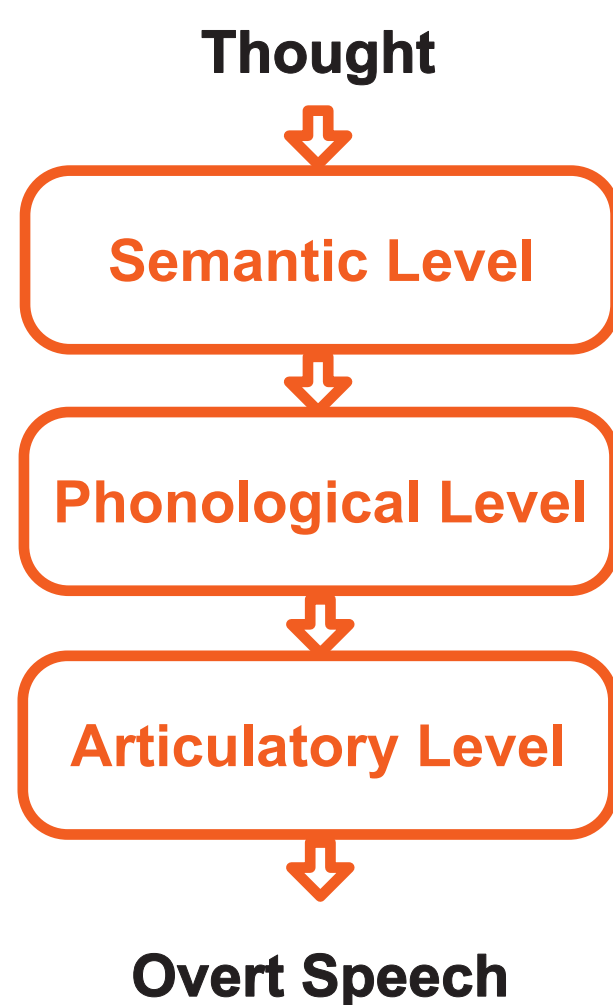


Introduction

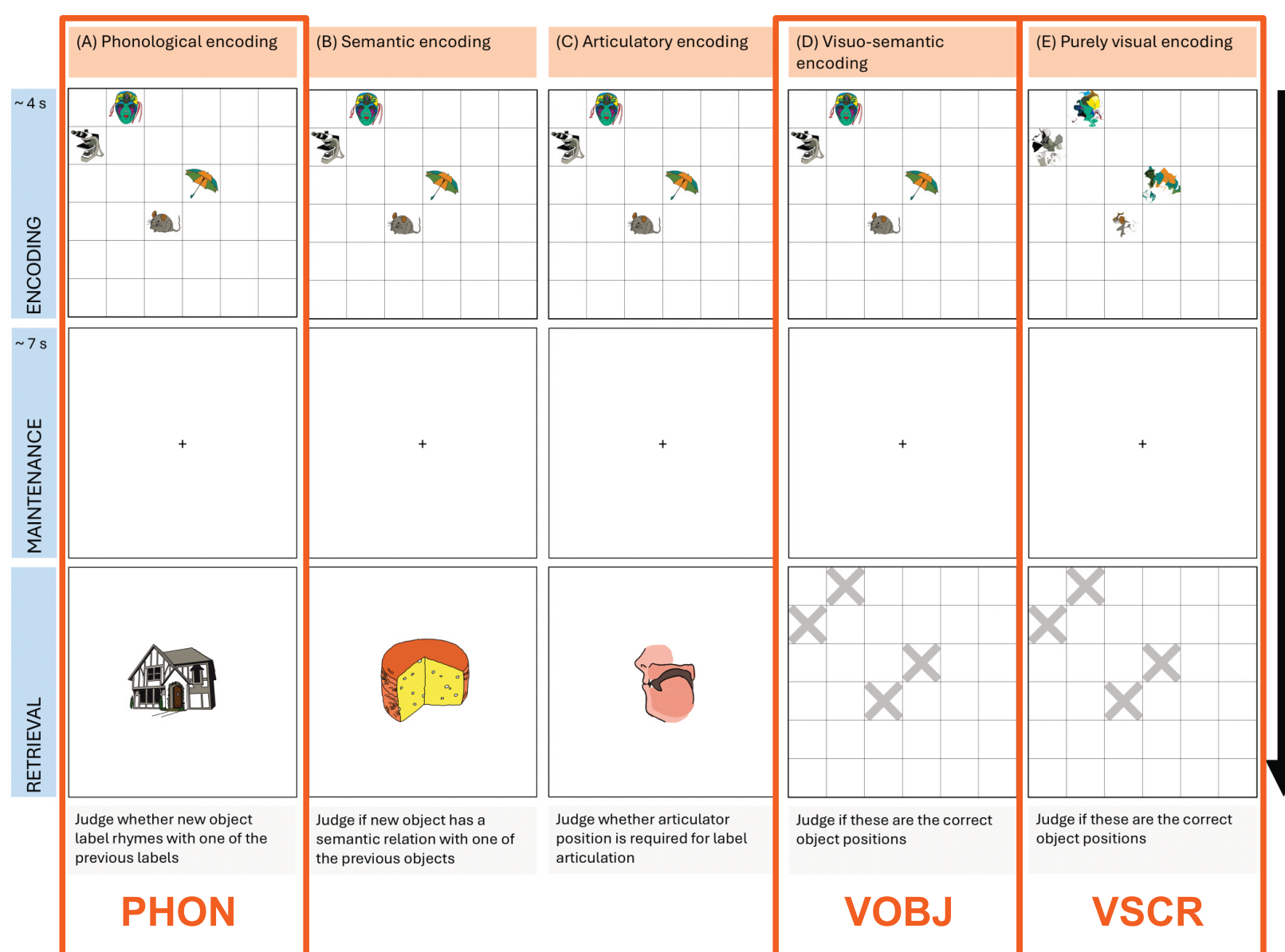
- **Modes of thinking** can differ between individuals - both in frequency and phenomenology [1].
- **Inner speech** can present as a full monologue or highly condensed at other times.
- **Levels of inner speech:** different linguistic processing stages are reached during an IS episode [2].



Aims of the LISP project:

- 1 Identify the oscillatory dynamics underlying internal verbalization vs. visual imagery
- 2 Explore individual differences through the Internal Representations questionnaire (IRQ)
- 3 Distinguish between semantic level, phonological level and articulatory level inner speech
- 4 Explore individual differences through the Varieties of Inner Speech Questionnaire (VISQ-R)

Materials & Methods



Conditions & Tasks:

- 3 conditions within-subject
- 40 trials per condition (blocked)
- pre-tests: digitspan & Corsi blocks
- questionnaires: IRQ [3], VISQ-R [4]

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 [5]
- automatic ICA-based removal of eye and muscle artefacts (SASICA) [6]
- 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 (cluster-alpha = 0.05) for PHON vs. VOBJ and VOBJ vs. VSCR for encoding and maintenance time windows in frequency bands pre-defined by hypotheses and condition-independent visual inspection.
- Linear mixed model (per region of interest and frequency band), FDR correction:

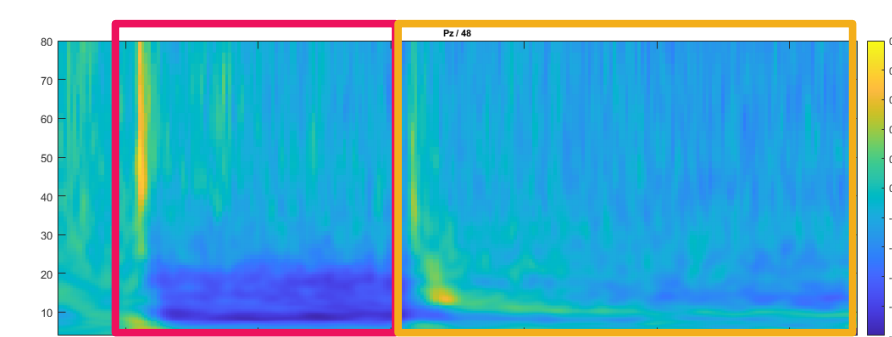
$$\text{Power} \sim \text{Condition} + \text{IRQ_IV} + \text{IRQ_VI} + \text{max_corsi} + \text{max_digitspan} + \text{Condition} * \text{IRQ_IV} + \text{Condition} * \text{IRQ_VI} + \text{Condition} * \text{max_corsi} + \text{Condition} * \text{max_digitspan} + (1 | \text{participant})$$

Results from Experiment 1

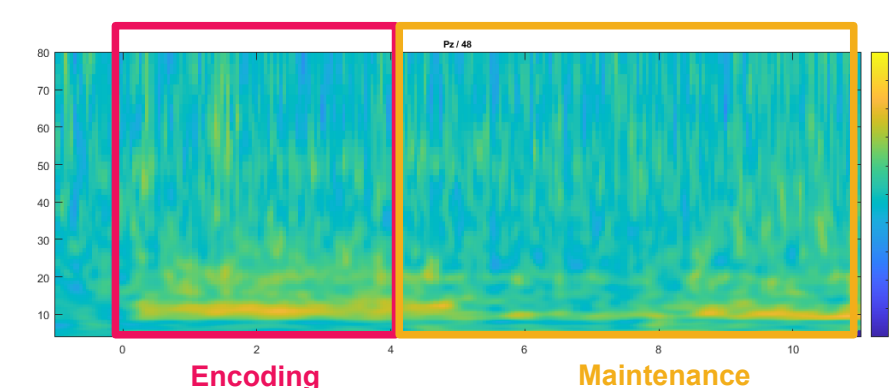
1 Alpha & beta distinguish verbal and visual processing

PHON - VOBJ

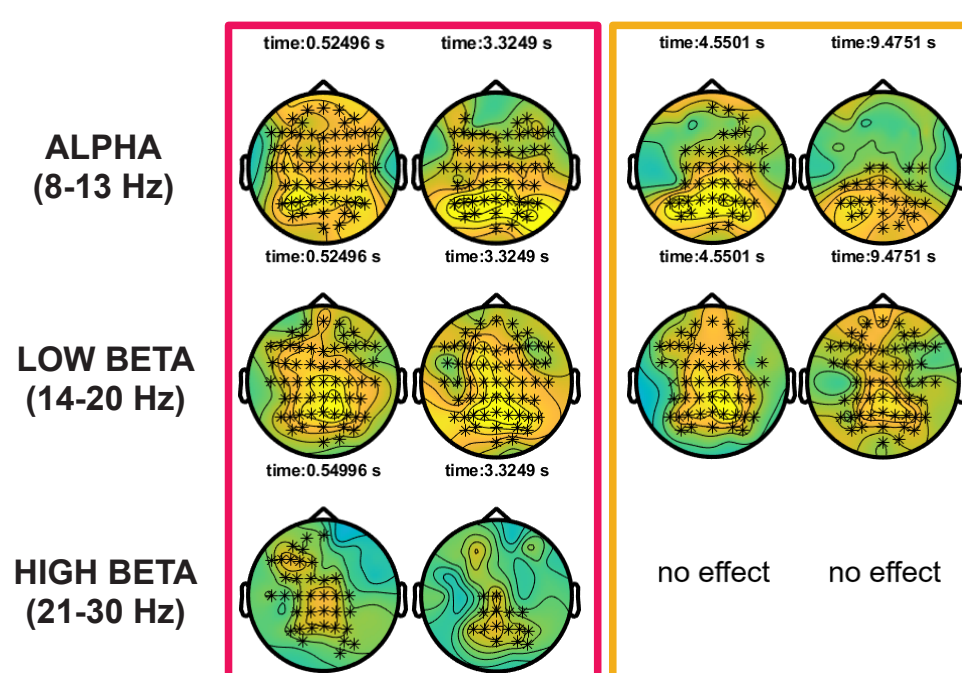
a) Time series for PHON



b) Raw effect of PHON-VOBJ

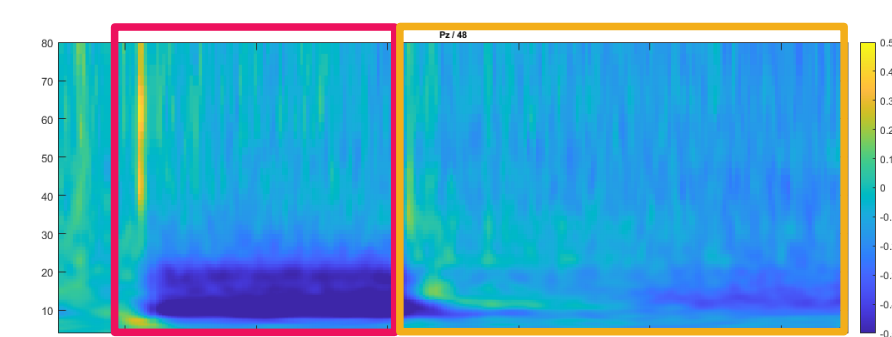


c) Clusters of PHON-VOBJ

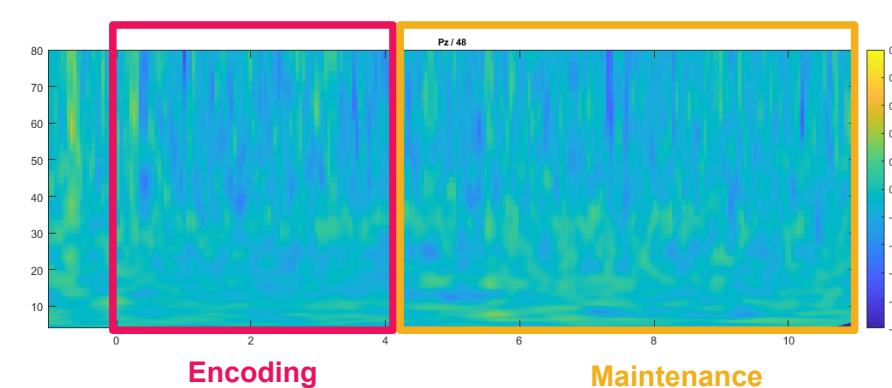


VOBJ - VSCR

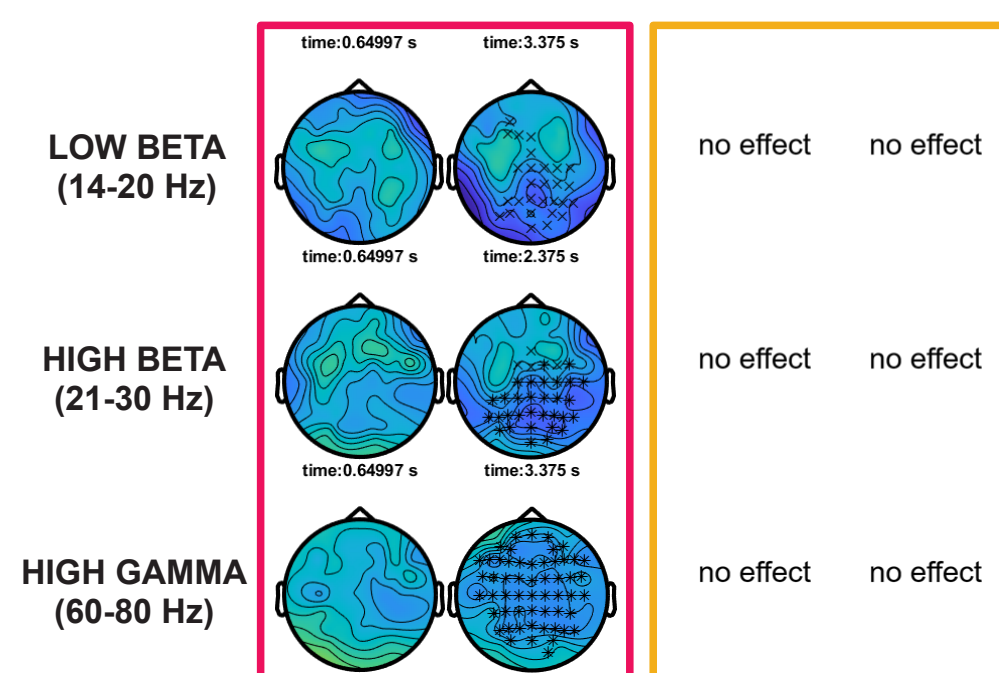
a) Time series for VOBJ



b) Raw effect of VOBJ-VSCR

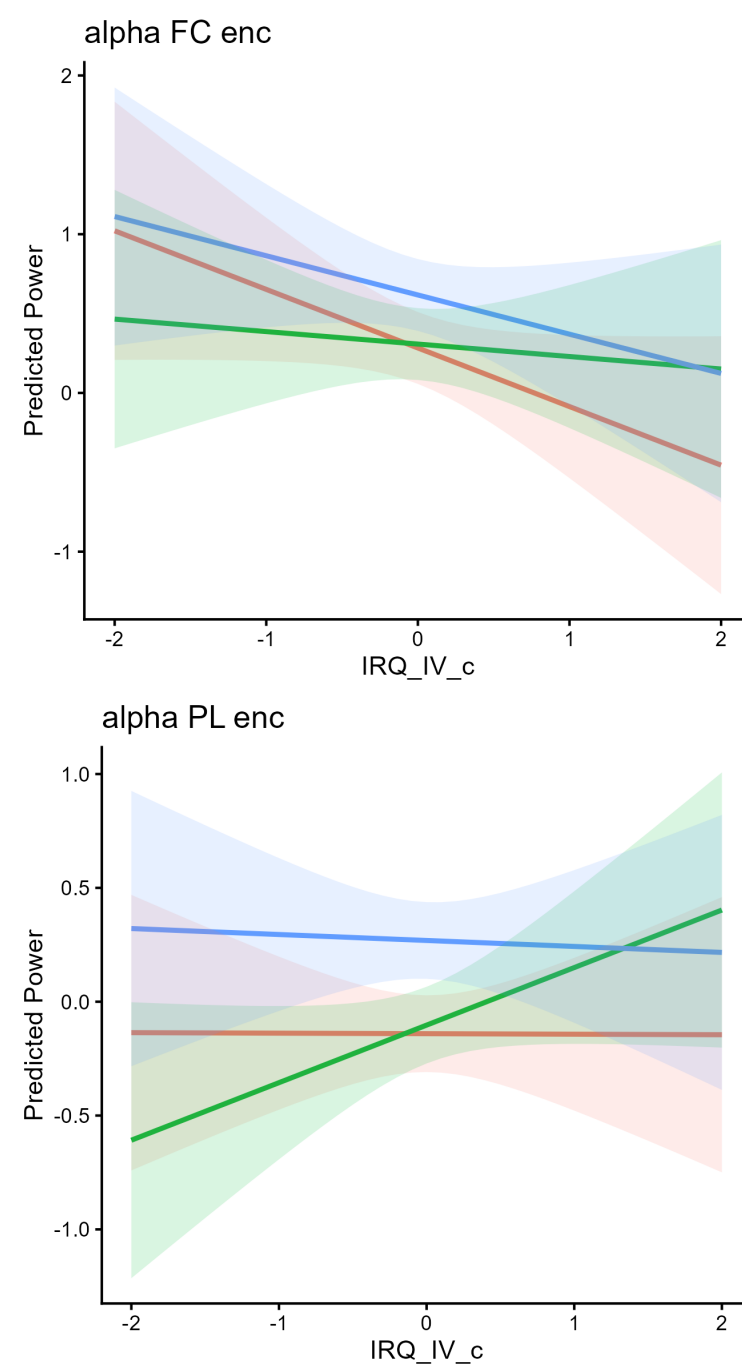


c) Clusters of VOBJ-VSCR

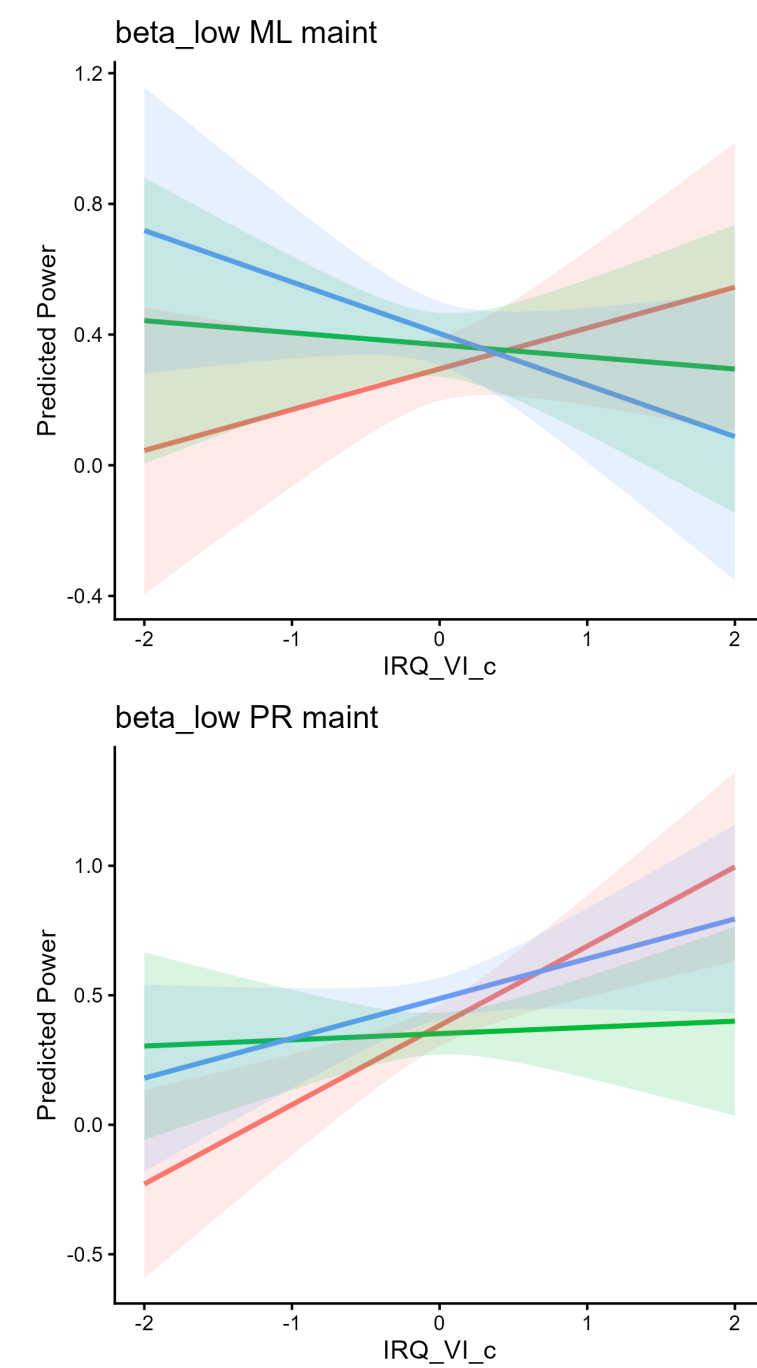


2 IRQ scores modulate power differences

Internal verbalization scores (IRQ-IV) predict condition specific differences in the **alpha band**.



Visual imagery scores (IRQ-VI) predict condition specific differences in the **lower beta band**.



Discussion

- **Visual and verbal working memory differ only in alpha and beta power**, particularly over posterior regions.

- Theta is typically more prominent in verbal WM tasks and increasing with task difficulty [7]. **Theta did not show differences here.**

- Beta and gamma power differences between VOBJ and VSCR likely reflect implicit naming or object binding.

- **Internal verbalization appears to affect the nameable object vs. scrambled images contrast**, possibly reflecting the assigning of labels to the shapes.

- Memory span also modulated condition-specific power differences in alpha and both higher and lower beta, as well as behavioral outcomes.

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