Texture Perception and Cortical Representation Under Cognitive and Sensory Impairment

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Overview

- Oral health issues have been associated with age-related dementias such as Alzheimer's disease (AD), a neurodegenerative disease affecting tens of millions of individuals worldwide [1]. Clinically, AD is characterized by behavioral and cognitive decline.
- One hallmark of aging in the brain is altered connectivity between regions, often reflected by increased inter-regional coherence.
- Changes in brain connectivity with aging and AD are also linked to motor impairments such as dysphagia (difficulty swallowing), which is prevalent in moderate to severe AD [2].
- Memory loss and loss of oral sensation are associated with AD, but the relationship between AD and age-related oral health issues remains unclear. The changes in brain and muscle control of oral movements in healthy aging and pathological (abnormal) aging haven't been fully explored.
- We aim to investigate how cortical representation of texture in brain regions changes under memory impairment alone and in combination with reduced sensory input

Methods

- **Subjects:** Data were collected from one healthy adult non-human primate (N = 1, age 21 years).
- **Behavioral Task:** The subject performed a texture discrimination task by licking a textured plate while receiving flavored juice as a reward.
- **Trial Structure:** Each trial lasted 4.5 seconds, during which the subject licked one of four texture plates varying in coarseness. There were 20 trials for each texture plate.
- **Experiments:**
  1. **Effect of Scopolamine:** Administration of scopolamine, an M1 muscarinic receptor antagonist, used to model the cognitive impairments (memory loss) observed in Alzheimer's disease.
  2. **Effect of scopolamine + nerve block:** A combination of scopolamine and a local nerve block was used to reduce peripheral tactile sensation on the tongue, simulating both memory impairment and sensory loss. This is crucial in understanding the effect of loss of sensation in the tongue.
- **Data Structure:**
  - **Independent Variables**
    - Brain regions: PF (Prefrontal Cortex), S1 (Primary Somatosensory Cortex), M1 (Primary Motor Cortex)
    - Texture Coarseness (Fine and Coarse): 1 (Fine), 4 (Coarse)
    - Condition: Control, Scopolamine, Scopolamine + Nerve Block
  - **Dependent Variables**
    - Corticocortical coherence (Computed using Chronux Toolbox [3])
    - Spike rate (Trial duration: 5 s, 5000 bins (Bin width: 1 ms))

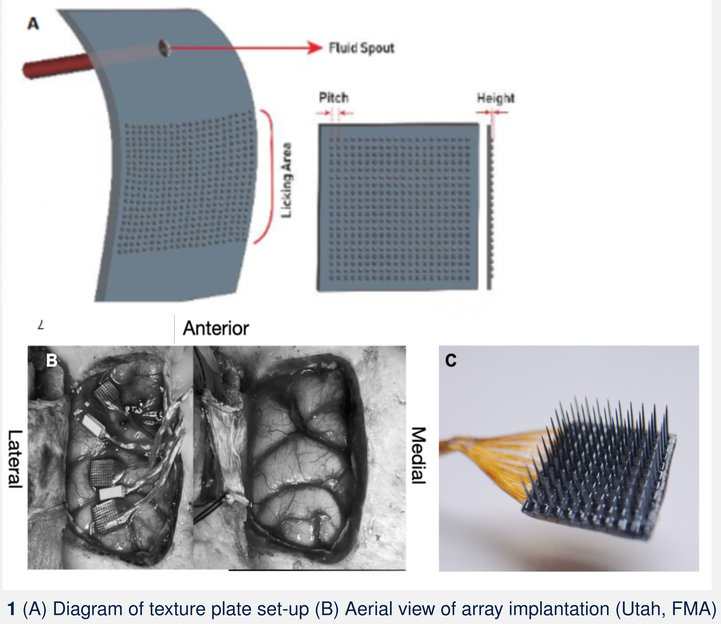

Fig. 1 (A) Diagram of texture plate set-up (B) Aerial view of array implantation (Utah, FMA) (C) Utah Array

Results

Effect of Texture Coarseness on Cortical Spike Rate

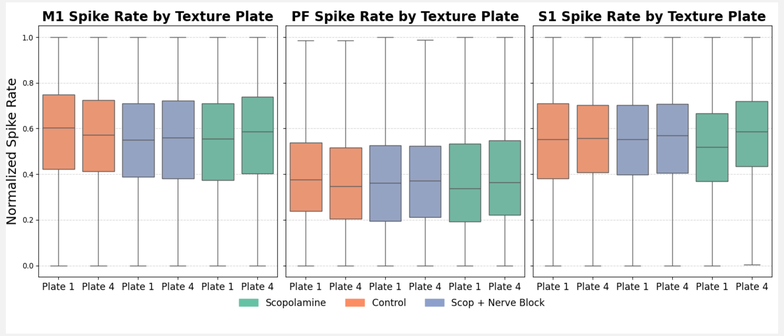

Fig 2. Box plots comparing the spike rates for fine (Plate 1) vs. coarse (Plate 4) textures. All texture pairs showed statistically significant differences (Mann-Whitney, ***, $p < 0.001$).

Which Band Exhibits the Highest Overall Coherence?

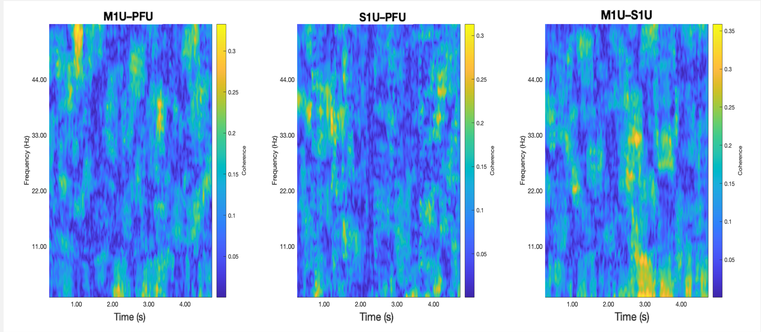

Fig 3. Coherograms of neuron pairings from brain regions during control condition. Coherence was highest in theta band, followed by gamma band.

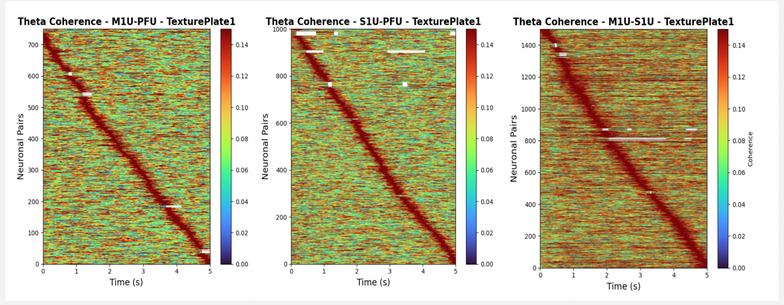

Fig 4. Theta-band coherograms across brain region pairs during the control condition (Texture Plate 1). Coherence is highest along the diagonal, indicating widespread temporal synchronization among neuron pairs

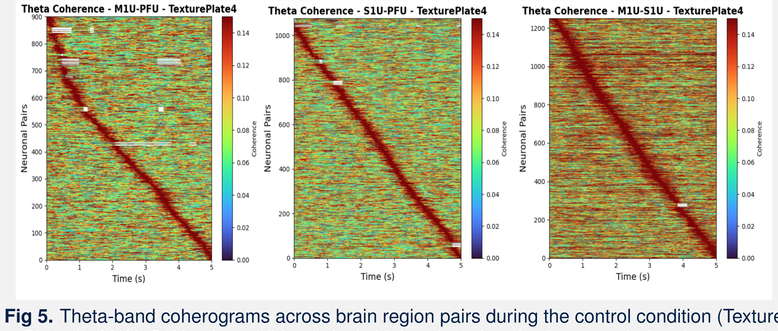

Fig 5. Theta-band coherograms across brain region pairs during the control condition (Texture Plate 4). M1U–S1U pairs exhibit relatively higher theta-band coherence during the control condition, as indicated by the more saturated red bands. This suggests stronger temporal synchronization between motor and somatosensory regions during texture interaction. Further analysis is needed to determine if this pattern persists across other experimental conditions

Results

Effect of Memory and Sensory Impairment on Coherence

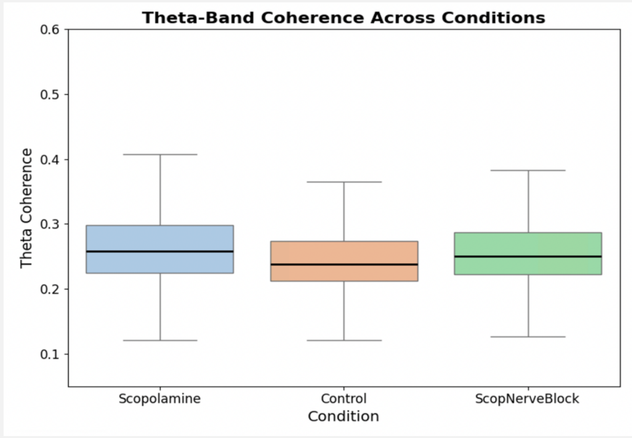

Fig 6. Theta-band coherence across experimental conditions (Control, Scopolamine, Scopolamine + Nerve Block). Median coherence was highest under Scopolamine and Scopolamine + Nerve Block conditions compared to Control. All group differences were statistically significant (Kruskal-Wallis, ***, $p < 0.001$, post-hoc paired comp., $p < 0.05$)

How do Condition and Texture Plate Affect Coherence?

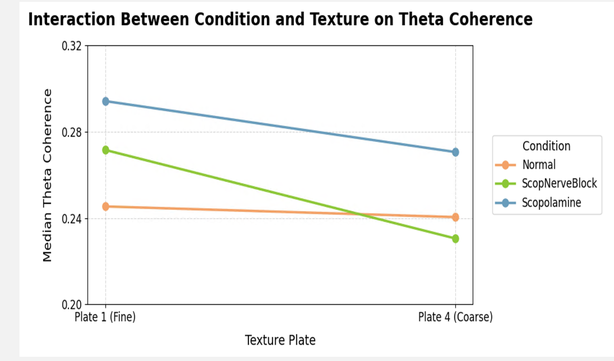

Fig 7. Scheirer–Ray–Hare test revealed significant main effects of experimental condition ($p < 0.001$) and texture plate coarseness ($p < 0.001$) on theta-band coherence, along with a significant interaction between condition and texture plate ($p < 0.001$).

Conclusions

- All three brain regions show a statistically significant difference in normalized spike rates between Texture Plates 1 and 4.
- Theta-band activity showed the strongest coherence between brain regions compared to all other frequency bands.
- Scopolamine, alone or combined with sensory loss (nerve block), led to elevated theta-band coherence, indicating that memory impairment and sensory deficits may enhance coherence.
- Condition and texture plate coarseness have significant effects on coherence. There is also a significant interaction effect between condition and texture plate coarseness. In other words, the effect of condition on coherence is not the same across all texture plates.

References

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Acknowledgments

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