Time-resolved EEG decoding of neural text representations during naturalistic braille reading

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Introduction

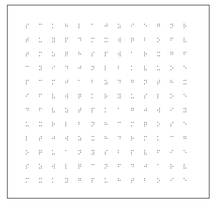
- Braille reading entails active arm/hand movements, posing a challenge to neurocognitive studies of braille text processing.
- Behavioral studies have used finger-tracking to study active reading [1,2], but neural studies often use passive reading paradigms [3,4].
- Here we capture neural text representations during active braille reading, integrating finger-tracking and EEG methods to analyze brain responses to participant-driven stimulus onsets.

Research Questions

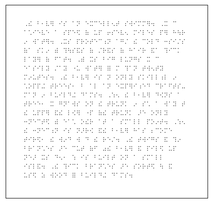
1. Can we capture time-resolved, neural text representations from active braille-reading?
2. How do such representations vary for sensory vs linguistic information?
3. How do haptic text representations differ for blind vs sighted individuals?

General Methods

Stimuli

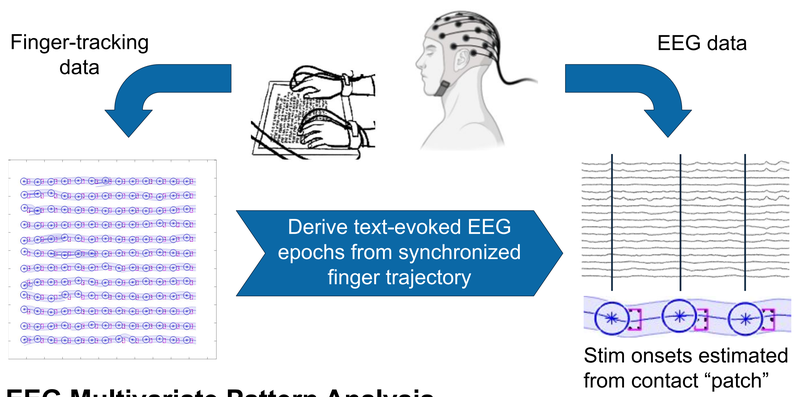


Expt 1:
Randomized grids of 156 single letters
(10 grids, read twice)

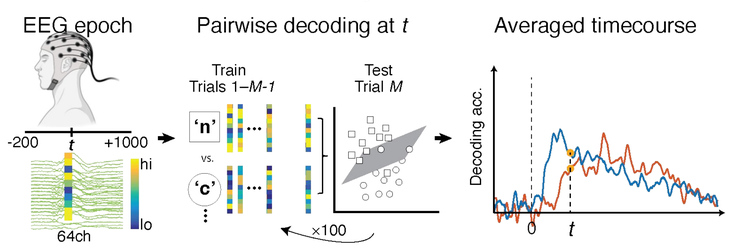


Expt 2:
Standardized IReST texts in Grade 2 braille
(10 texts, read twice)

Experimental Setup & Data Acquisition



EEG Multivariate Pattern Analysis



Experiment 1: Individual letters

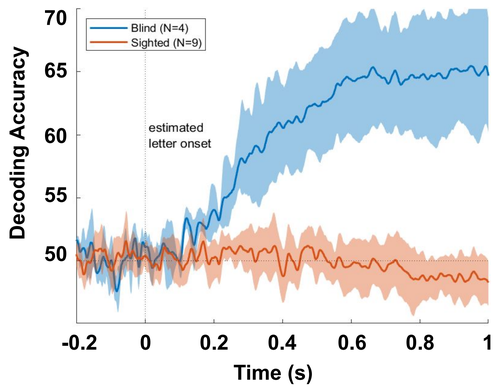
Task:
Read all letters, report vowels aloud (vigilance targets)

Participants:
- 4 braille readers (3 male; 37.8y ± 15)
- 9 sighted controls (5 male; 26.1y ± 8.3)

Results

Pairwise letter decoding

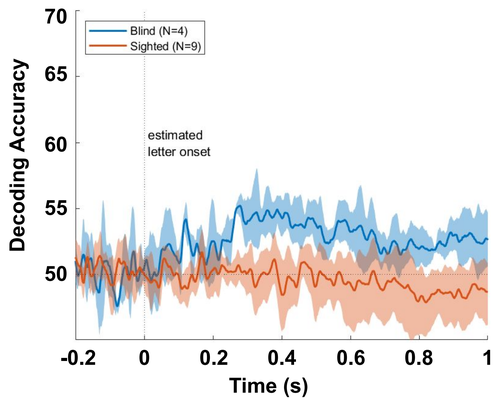
All letters



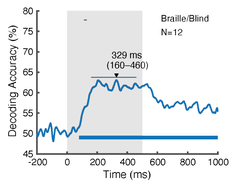
Strong decoding when including vowel-consonant pairs reflects task-relevant neural and motor signals in braille readers.

Sighted controls showed chance-level decoding across all pairs.

Consonants (non-targets) only



Above-chance consonant decoding reveals non-target letter representations in braille readers, supporting previous work using static letter presentation [3].



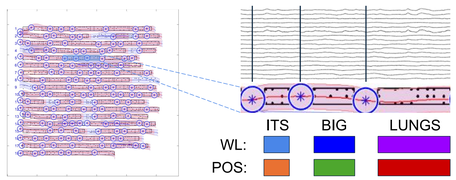
Gray region: stimulus presentation

Shaded bands: bootstrapped 95% CIs

Experiment 2: Text passages

Task:
Read texts once aloud, once silently

Participants:
- 3 braille readers (2 male; 45y ± 9.4)
- 9 sighted controls (5 male; 26.1y ± 8.3)



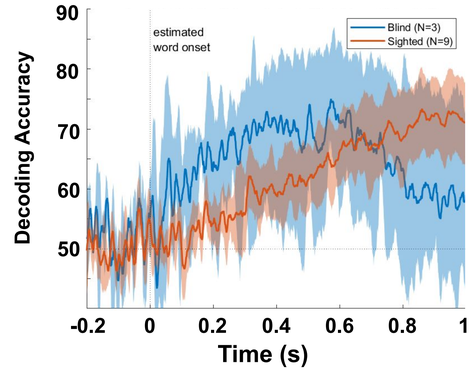
WORD DECODING LABELS

Word lengths (3)	Parts of Speech (8)
S (1-2 chars)	Pronoun
M (3-4 chars)	Adjective
L (5-9 chars)	Noun
⋮	

Results

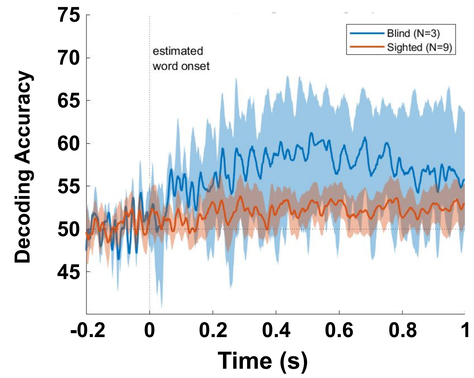
Pairwise word decoding

Word lengths



Above-chance word length decoding in both blind AND sighted, revealing low-level, sensory representations unassociated with braille literacy.

Parts of speech



Above-chance part-of-speech decoding found in blind, but NOT sighted, indicating higher-level, linguistic representations only in braille readers.

Summary/Conclusions

- In braille readers, strong letter decoding when including target/non-target (vowel/consonant) comparisons reveals task-relevant neural and motor activity.
- Above-chance consonant decoding for blind, but not sighted; comparable to results from previous decoding studies in static presentation paradigms.
- We found above-chance decoding of both linguistic (parts of speech) and sensory (word length) information in blind readers, but only the latter in sighted.
- Results establish the promise of our approach to capture multiplexed, dissociable sensory and linguistic neural representations during naturalistic, continuous braille processing.

References

1. Wilson, C., Mc Clinton, Z., Silvano, E., Alfonso, C., Jaicaman, L. P., Yun, H., & Bedny, M. (2024). *Contextual, lexical, and sublexical effects on braille reading.*
2. Teng, S., & Mackeben, M. (2023). Reading styles modulate perceptual roles of the hands in bimanual braille reading. *Journal of Vision*, *23*(9), 6003-6003.
3. Teng, S., Cichy, R., Pantazis, D., & Oliva, A. (2024). Touch to text: Spatiotemporal evolution of braille letter representations in blind readers. *bioRxiv*.
4. Haupt, M., Graumann, M., Teng, S., Kaltenbach, C., & Cichy, R. (2024). The transformation of sensory to perceptual braille letter representations in the visually deprived brain. *Elife*, 13, RP98148.

Acknowledgments

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