

The Influence of Stimulus Uncertainty on Inter-subject Synchronization of Cortical MEG Activity during Natural Music Listening

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BACKGROUND

Inter-subject correlations (ISC) reflect how and when neural responses are in synchrony across participants and it has been proven useful to study neural responses in the context of naturalistic stimuli.

ISC during listening has been shown to be modulated by **attention & musical training** (Puschmann et al., 2021), by **familiarity of musical genres** (Madsen et al., 2019) and it has been used to study **musical engagement** (Omigie & Mencke, 2023).

It has been suggested that ISC are linked to **surprisal**, i.e. unexpected events in the music (e.g. Dauer et al., 2021).

Open question:
How does stimulus uncertainty and style-specific musical training interact to influence ISC during naturalistic music listening?

The study aimed to investigate whether ISC is (potentially jointly) influenced by

- 1) the levels of uncertainty naturally present in music and
- 2) different style-specific musical training.

METHODS

FREE LISTENING PARADIGM

STIMULI

Low uncertainty condition: 20 tonal piano music excerpts | classic romantic repertoire | 30-60s (t01-t20)

High uncertainty condition: 20 atonal piano music excerpts | 20th century/modern repertoire | 30-60s (a01-a20)

→ significantly different in key and pulse clarity values

→ similar in tempo and event density (Fig. 1)

→ MIR Toolbox for Matlab (Lartillot and Toivainen, 2007a)

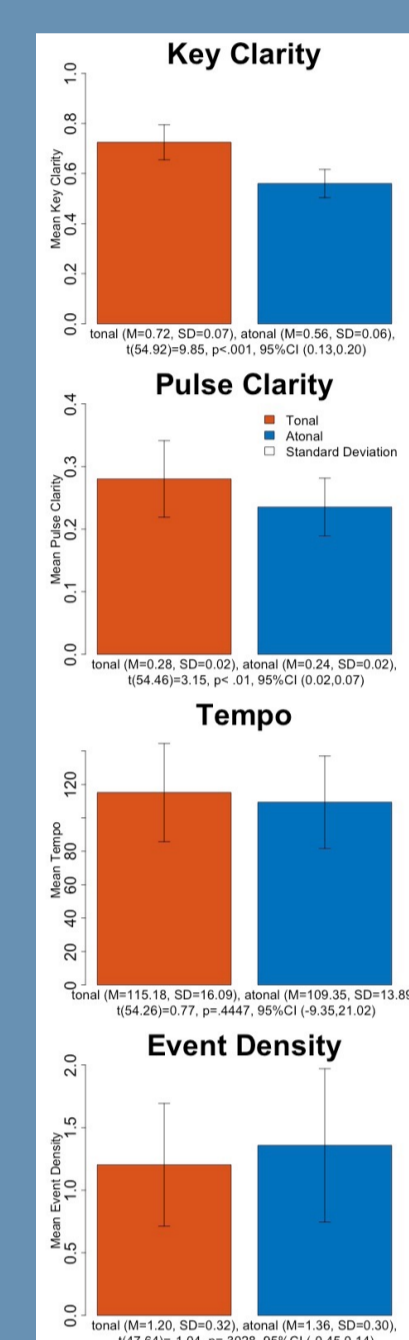


Figure 1. Stimuli Analyses

1st Session: MEG Recordings

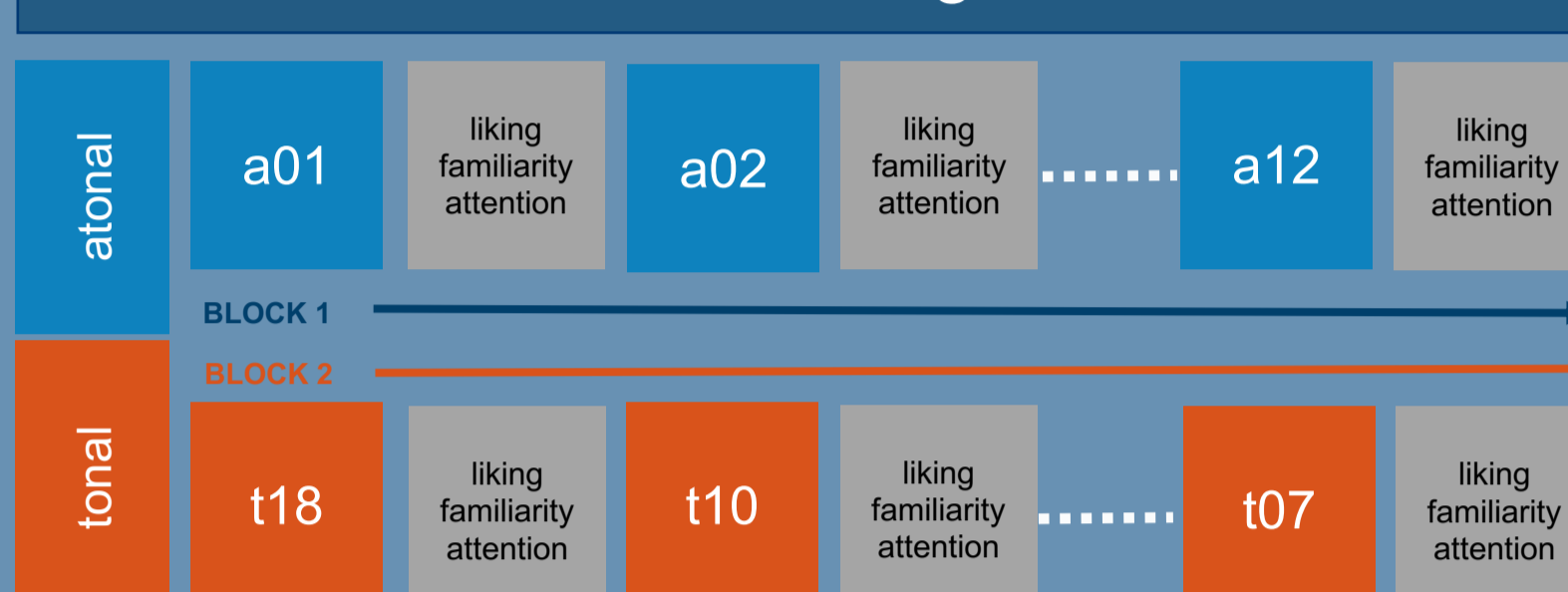


Figure 2. Experimental Design MEG Recordings. Blocks were counterbalanced, trial order was randomized. Active listening task followed by three control questions. Instruction: "Please listen attentively but relaxed to the music". Session length = 30 minutes, self-paced procedure.

2nd Session: Continuous Ratings

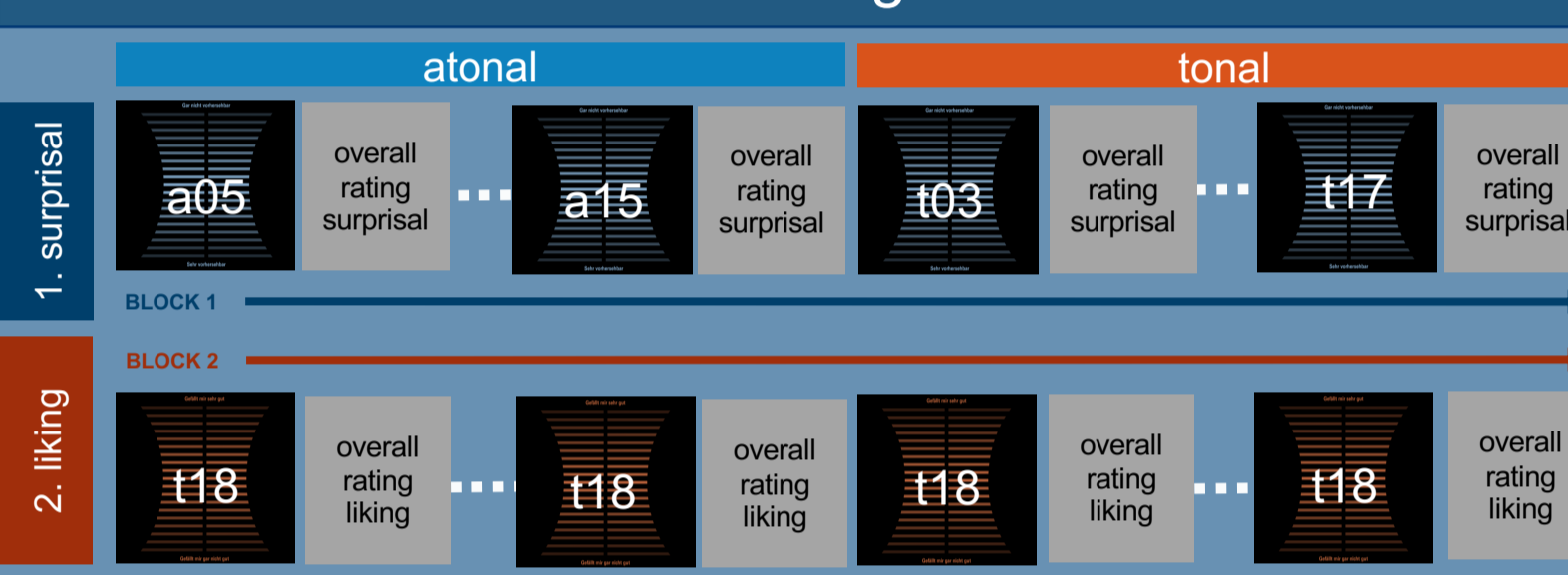


Figure 3. Experimental Design Continuous Ratings. Pieces from 1st session were played via headphones, ratings on tablet PC. Blocks (atonal & tonal) were counterbalanced, trial order was randomized. Software: OpenSesame. Session length = 60 minutes, self-paced procedure.

SAMPLE

58 healthy right handed participants (31 female, 27 male, mean age = 35 ± 6.63)

Group1: Non-Musicians (NM) → no more than 3 years of musical training + no training before the age of 10

Group2: Professional musicians specialized in classic-romantic music (CM) → professionally active as musician with classic-romantic music

Group3: Professional musicians specialized in contemporary classical music (CCM) → professionally active as musician with contemporary classical music (exclusion criteria e.g. composers, electronic music - musicians)

RECORDINGS & ANALYSES

Continuous ratings: removal of first 5 seconds | median filter for piece removal (order: 300) | piece wise analyses by calculating means

MEG & MRI: 275-channel whole-head MEG system with axial gradiometers (Omega 2000, CTF Systems) | T1-weighted MRIs (Siemens Magnetom Trio, Siemens)

MEG data preprocessing with Brainstorm: notch filter (50,100,150) | band-pass filter (0-100Hz) | 200 Hz downsampling | ICA | headmodel: BEM volume conduction model | dSPM source model with 15,000 surface vertices

MEG ISC: stimulus wise computation of phase-locking values for all pairs of participants (within group) | 6 frequency bands (delta: 0.5-4 Hz; theta: 4-8 Hz; alpha: 8-12Hz; beta: 12-25Hz; low gamma: 25-45Hz; high gamma: 55-90Hz) (Thiede et al. 2020; Puschmann et al., 2021)

CONTINUOUS RATINGS: MEASURING SURPRISAL

1. BETWEEN SUBJECTS

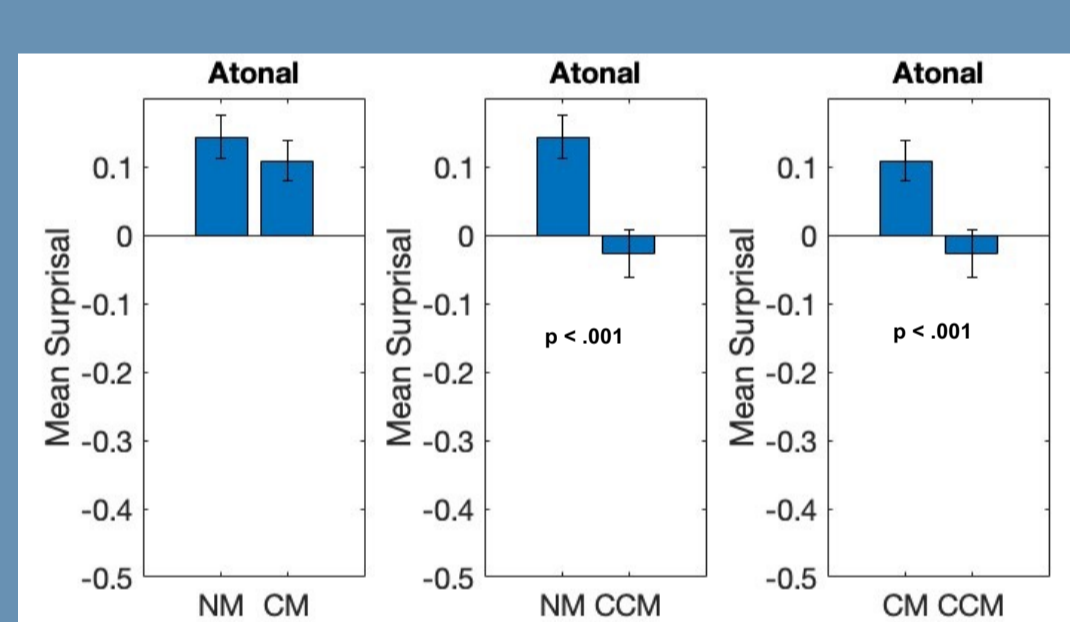


Figure 4. Mean Ratings Atonal Condition

- independent sample t-tests revealed no difference between NM & CM with regard to surprisal ratings (range -1:1) in atonal music
- CCMs significantly lower surprisal ratings for atonal music in contrast to NM and CM (small effects)

2. WITHIN SUBJECTS

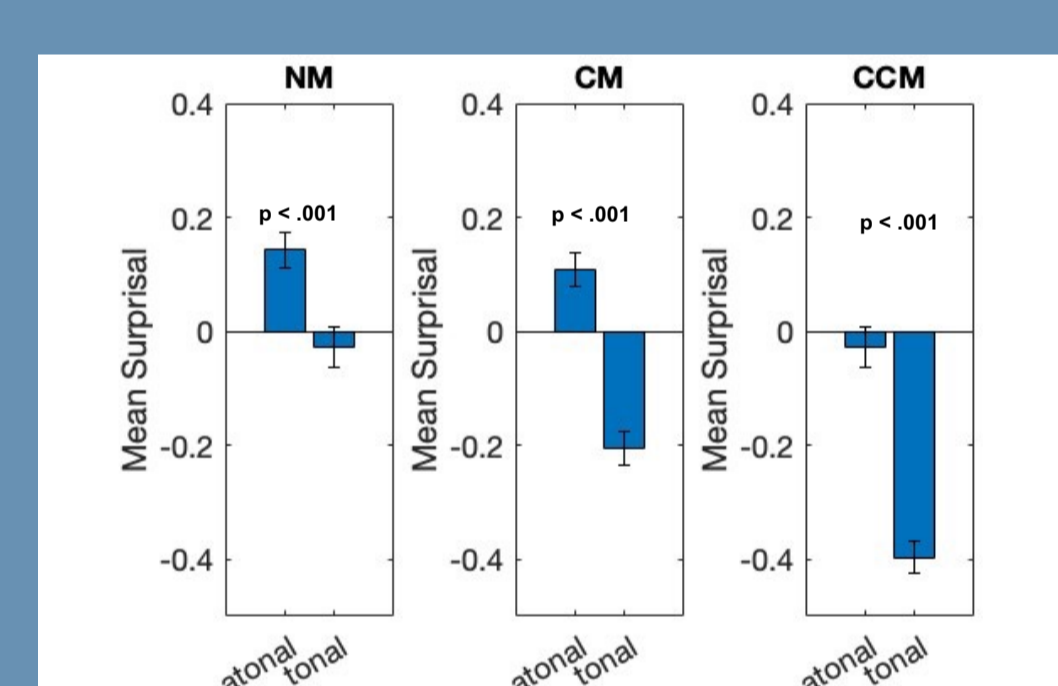


Figure 6. Mean Ratings Groups

- dependent sample t-tests revealed significant differences between tonal and atonal music in all three groups (small-medium effects)
- next steps: linear mixed effects models

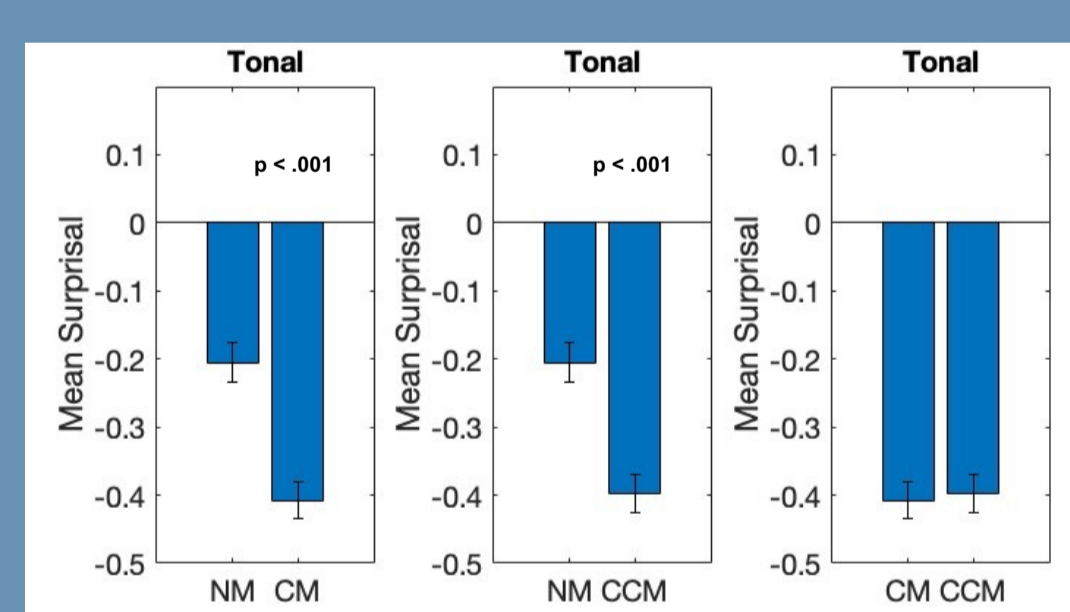


Figure 5. Mean Ratings Tonal Condition

- independent sample t-tests revealed no difference of mean surprisal between CM & CCM
- but significant differences between NM & CM as well as between NM & CCM (small effects)

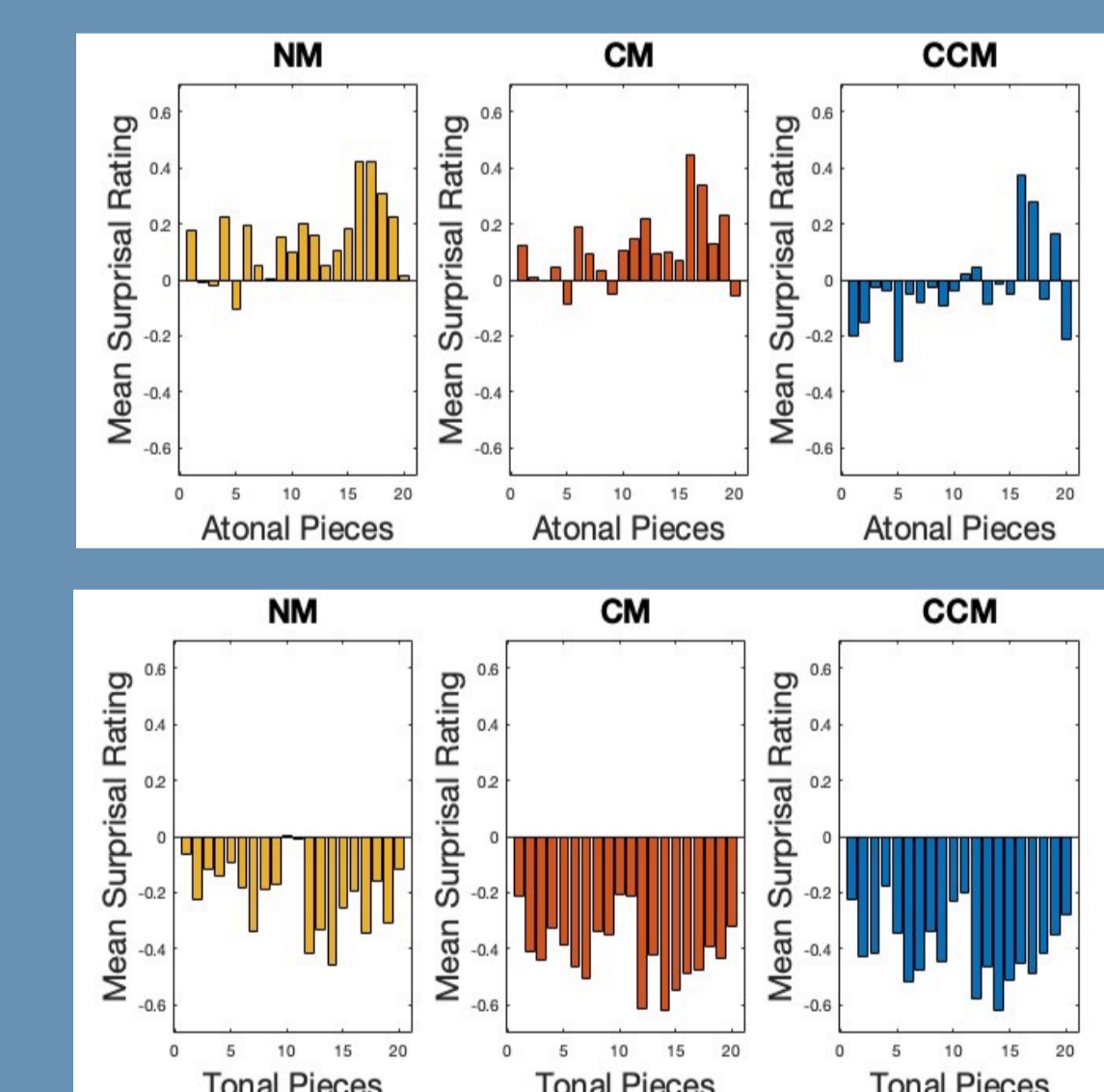


Figure 7 & 8. Mean Surprisal Ratings. Group-wise display of mean surprisal ratings for individual pieces in both conditions. Range (-1:1).

MEG INTER-SUBJECT CORRELATIONS: Effects of uncertainty on ISC

3. WITHIN SUBJECTS ISC: ATONAL – TONAL

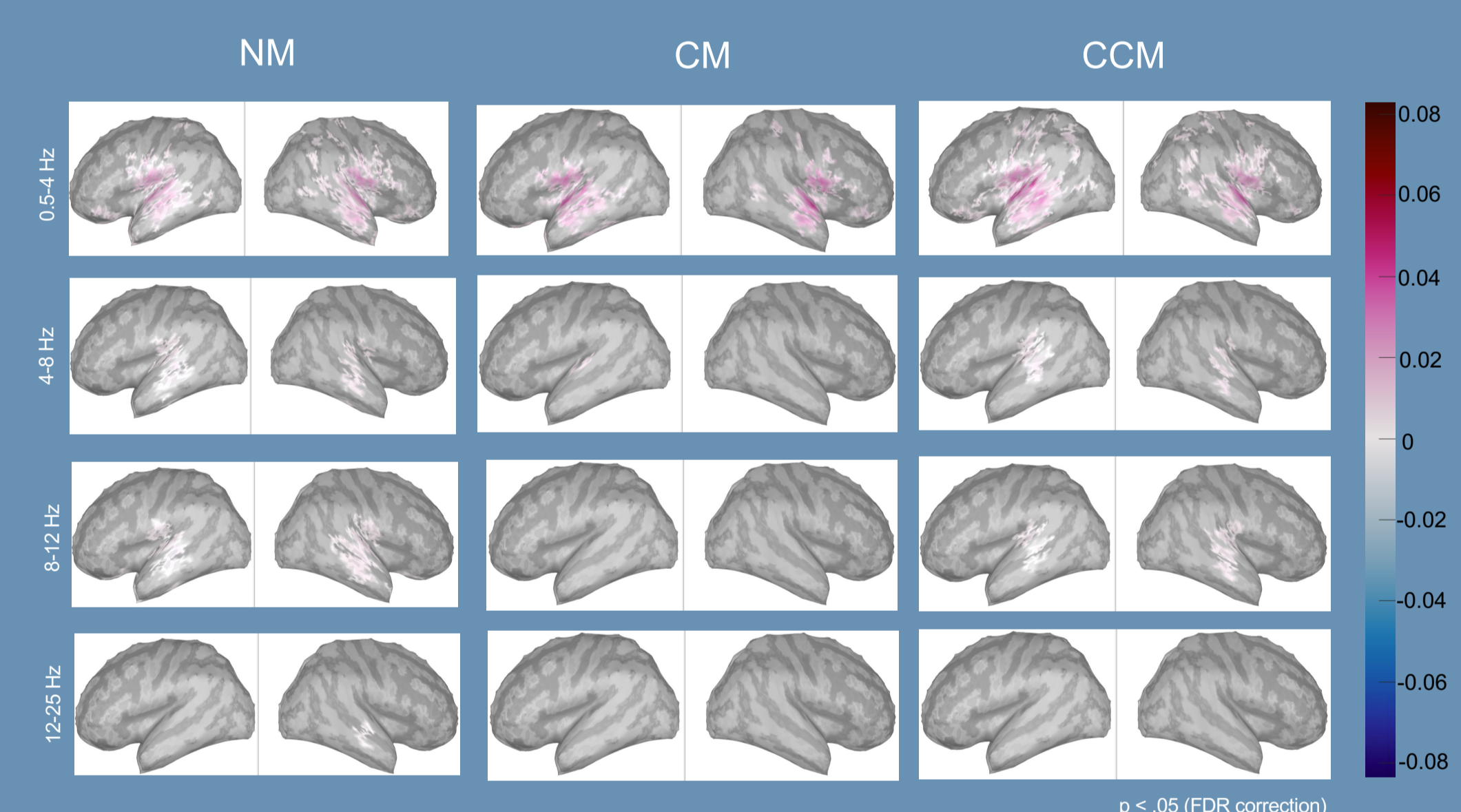


Figure 9. MEG ISC

- significantly stronger ISC for atonal music in all three groups in the delta band (0.5-4 Hz)
- additionally: NMs and CCMs show similar pattern with small ISC differences in the theta (4-8 Hz) and alpha (8-12 Hz) band

4. WITHIN SUBJECTS: SUBSETS high – low surprisal

- MEG data selection based on behavioral surprisal ratings
- 10 pieces in each condition: 5 high and 5 with low surprisal rating in each group → high – low

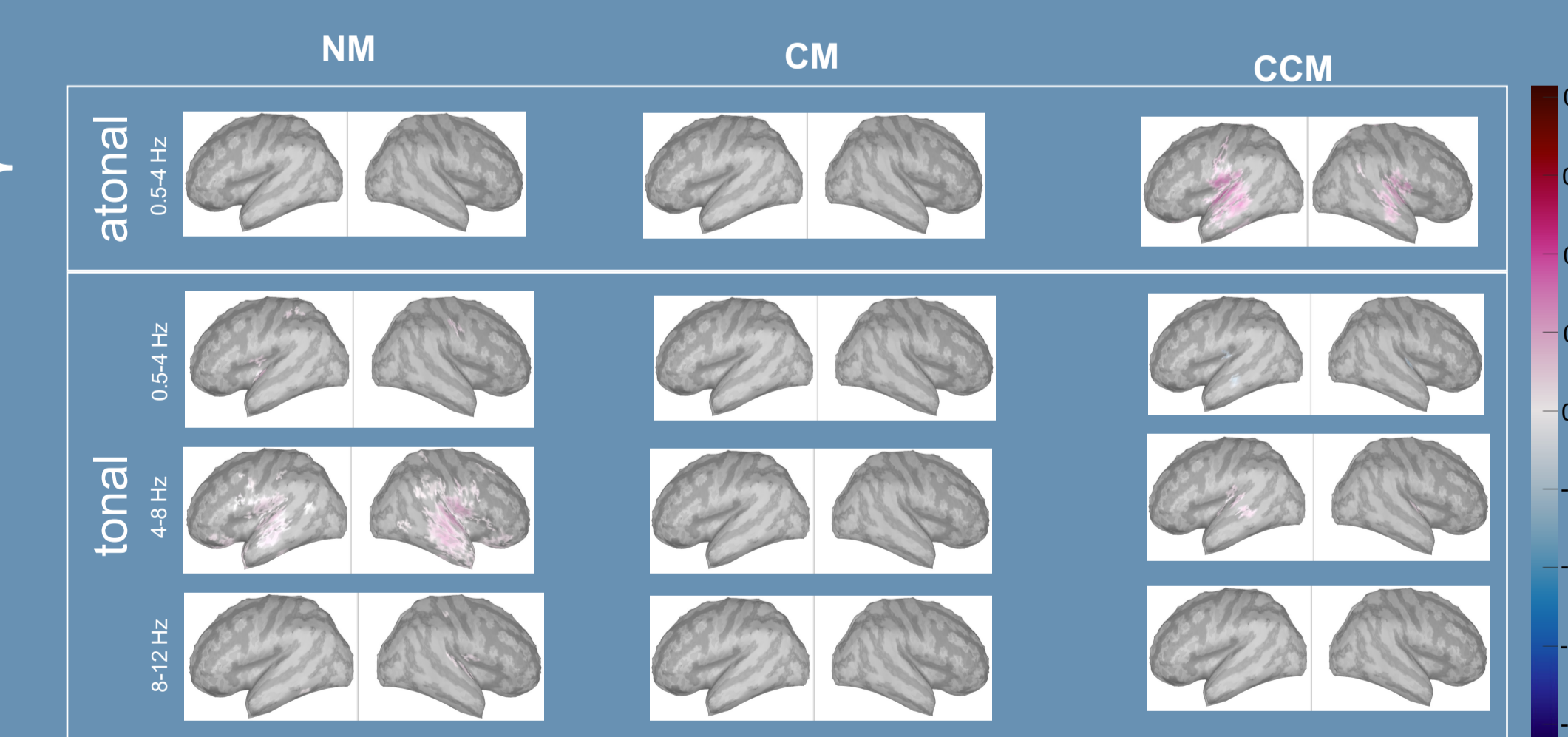


Figure 10. Surprisal Subset

- atonal condition: stronger ISC for high surprisal pieces in CCM (delta band)
- tonal condition: stronger ISC for high surprisal pieces in NMs (theta band)
- tonal condition: small effect for CCMs (theta band); no difference for CM

RESULTS

CONCLUSION

Behavioral Surprisal Ratings

→ on the one hand, pieces were **rated very differently**; on the other hand a **clear pattern across groups** is observable

→ tonal music is perceived as very predictable by CM and CCM due to their expertise; on the contrary, in case of **atonal music**, NM and CM show similar tendency, i.e. rating it to be very unpredictable → **CCM show style-specific training effects** (Fig. 4 & 5)

→ Fig 7, CCM atonal: observable **effect of familiarity and style specific training on surprisal ratings** in the sense of a **more differentiated** rating by CCMs

MEG ISC

→ preliminary within subjects results (Fig. 9) in line with finding that low level features and bottom up processes are driving ISC (Omigie & Mencke, 2023)

→ current stage of analysis points to a stronger inter-subject synchronization of cortical activity in the atonal condition (see Keitel et al. 2023)

→ subset approach: higher discrepancy between high and low surprisal in atonal for CCM: both observable in behavior as well as in ISC activity

1. MEG ISC seems to reflect behavioral surprisal ratings
2. Follow up: do CCMs have a more differentiated predictive model for atonal music?

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