The neural dynamics of letter perception in blind and sighted readers

Santani Teng[1], Radoslaw Cichy[1], Dimitrios Pantazis[2], & Aude Oliva[1]

[1]Computer Science & Artificial Intelligence Laboratory, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology

Introduction

- Visual cortical regions are known to play a role in tactile Braille reading in blind persons[4]. However, do they represent stimuli in the same fashion?
- More generally, are multimodal stimuli such as letters represented in a modality-independent way? If so, what are the dynamics of the transformation from modality-specific to modality-independent stimulus information?
- Here we investigated whether visual letter reading by sighted people elicits neural representations similar to those elicited by tactile Braille reading in blind persons.
- A comparison between typically sighted and congenitally or early-blind participants avoids confounds of visual imagery or prior experience.

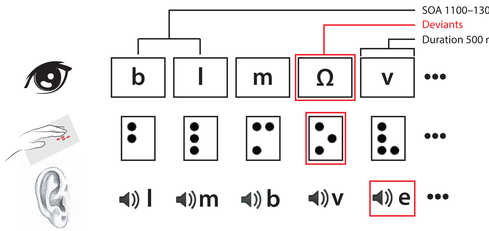
Methods

Stimuli & Task

Sighted and blind participants were presented with single letters during MEG scanning. Visual stimuli were lower-case Roman letters; tactile stimuli were lower-case Braille letters; auditory stimuli were spoken letters.

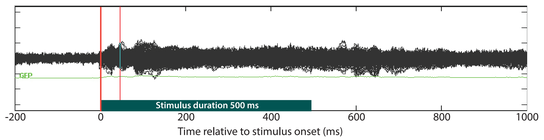
Sighted participants were run in the visual and auditory conditions. Blind people were run in the tactile (braille) and auditory conditions.

Task: Subjects read or listened passively to the letters and responded with a button press to occasional deviant targets.



Extracting MEG trial epochs

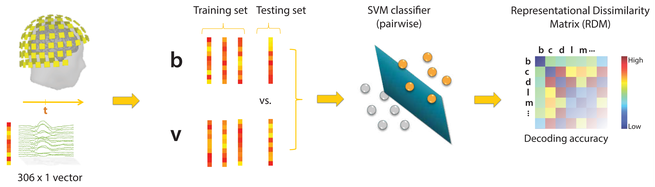
- We extracted trial epochs for each letter condition (-200 to +1000 ms relative to stimulus onset). Button-press target trials were excluded from further analysis.
- Thus, in each experiment, **10 conditions of ~100 trials each** were extracted.



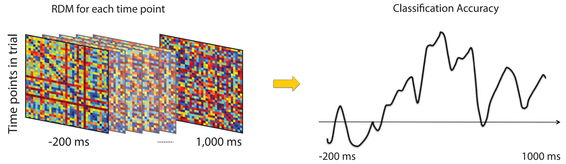
Decoding Analysis and Results

Multivariate analysis: Decoding letter identity from MEG epochs

- First, at each time point in the trial epoch, we produce a **Representational Dissimilarity Matrix (RDM)**[1,4], a decoding matrix of all pairwise comparisons. Highly decodable pairs of stimulus conditions are more dissimilar.

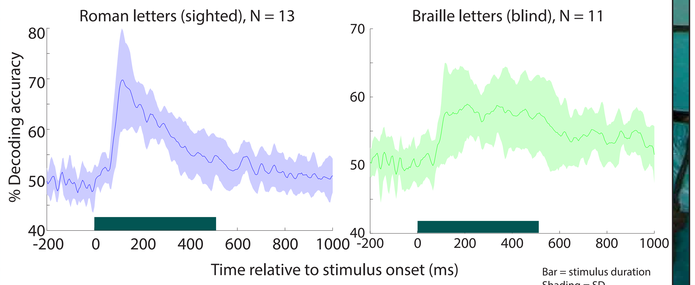


- Second, the RDM accuracies are averaged to produce a single decoding accuracy value for each time point. This yields a **temporal decoding curve** when repeated for all time points.



Results: Decoding letter identity from MEG

- **Single letters were discriminated by both tactile and visual representations**, with different temporal signatures: Visual letter decoding showed a more rapid onset, higher peak decodability, and more rapid falloff. Braille temporal decoding curves tended toward a slower, more sustained profile.

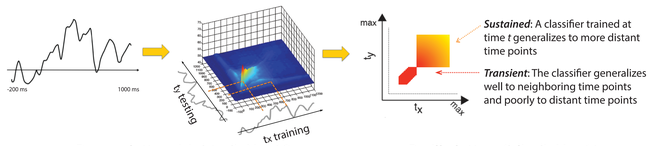


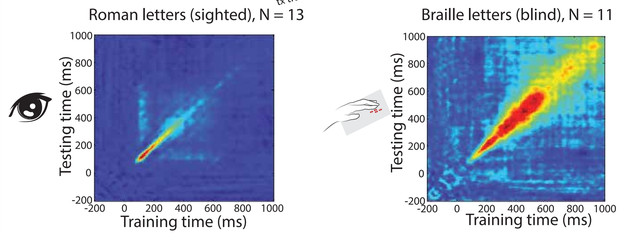
- The temporal decoding time courses indicate that stimulus information can be read out from temporal patterns of neural activity. However, are they representing the same kind of information structure across time? We address this question more directly using representational similarity analysis in the next section.

Comparing Across Time & Subjects

Temporal generalization: Transient or sustained representations?

- Training a classifier at each time point and testing it at all other time points yields a temporal generalization or **"time-time" decoding matrix**[1,2].

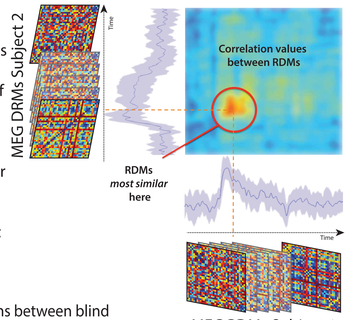




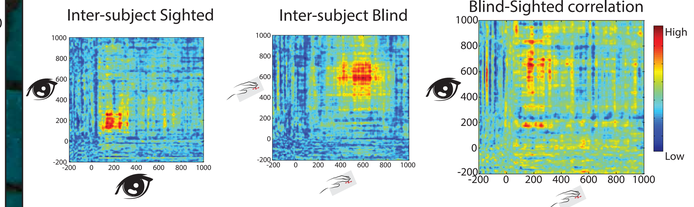
- Dissociable transient and mild sustained representations for visual letters (as with other visual objects)[2], and slower, more sustained dynamics in Braille representations.

Comparing representational content across populations

- **When are the representations of different individuals/groups similar?** Cross-correlating RDMs across time points can show consistency of within-group representations as well as the similarity of representations across groups.
- We found high inter-subject (within-group) correlations at ~200 ms for sighted subjects and ~600 ms for blind subjects, suggesting that **visual and tactile representations of letters arise at different time scales**.

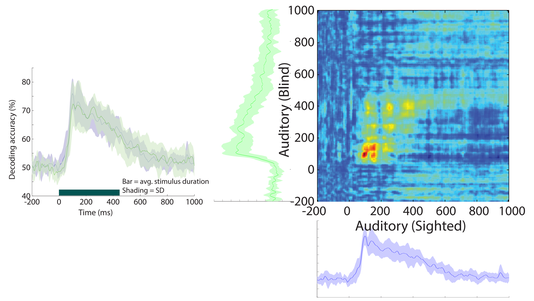


- Importantly, we found that RDMs correlations between blind and sighted subjects peak ~ 200 ms for sighted and ~600 ms for blind individuals, suggesting that a **similar, amodal representation may exist across people who have only learned to read visually, or via Braille**.



Auditory control: Spoken letters

- Can disparate and common dynamic processes between Braille (blind) and visual (sighted) letter representations be attributed to group or modality differences? I.e., do the two groups represent identical stimuli similarly?



- Blind and sighted groups (both N = 7) had nearly identical temporal decoding responses to auditory (spoken) letter stimuli.
- RDM correlation revealed strongly similar responses between ~50-150 ms post onset, with a tendency for sustained response in the blind group.

Conclusions

- Within- and between-group RDM correlations revealed disparate and common dynamic processes between blind Braille and sighted visual letter readers. This suggests some components of letter processing common across modalities.
- The neural time course of letter recognition varies with modality: visual letter recognition occurs with a faster onset, higher peak, and faster offset compared to Braille reading in early-blind participants. Thus, similar components of processing may occur at different times contingent on the modality of presentation.
- Sighted subjects' neural responses were most similar to each other (correlated most strongly) at ~200 ms, compared to ~600 ms for blind subjects. Blind and sighted subjects' responses were most similar to one another at ~200 ms for blind and ~600 ms for sighted subjects. These results suggest dissociable commonalities within and between groups.
- A similar experiment presenting auditory spoken letters to both groups showed strong similarity of responses between groups. Thus, differences in representational structures are unlikely to be inherent group differences.

References

1. Cichy, R.M., Pantazis, D., & Oliva, A. (2014). Resolving human object recognition in space and time, Nature Neuroscience, 17, 455-462.
2. King, J-R., & Dehaene, S. (2014). Characterizing the dynamics of mental representations: the temporal generalization method. Trends in Cognitive Science, 18, 203-210.
3. Kriegeskorte, N. (2008). Representational similarity analysis: Connecting the branches of systems neuroscience. Frontiers in Systems Neuroscience, 2, 4.
4. Pascual-Leone, A., Amedi, A., Fregni, F., and Merabet, L.B. (2005). The plastic human brain cortex. Annual review of neuroscience 28, 377-401.