reliability [4] was good to excellent for most non-BOLD measures, while BOLD response reliability was poor in the target region (DH left, C6), but good in an extended area.

Conclusion

- Heat pain stimuli as short as 1s evoked a robust BOLD response in the ipsilateral dorsal horn in spinal cord segment C6
- The reliability of the peak BOLD response was poor in the target area, but in the good range in a region including the draining veins
- Further analysis showed that reliability did not improve when taking into account more trials or when accounting for spontaneous fluctuations of BOLD activity
- Future studies could assess to what extent spinal cord BOLD reliability is tied to stimulus features or data processing approaches [5]

References

1) Fields, H. (2004). State-dependent opioid control of pain. *Nature Reviews Neuroscience, 5*(7), 565–575.
2) 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), 176–18
3) Summers, P. E., Brooks, J. C. W., & Cohen-Adad, J. (2014). Spinal cord fMRI. In J. Cohen-Adad & C. Wheeler-Kingshott (Ed.) *Quantitative MRI of the spinal cord*. (pp. 221–239). Elsevier.
4) Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. Psychological Bulletin, 86(2), 420.
5) De Leener, B., Lévy, S., Dupont, S. M., Fonov, V. S., Stikov, N., Louis Collins, D., Callot, V., & Cohen-Adad, J. (2017). SCT: Spinal Cord Toolbox, an open-source software for processing spinal cord MRI data. *NeuroImage, 145*, 24–43.