Dissociated neural representation of content and structure in auditory sequence memory

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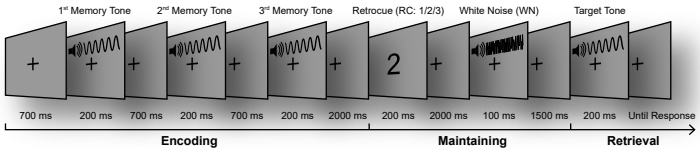
Introduction

Memory is formed by organizing multiple events according to certain relationship. Thus, memorizing a temporally structured experience (e.g., a piece of melody) necessitates storage of two types of code – content (e.g., frequency for each tone) and structure (e.g., the ordinal position for each tone) – in brain activities. How these two codes of an auditory sequence work during a working memory (WM) process are investigated in the current research.

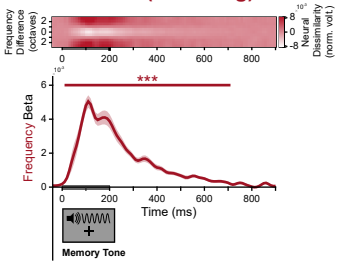
Methods



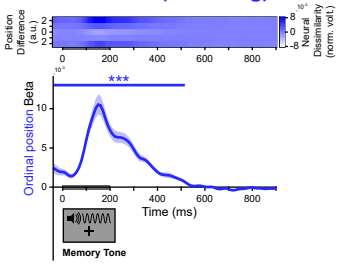
Participants were instructed to memorize both frequency and ordinal position of three pure tones with different frequencies. A retrocue (RC) indicated which tone's frequency would be tested at the end of the current trial (100% valid). In the subsequent delay, a white noise (WN) was presented. At the end of the trial, target tone was presented, and participants were instructed to report the target tone's frequency was higher or lower than the cued tone's frequency.

Results — Encoding

Content code (encoding)

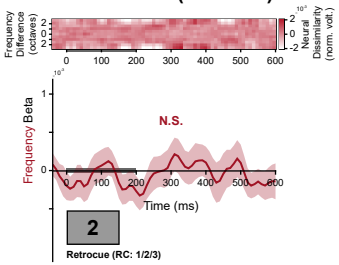


Structure code (encoding)

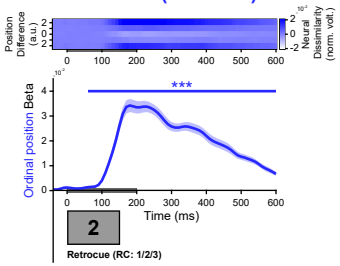


Results — Maintaining (after RC)

No content code (after RC)

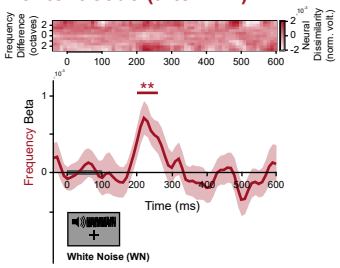


Structure code (after RC)

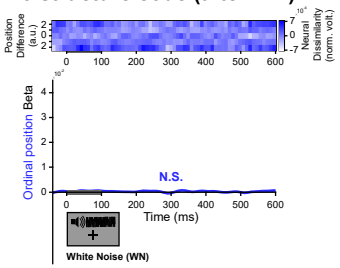


Results — Maintaining (after WN)

Content code (after WN)



No structure code (after WN)



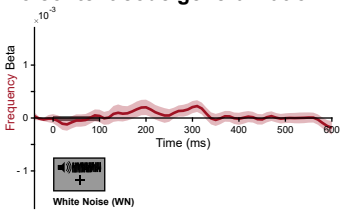
Summary 1

- Factorized content and structure codes during encoding period.
- A positional retrocue during maintaining period activates structure information but not content.
- An auditory white noise during maintaining period triggers content response but not structure.

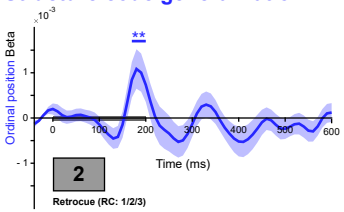
Results — Generalization

Cross-temporal generalization (representation similarity analysis)

No content code generalization

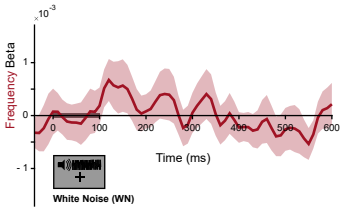


Structure code generalization

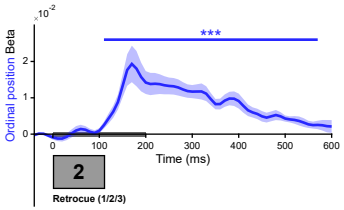


Cross-temporal generalization (logistic regression models)

No content code generalization



Structure code generalization

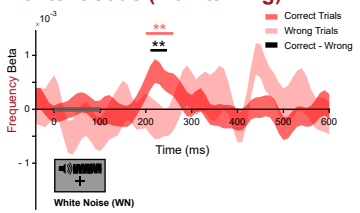


Summary 2

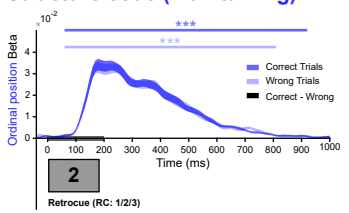
- Structure representation remains unchanged.
- Content code undergoes a transformation throughout memory progress

Results — Correct VS. wrong trials

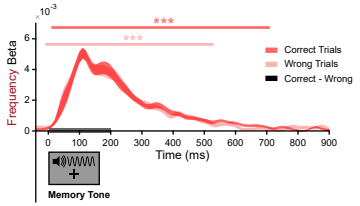
Content code (maintaining)



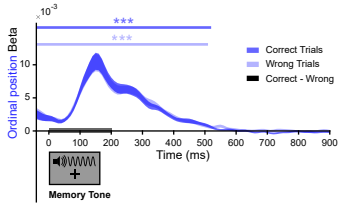
Structure code (maintaining)



Content code (encoding)



Structure code (encoding)



Summary 3

- Content instead of structure information maintained in WM is largely correlated with recalling memory performance, and this is not due to initial sensory encoding

Discussion

- In an auditory delayed-match-to-sample task, we found dissociated neural codes, showing largely distinct characteristics, for structure (i.e., ordinal position of a tone in a list) and content (i.e., frequency of a tone) information.
- The structure codes representing somewhat high-level and abstract information of the stimuli are kept constant throughout the working memory process[1].
- In contrast, the content codes for specific sensory properties are transformed from encoding to maintaining period[2,3].
- The structure and content codes are represented in a factorized way[4], which could benefit for applying structure knowledge on new inputs to form new memory effectively and efficiently[5].

Reference

1. Luyckx, F., Nili, H., Spitzer, B., & Summerfield, C. (2019). Elife.
2. Wolff, M. J., Kandemir, G., Stokes, M. G., & Akyürek, E. G. (2020). Journal of Neuroscience.
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