Levels of Inner Speech
An investigation of oscillatory dynamics

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INTRODUCTION

- Internal verbalization shows a large phenomenological variability [1].
- The variability in lexical, phonological, and motoric detail can be explained through self-monitoring loops at certain stages in speech production processes [2, 3].
- Investigations of inner speech use widely different paradigms and stimulus materials [4].
- **Neurophysiological evidence of different inner speech levels in comparable experimental settings is missing.**
- Working memory provides a good setting for comparing different forms of internal verbalization and visuospatial cognition based on identical stimulus material.
- Phonological level as the target of the first of three planned EEG studies.

➢ **Expected markers of phonological encoding:** decreased alpha and beta power [5].

➢ **Expected markers of phonological maintenance:** increased alpha and theta power [6].

MATERIALS & TASK

- Within-subject design
- 3 conditions, 40 trials per condition

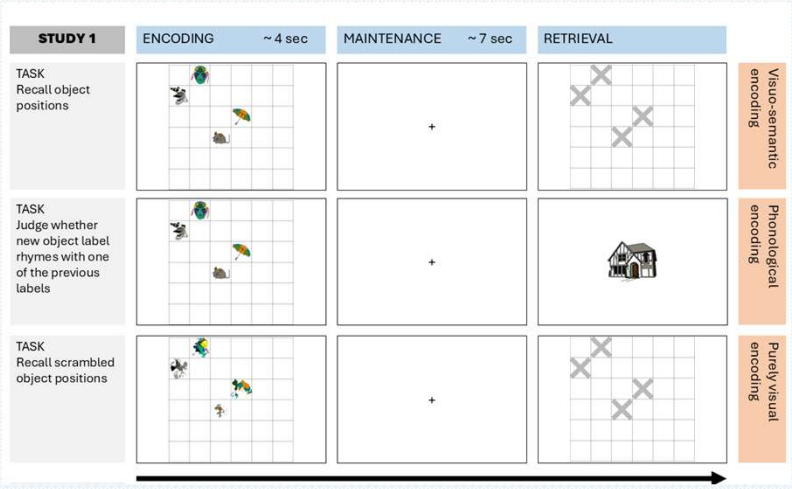


Figure 1: Overview of the conditions, tasks, and trial flow

RECORDING + ANALYSIS

➢ **Participants:**
- Healthy German-speaking adults (**n = 35**; 12 ♂)
- Mean age: 22.7 (SD = 3.7) years

➢ **EEG-Recording:**
- 64-channel active electrode system (g.SCARABEO electrodes, g.GAMMACAP extended 10-20 layout)
- g.tec g.HIAMP amplifier system (sampling frequency 512 Hz)

➢ **EEG-Preprocessing:**
- semi-automatic artefact rejection
- high-pass filtered at 0.3 Hz, low-pass filtered at 100 Hz
- removal of microsaccades using *costrap* algorithm [7]
- automatic ICA-based removal of eye and muscle artefacts (*SASICA*) [9]
- re-referencing to averaged mastoids
- bad channel interpolations
- cut epochs ([-3 s, 11 s])
- notch filter to reduce line noise at 50 Hz

➢ **Time-Frequency-Analysis:**
- Wavelet analysis (wavelet width = 12, 80 logarithmically spaced frequency bins between 5 Hz – 80 Hz)
- Baseline: [-1, -0.1] (inter-trial intervals)
- Selection of frequency bands based on condition-independent visual inspection and hypotheses

➢ **Statistics:**
- Cluster-based permutation tests ($p < 0.05$) for
  i) PHON vs. VOBJ and VOBJ vs. VSCR
  ii) For encoding and maintenance time windows
  iii) In frequency bands pre-defined by hypotheses and condition-independent visual inspection.

RESULTS

PHON - VOBJ

Figure 2: Time-frequency data for phonological condition (Pz)

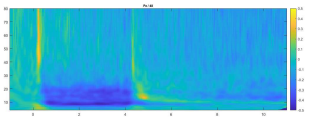
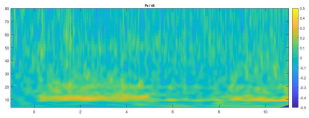
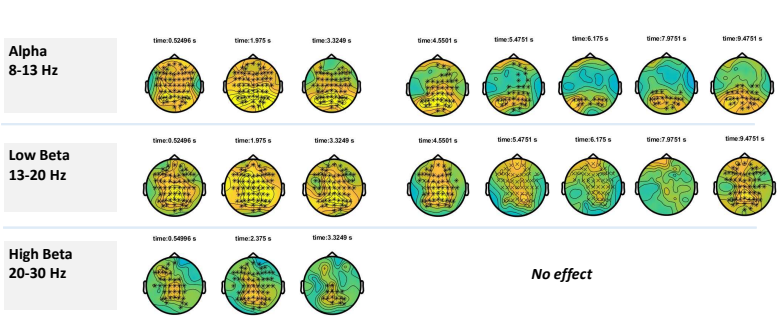


Figure 3: Raw effect of PHON-VOBJ condition (Pz)





VOBJ - VSCR

Figure 4: Time-frequency data for visuo-semantic condition (Pz)

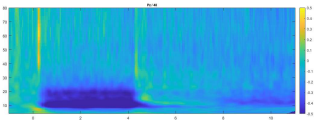
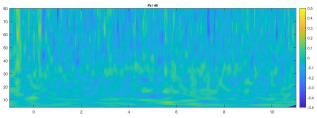
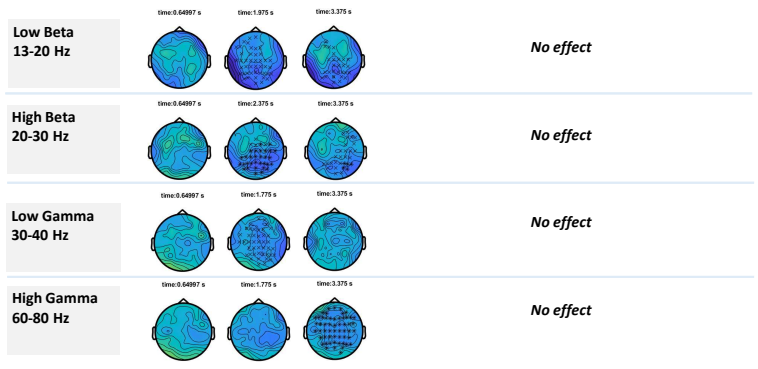


Figure 5: Raw effect of VOBJ-VSCR condition (Pz)





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DISCUSSION

- Significant differences in the alpha and beta bands reflect task-dependent neural activity.
- Only small differences between the visual task with recognizable objects and the same task with scrambled images.
- No increase in alpha and theta during phonological maintenance, contrary to the hypothesis.
- Decrease in alpha and beta bands is stronger in visual conditions than in the phonological condition, contrary to the hypothesis.
- Future studies will target semantic-level and articulatory-level verbalization to investigate the existence of the proposed inner speech levels.

Differences in the baseline period?