Differential Modulation of Theta and Beta Oscillations by Audiovisual Congruency in Letter-Speech Sound Integration

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Background

The integration of visual letters and speech sounds (i.e., L-SS integration) is a crucial part of learning to read.

Early neuroimaging studies investigating this integration have revealed a modulation by the audiovisual congruency (audiovisual congruent [AVc] > audiovisual incongruent [AVi]) (i.e., congruency effects) (e.g., van Atteveldt et al., 2009).

Time domain

Nash et al. (2007) have revealed stronger congruency effects of auditory ERP in time windows of N1 (50–125 ms) and P2 (200–300 ms) using an AV priming paradigm.

Frequency domain ?

Power and phase properties (phase resetting & coherence) of oscillatory neural responses in theta & beta bands have been reported to be related to AV integration processing (Keil & Senkowski, 2018).

Phase-resetting can be reflected by increased intertrial phase coherence (ITPC) induced by other sensory stimuli when comparing prestimulus and poststimulus ITPC values.

Aim

To investigate the **congruency effects** of L-SS integration and evaluate the contributions of **theta- & beta-band** powers and ITPC values during L-SS integration by using an AV priming paradigm.

Methods

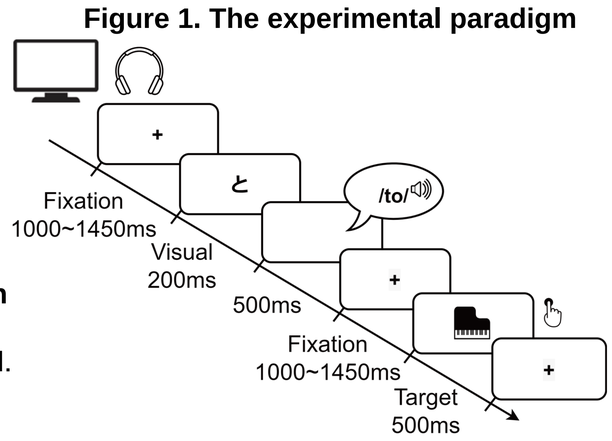
Participants: 34 Japanese university students (age range 18–27 yr; 18 females)

Priming task (in Japanese):
- presenting visual primes 200 ms before the onset of letter sounds.
- 5 conditions (**Table 1**)
- press button for target picture (piano) (**Figure 1**)

Condition	Visual Prime	Auditory stimuli
Congruent	と	/to/
Incongruent	ね	/to/
Baseline	ゐ	/to/
Control 1	と	/tos/*
Control 2	ゐ	/tos/*

Table 1. Example trials for each condition of priming task.
/tos/* represents a scrambled speech sound.

Figure 1. The experimental paradigm



EEG recordings:
29 active channels following standard 10–20 montage.

Analysis:
- **Power:** Based on the visual inspection of these regions of interest from previous studies, we chose below time windows for analyzing power differences.

  ⇒ Theta band (5–7 Hz) 0–200 ms
  ⇒ Beta band (20–35 Hz) 0–250 ms

  Significant differences evaluated by cluster-based permutation tests.

- **ITPC:** 1) Phase resetting was testified by comparing prestimulus (-250– -50 ms) and poststimulus (0–200 ms) ITPC values by using a pre-post (pre-, post-auditory onset) × electrode (FC1, FC2, C3, C4 & Cz) ANOVA.

  2) Congruency effects of L-SS integration on phase consistency of neural responses was compared between congruent (AVc) and incongruent (AVi) conditions using cluster-based permutation tests.

References

Nash et al. (2017). Are the literacy difficulties that characterize developmental dyslexia associated with a failure to integrate letters and speech sounds?
van Atteveldt et al. (2004). Integration of letters and speech sounds in the human brain.
Keil & Senkowski (2018). Neural Oscillations Orchestrate Multisensory Processing.

Results (Power)

Cluster-based permutation tests between AVc & AVi conditions ($p < 0.05$):
⇒ Theta band (28–148 ms, $p = 0.0405$)
⇒ Beta band (40–248 ms, $p = 0.008$)

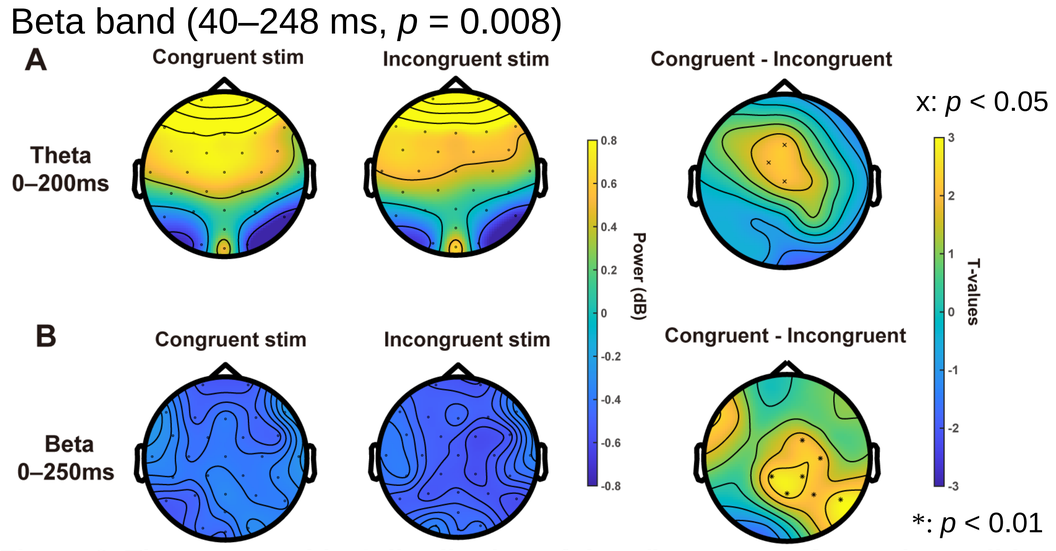


Figure 2. The topographical distribution of theta/beta power for each condition

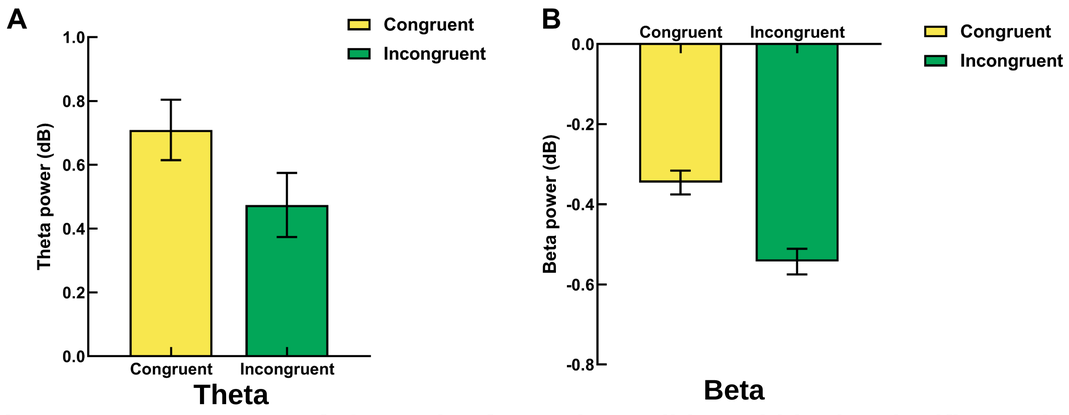


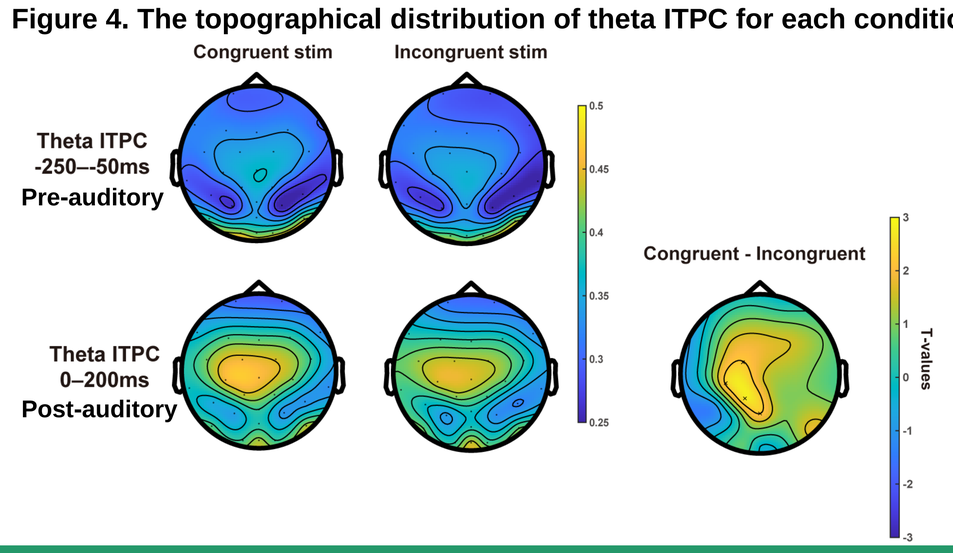
Figure 3. Mean powers of electrodes for each condition within the significant clusters

Results (ITPC)

1) ANOVA results showed the main effect of pre–post comparison:
⇒ Theta band (AVc: $F(1,160) = 168.40$, $p < 0.001$; AVi: $F(1,160) = 178.46$, $p < 0.001$; no interaction)
⇒ Beta band (AVc : $F(1,160) = 152.88$, $p < 0.001$; AVi: $F(1,160) = 122.22$, $p < 0.001$; no interaction)

2) Cluster-based permutation tests between AVc & AVi conditions: Theta band (36–164 ms, $p = 0.033$; left temporoparietal region); Beta band (ns)

Figure 4. The topographical distribution of theta ITPC for each condition



Discussion & Conclusion

Congruency effects of theta-band power at left frontocentral sensors
⇒increased neural processing in the left auditory region caused by cross-modal influence during L-SS integration.

Increased theta ITPC for poststimulus in the auditory cortex
⇒Phase resetting occurred; visual letters reset the phase of ongoing activities & amplified neuronal responses to prepare for auditory sounds.

Increased theta ITPC for AVc in the left temporoparietal region
⇒ Increased functional coupling between cortices for AVc; highly synchronous firing of assemblies of neurons oscillating.

Decreased beta-band power for AVc in the right centroparietal regions
⇒ Occurrence of expectancy violations during language processing, as visual letters can serve as a visual cue for the upcoming auditory stimuli.

Conclusions

Theta band: more likely to be related to the **L-SS integration networks**.

Beta band: more likely to be related to **task design** (priming paradigm).