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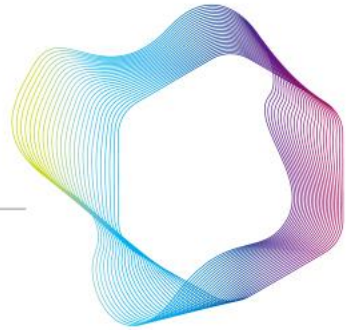

Using spatialized water sound sequences for traffic noise mitigation:

correlation analysis of subjective evaluation and neural measurements

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1) traffic noise and water sound

Traffic noise is a big concern for urban designers and landscape managers since it has been proven to impact **public health** physically and mentally.

The introduction of **natural sounds** (e.g. water sounds, bird songs) into noisy urban environments has been treated as an effective strategy for noise reduction and abatement. Among them, **water sounds** are commonly used to mask traffic noise varying in its **sound features**.

Evidence showed that to optimize the effects of the Informational Masking the sou nd level of water sound should be **-3dB** than the traffic noise.

Question: Can the spatial setting of water sounds improve the masking effect on road traffic noise?

From https://ec.europa.eu/research-and-innovation/sites/default/files/hm/field/image/noise%20rome.jpg

From https://www.maxpixel.net/static/photo/1x/

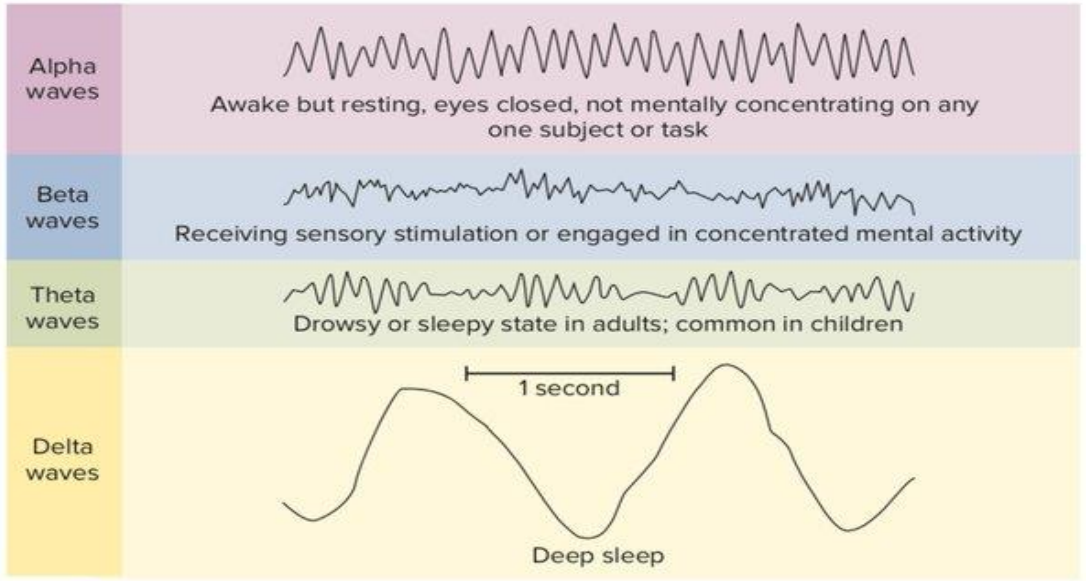
2) the application of EEG (electroencephalogram)

- Neural oscillation

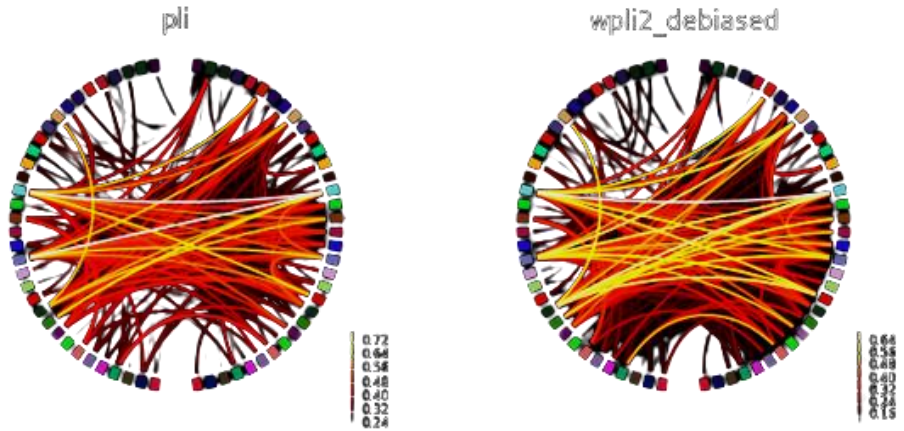
Neural oscillations are rhythmic electrical activity generated in the central nervous system, **spontaneously** and in response to **external events**, which could be used as indicators of sonic environments related to the **comfort** and **restoration** of individuals.

- Brain connectivity

Brain functional connectivity is defined as the statistical relationships between cerebral signals over time and thus potentially allows conclusions to be made regarding the **functional interactions** between two or more **brain regions** (*Gaudet, Isabelle, et al. 2020*).



From *Perrotta, G. (2019). Sleep-wake disorders: Definition, contexts and neural correlations. J Neurol Psychol, 7(09)*

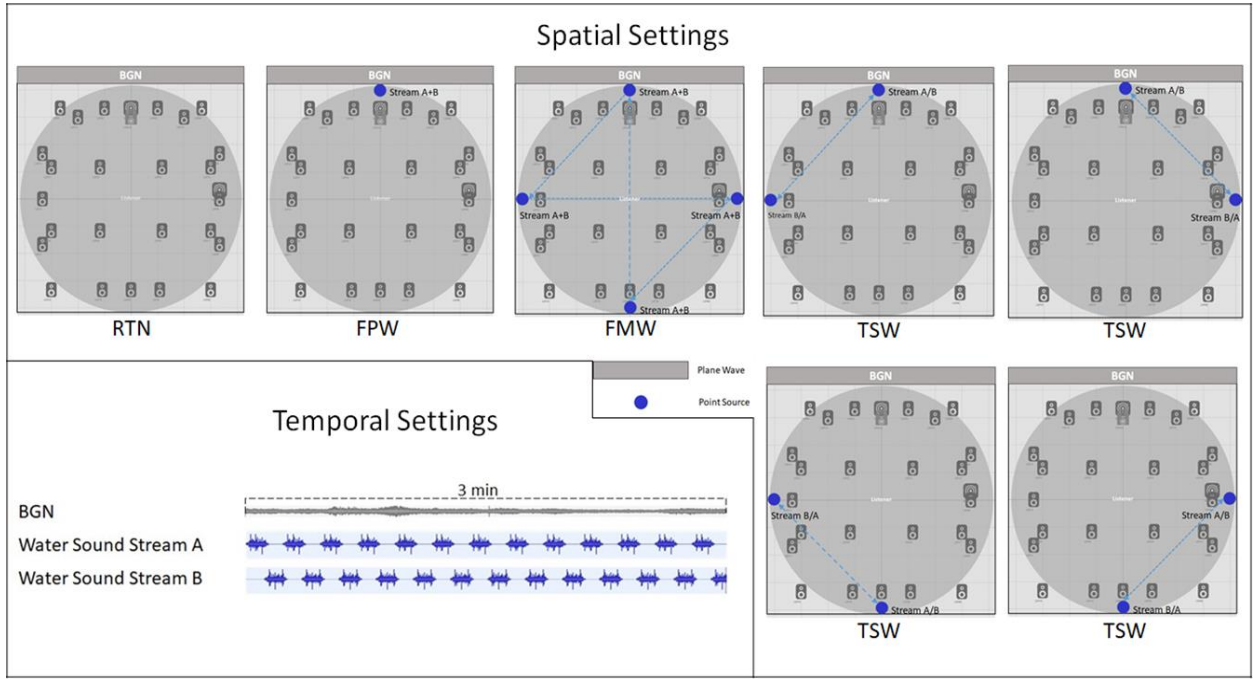


From https://mne.tools/0.13/auto_examples/connectivity/

1) the independent variable

The spatial settings of the water sounds:

- Frontal-fixed Position Water sound (FPW)
- Two-position Switching Water sound (TSW)
- Four-position randomised Moving Water sounds (FMW)
- Road Traffic Noise (RTN)



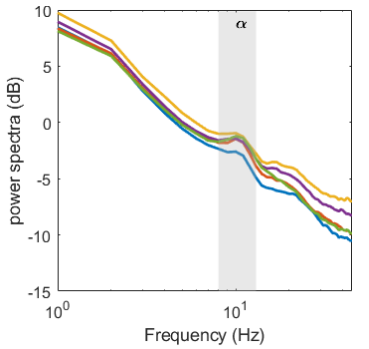
2) the dependent variables

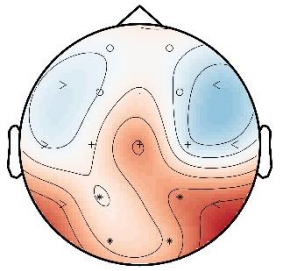
- **Post-doc questionnaire:**

➢ Objective descriptors
naturalness, mechanicalness, smoothness, rhythmicalness, spaciousness, and familiarity

➢ Positive component of emotional saliency (ES+):
pleasant, happy, stimulating, attractive, energetic, calm;

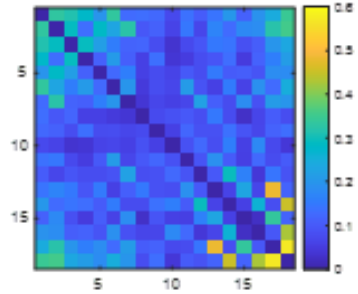
➢ Negative component of emotional saliency (ES-):
boring, unpleasant, nervous, weak, sad, unattractive

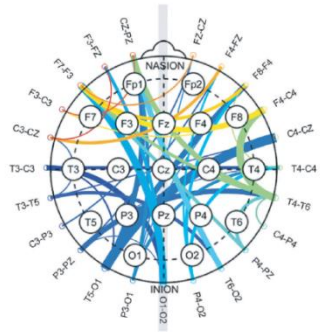




- **EEG measurements:**

➢ spectral power distribution (frequency bands: delta/theta/alpha/beta/gamma)





➢ theta/alpha ratio + alpha/beta ratio

➢ brain connectivity (dwPLI)

Experiment Procedure

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1) the playback of sounds

- **Place:**

  Sens i-Lab, the Department of Architecture and Industrial Design

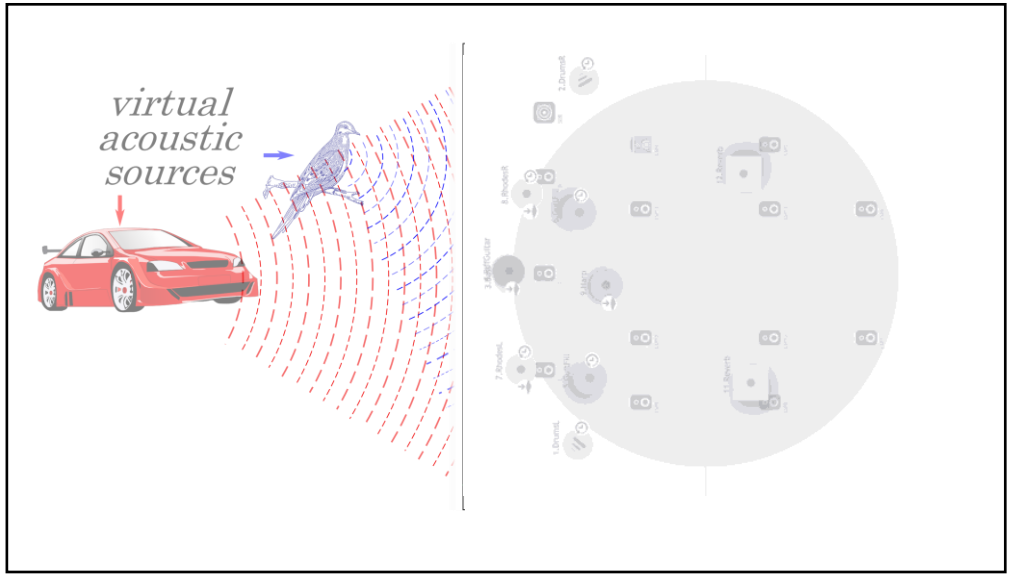
- **Sound system:**

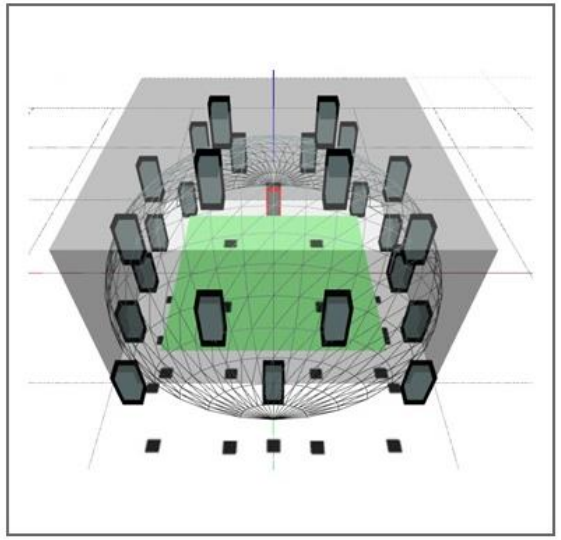
  Astro Spatial Audio (25 Adorn A55 Martin Audio; 2 Sx110 Martin Audio; SARA II Premium Rendering Engine)

- **Spatial sound settings:**

  > Plane wave: traffic noise
  Recorded from: a real urban park (65 dB(A))

  > Point source: water sounds
  Recorded from: a water stream (62 dB(A))



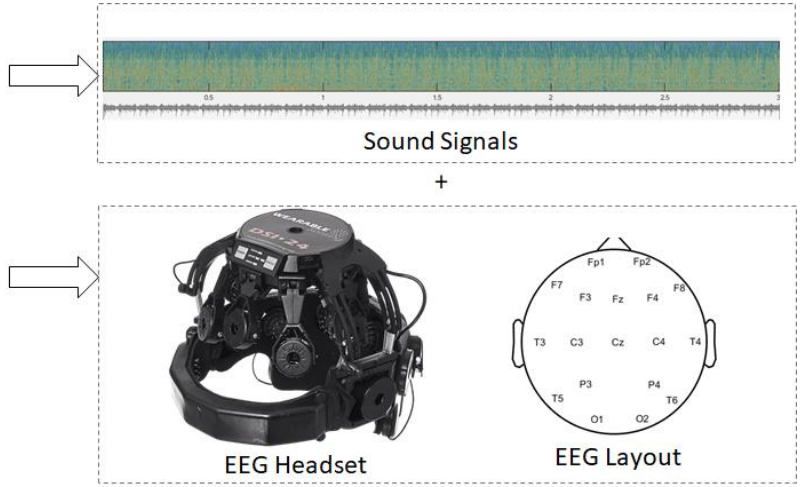


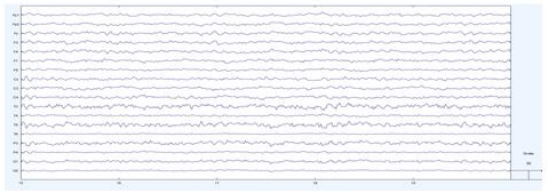
2) data collection

The brain signals of twenty subjects were measured by a wearable EEG headset (DSI-24).
After 3 minutes of listening for each condition, subjects were asked to answer the questionnaires. The listening o rders of four conditions were balanced across subjects.

How much the SOUND you just heard is:
Pleasant
Unpleasant
Stimulating
Boring
Attractive
Unattractive
How much the SOUND you just heard makes you feel:
Calm
Nervous
Weak
Energetic
Happy
Sad

Test Scenario





Data Collection

1) the pipeline of EEG analysis

- Brain Regions Division:

- frontal (Fp1, Fp2, F3, F4),
- left temporal (F7, T3, T5),
- central (Cz, C3, C4),
- right temporal (F8, T4, T6)
- posterior regions (P3, P4, O1, O2)

- Relative Spectral Power of frequency bands:

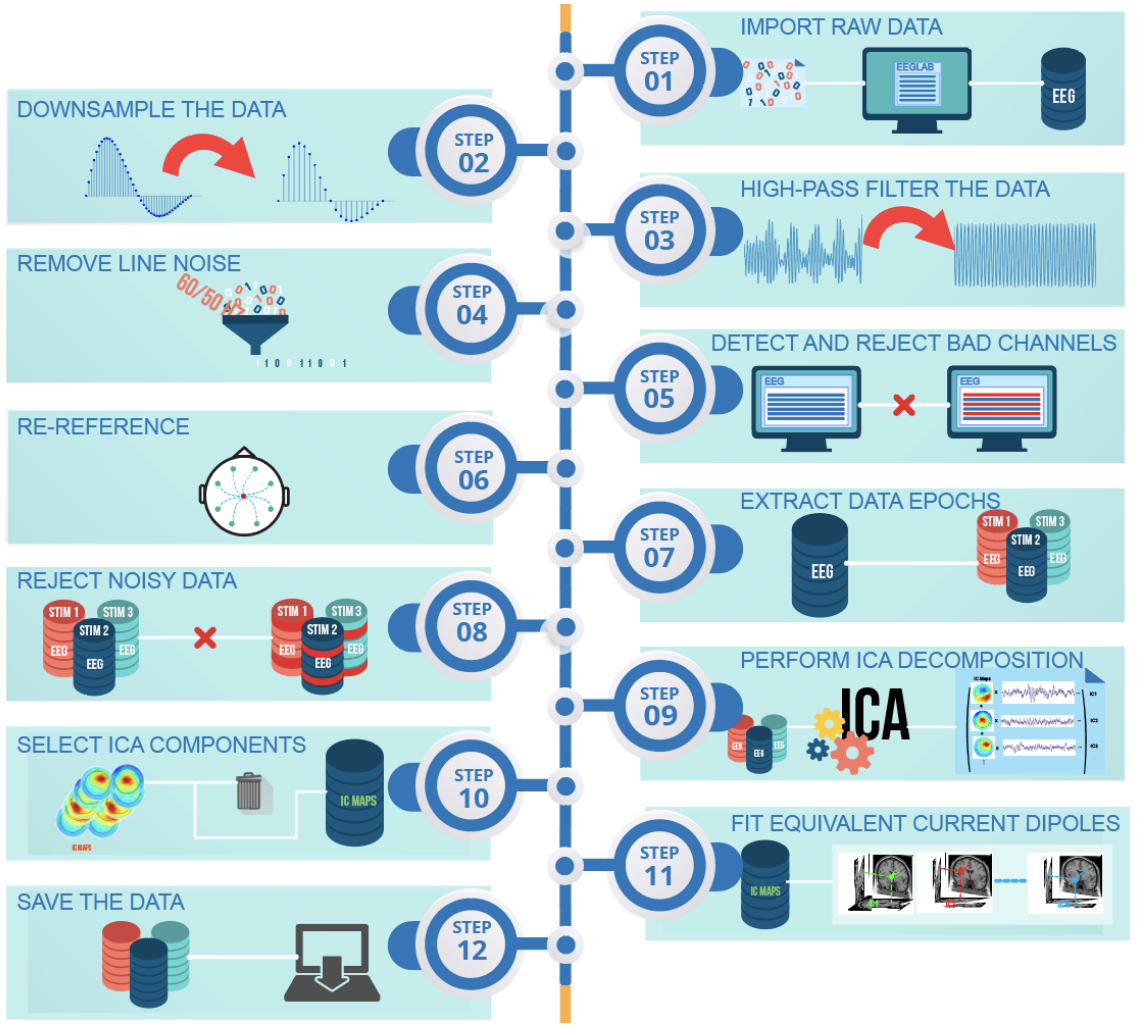
$$RP(f_{1,}\, f_{2,}) = \left[P(f_{1,}\, f_{2,})/P(1,45)\right] \cdot 100$$

(delta/theta/alpha/beta/gamma)

- Brain Connectivity Index:

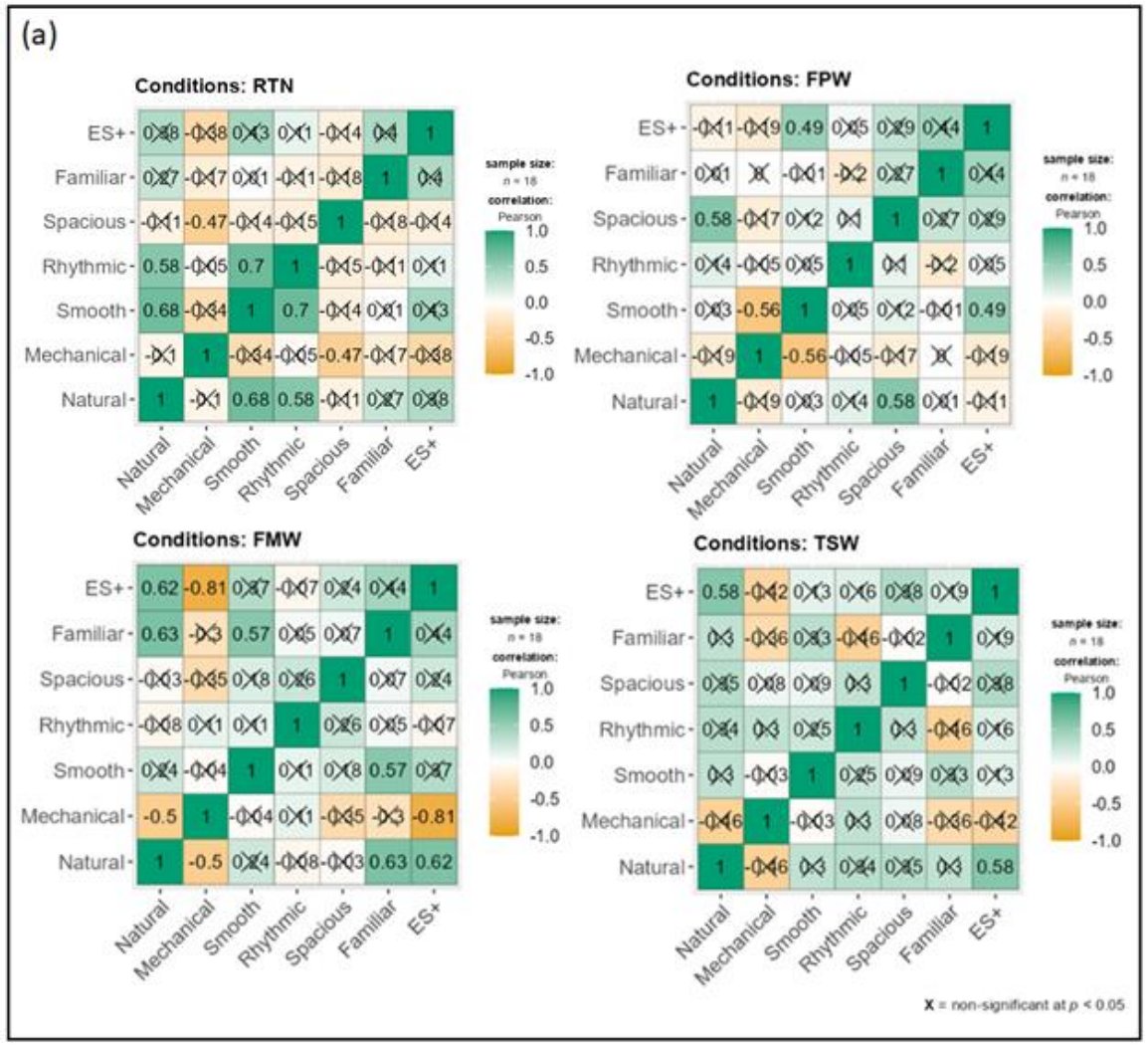
the debiased weighted phase lag index dwPLI (*Vinck, Martin, et al., 2011*)

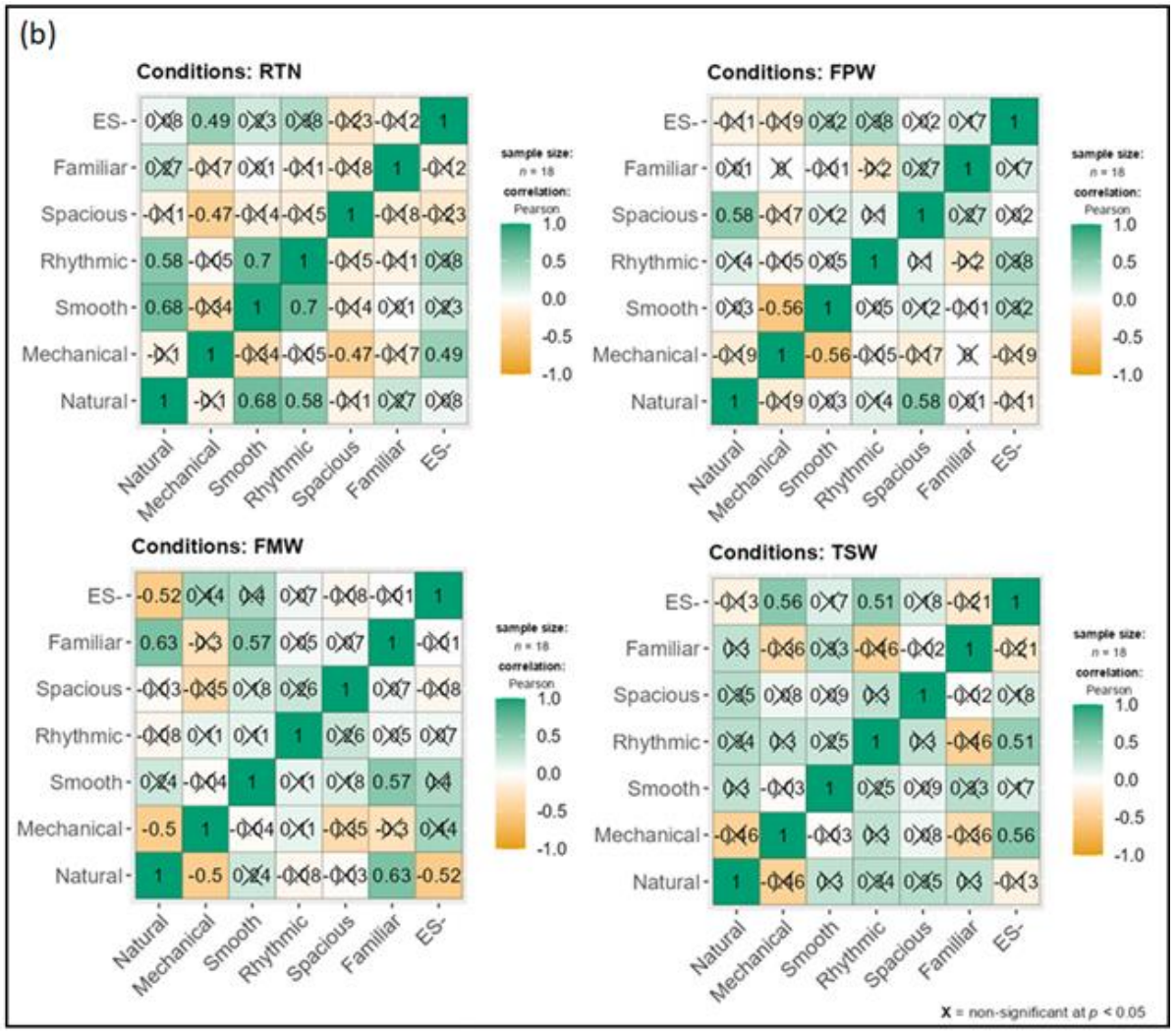
$$dwPLI = \frac{\sum_{j=1}^{N}\sum_{k\neq j}\Im\{X_j\}\Im\{X_k\}}{\sum_{j=1}^{N}\sum_{k\neq j}|\Im\{X_j\}\Im\{X_k\}|}$$



From https://eeglab.org/assets/images/tutorial_image.png

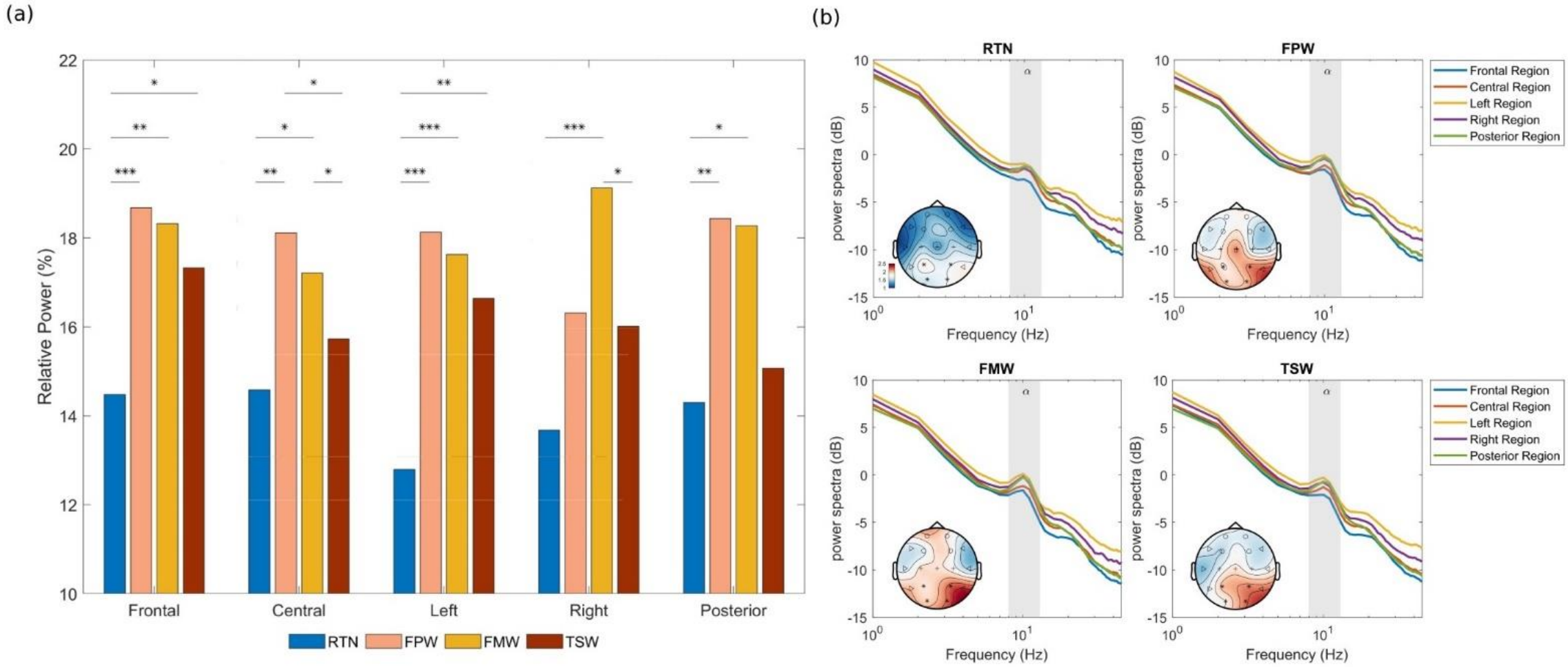
1) Correlation results: subjective descriptors - emotional salience



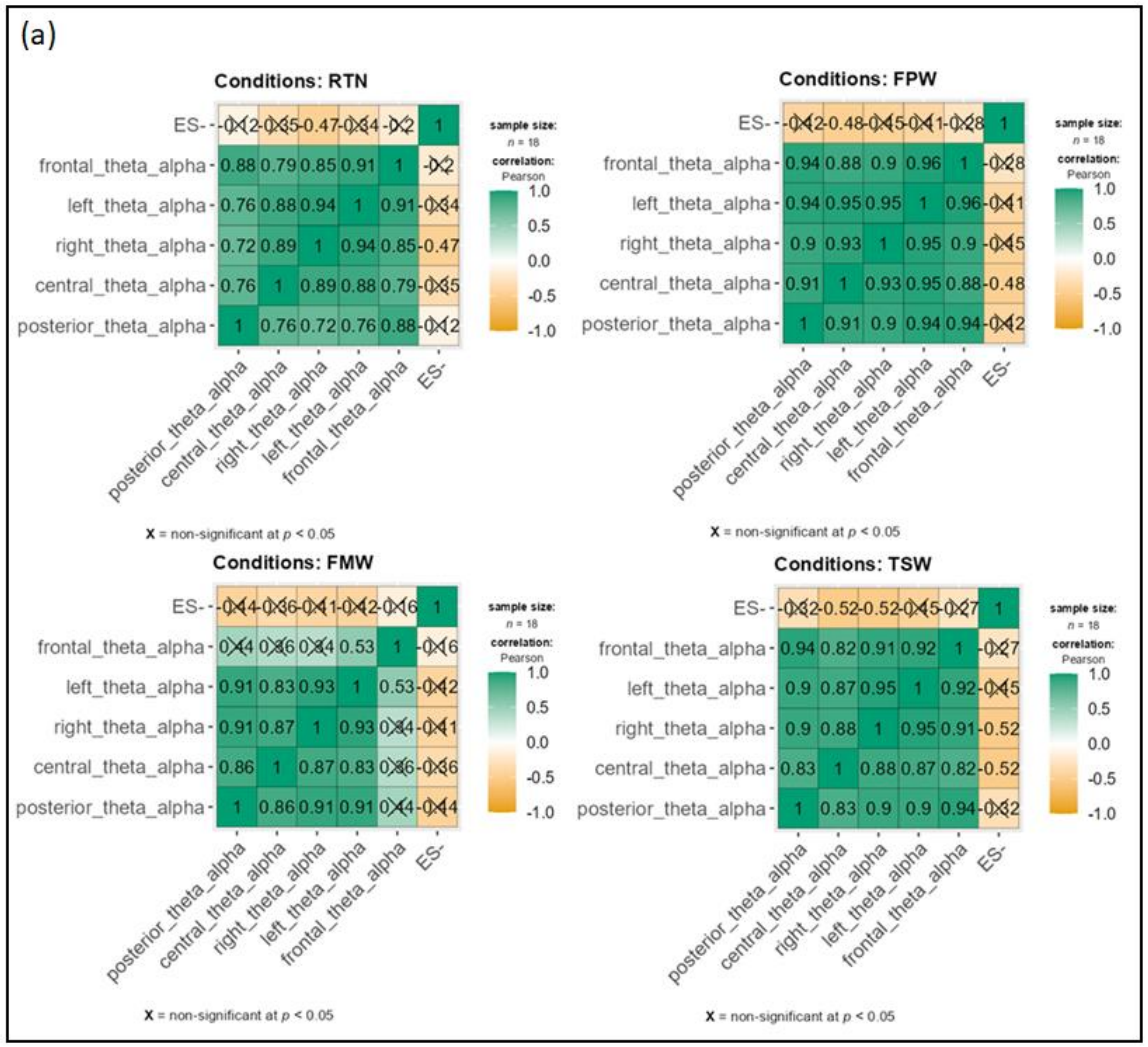


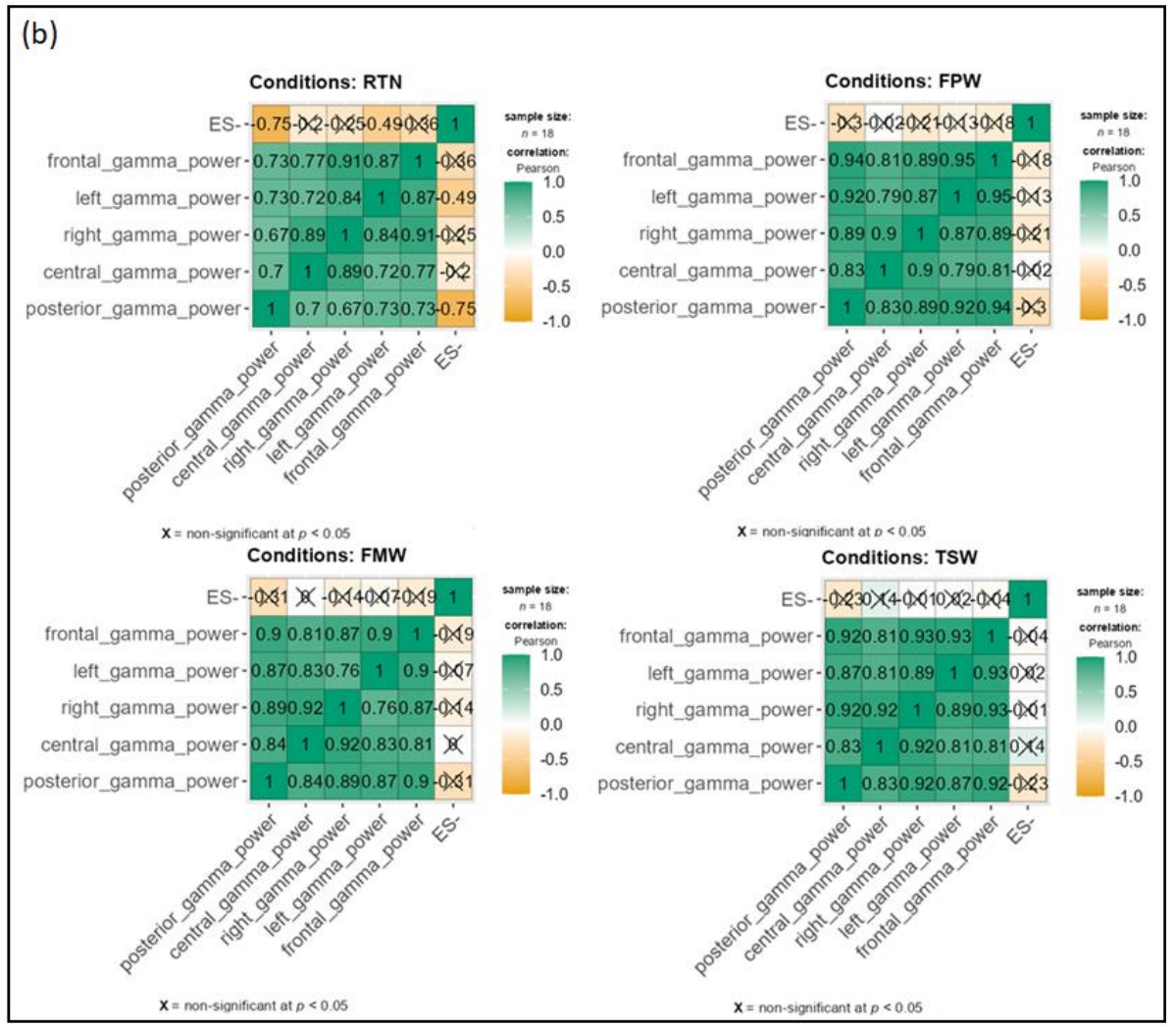
Results

2) The results of EEG spectral power across different conditions and brain regions

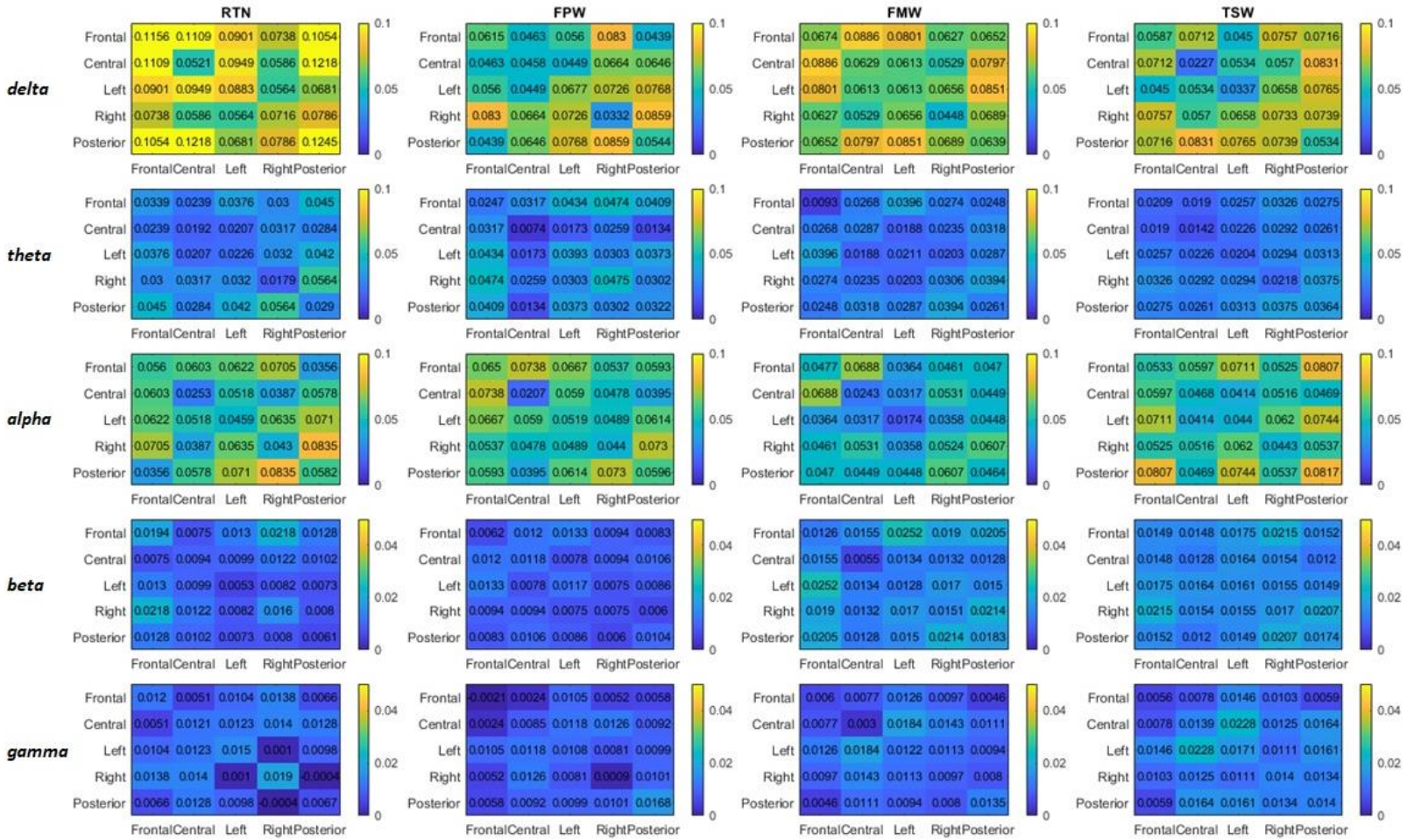


3) The correlation results of theta alpha ratio, gamma power and emotional salience

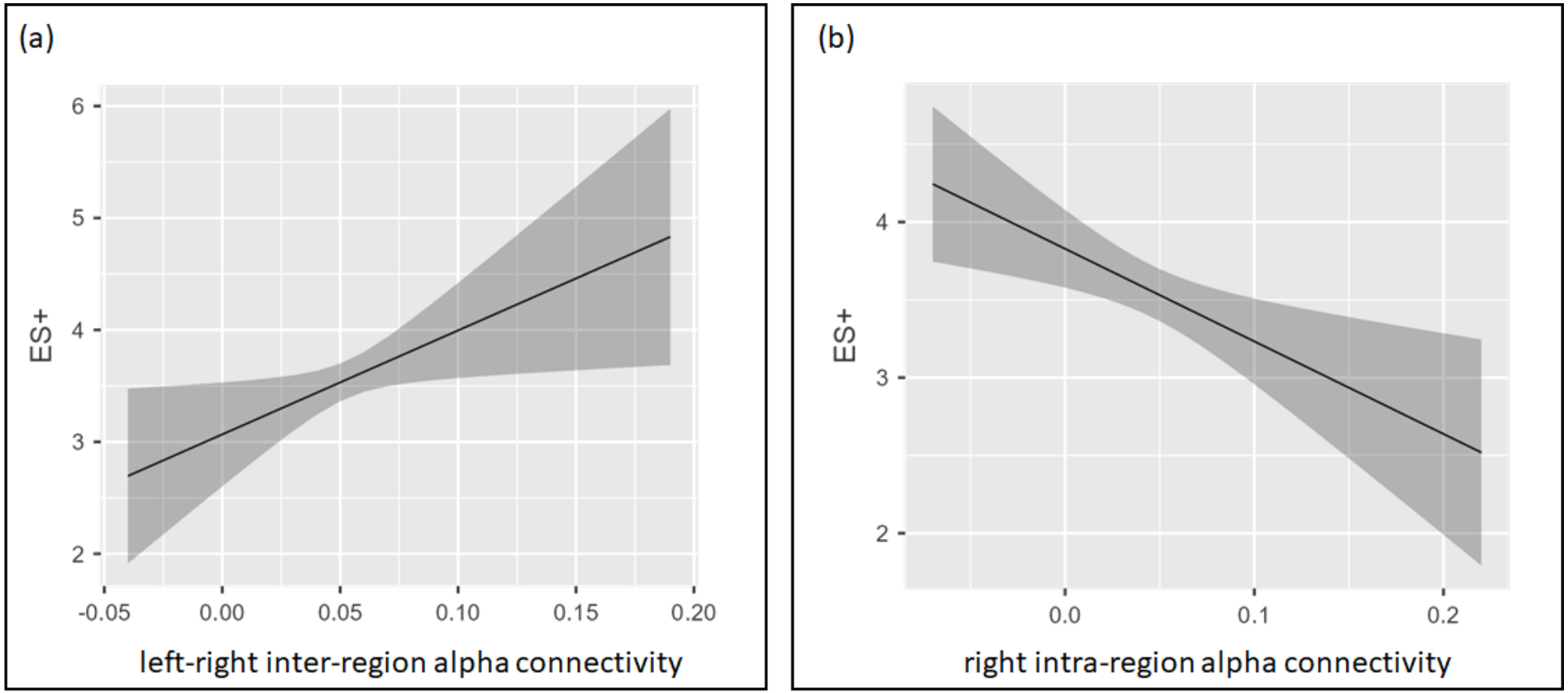




4) The results of connectivity analysis across different conditions and frequency bands



5) The correlation results of left-right alpha , intra-right alpha connectivities and emotional salience



Conclusions

1) the **mechanical** road traffic noise influenced both the **positive** and **negative** components of the emotional saliency. **Natural** features are inversely correlated to ES-.

2) the overall effects of the **alpha band** power revealed the positive effects of spatial settings react on ES+ scores, and the difference between **left-right inter-region** and **right intra-region alpha** connectivity related to the ES+ scores differently no matter of the water sound conditions or only traffic noise.

3) the spectral power of the **gamma band** and the **theta alpha ratios** used as the cognitive load index had shown relationship with the negative emotional salience that need further and deeper investigations.

End

Thank you!