Interacting Emotional and Cognitive Processes
Research Question

Emotion ← **Salience** / *Bottom-Up* → **Cognitive Resources** ← **Executive functions** / *Top-Down* → **Cognition**
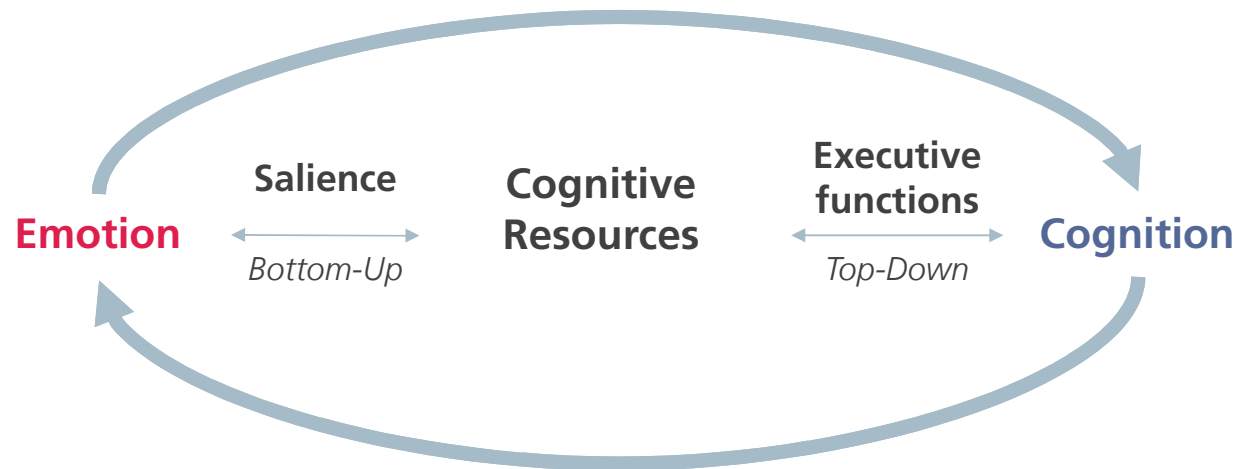
How and in what circumstances do cognitive states, like attention or cognitive load, top-down modulate emotional processing?

How do emotional stimuli affect cognitive processes, such as memory, attention, or executive functioning due to their salience and bottom-up effects?

Less Research in Naturalistic Environments Studying the Interaction of Multiple Load Levels and Emotions!

Interacting Emotional and Cognitive Processes
Bottom-Up and Top-Down Effects on Cognitive Resources
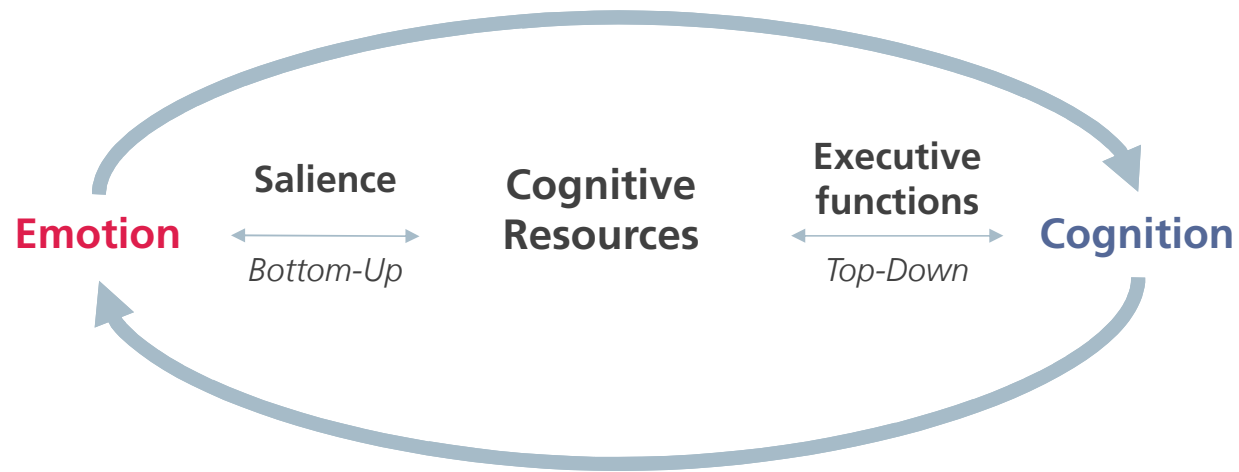
Emotion ⟷ **Salience** *Bottom-Up* ⟷ **Cognitive Resources** ⟷ **Executive functions** *Top-Down* ⟷ Cognition

71 kmh

Emotional speech affects visuo-spatial attention (Dolcos & Denkova, 2014; Dolcos et al., 2011)

Cognitive load modulates emotional speech processing (e.g., Zekveld et al., 2018)

If cognitive resources are available **prefrontal control mechanisms** prevent interference (Schweizer et al. 2019; Pacios et al. 2021).
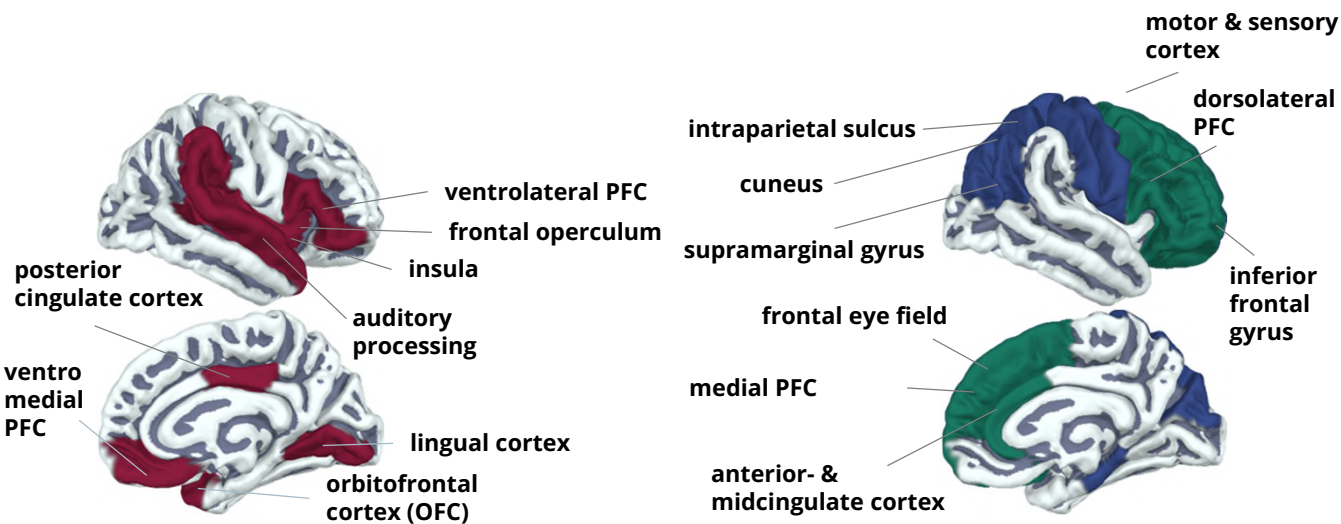
CARL VON OSSIETZKY UNIVERSITÄT OLDENBURG   ANCP   Fraunhofer IAO

Interacting Emotional and Cognitive Processes
Neurophysiological Basis

Emotion ←—— Salience ——→ Cognitive Resources ←—— Executive functions ——→ Cognition

Bottom-Up *Top-Down*

ventrolateral PFC
frontal operculum
insula
posterior cingulate cortex
auditory processing
ventro medial PFC
lingual cortex
orbitofrontal cortex (OFC)

motor & sensory cortex
intraparietal sulcus
dorsolateral PFC
cuneus
supramarginal gyrus
inferior frontal gyrus
frontal eye field
medial PFC
anterior- & midcingulate cortex

Emotional speech affects visuo-spatial attention (Dolcos & Denkova, 2014; Dolcos et al., 2011)

Cognitive load modulates emotional speech processing (e.g., Zekveld et al., 2018)

If cognitive resources are available **prefrontal control mechanisms prevent interference** (Schweizer et al. 2019; Pacios et al. 2021).

Neuroergonomic power indices
frontal θ / parietal α
(Gevins et al., 1995; Raufi & Longo, 2022)
lateralized α
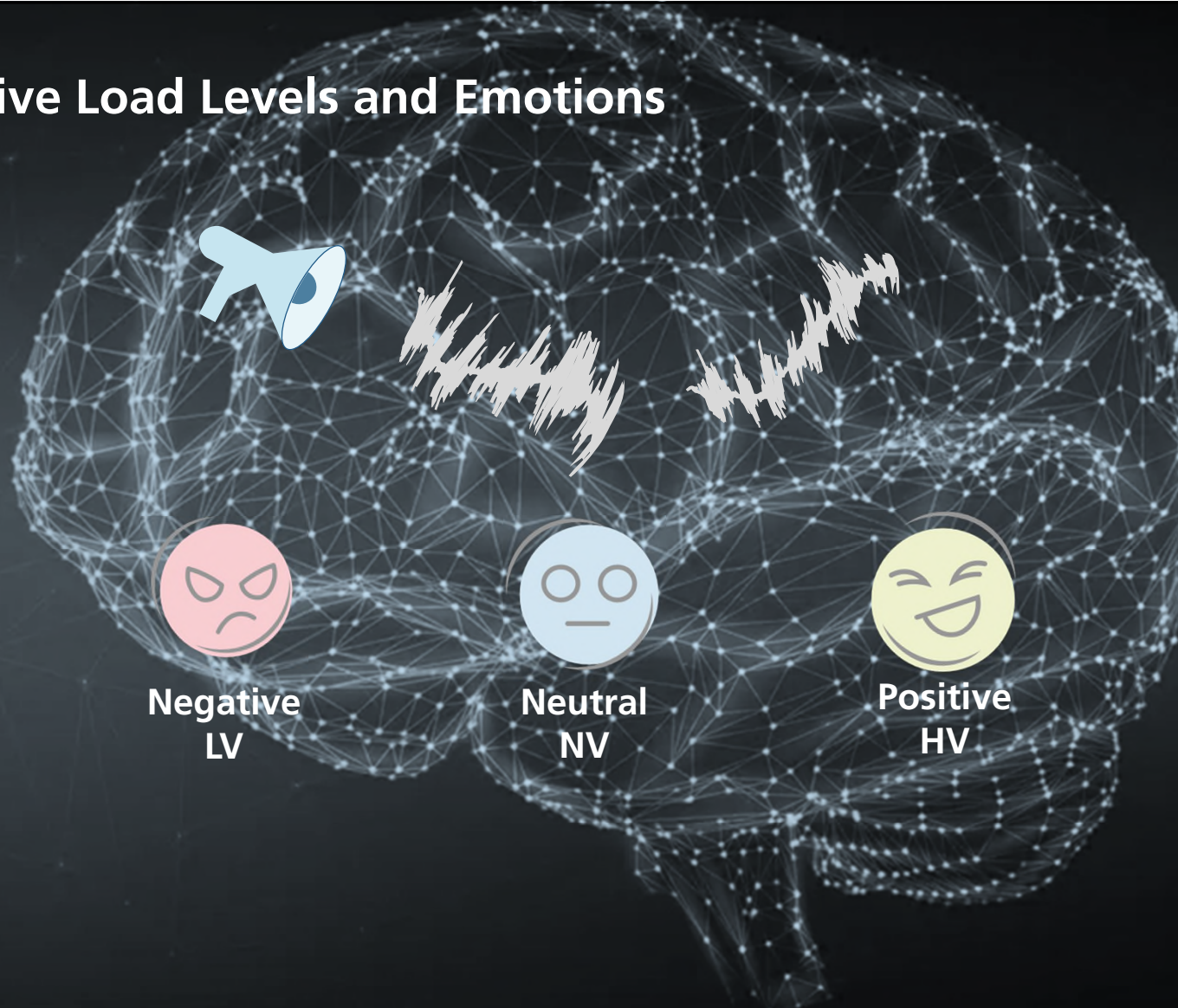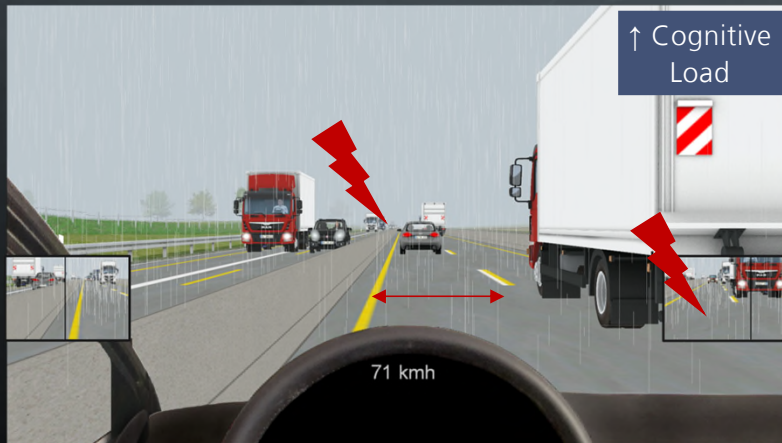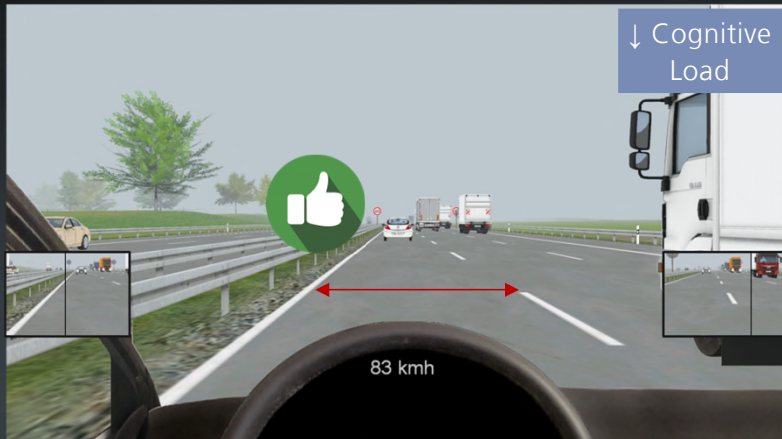(Ahern & Schwartz, 1985; Smith et al., 2017)

Manipulating Multiple Cognitive Load Levels and Emotions

↓ Cognitive Load

83 kmh

↑ Cognitive Load

71 kmh

Negative
LV

Neutral
NV

Positive
HV

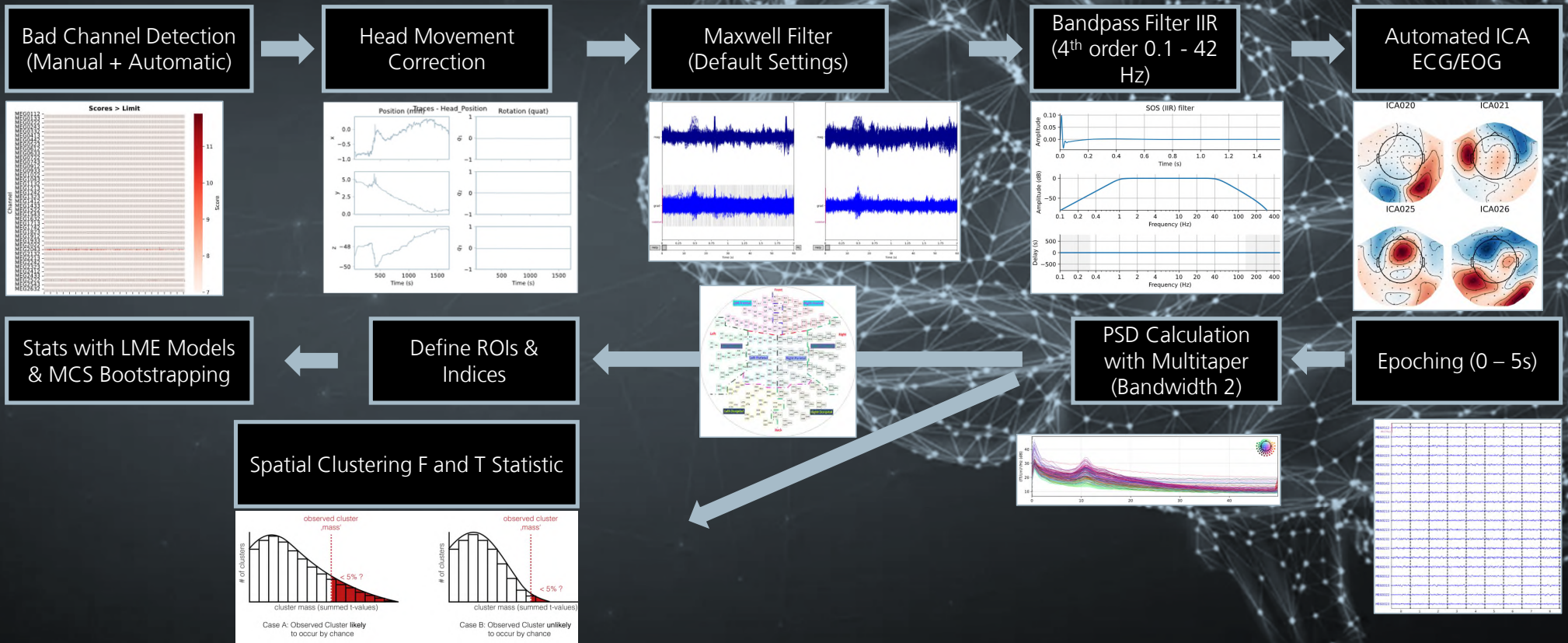CARL VON OSSIETZKY
UNIVERSITÄT
OLDENBURG

ANCP

Fraunhofer
IAO

Magnetoencephalography Study: Emotional Speech and Simulated Driving

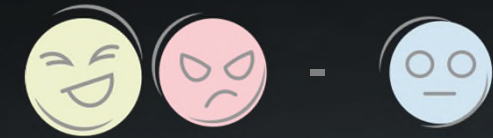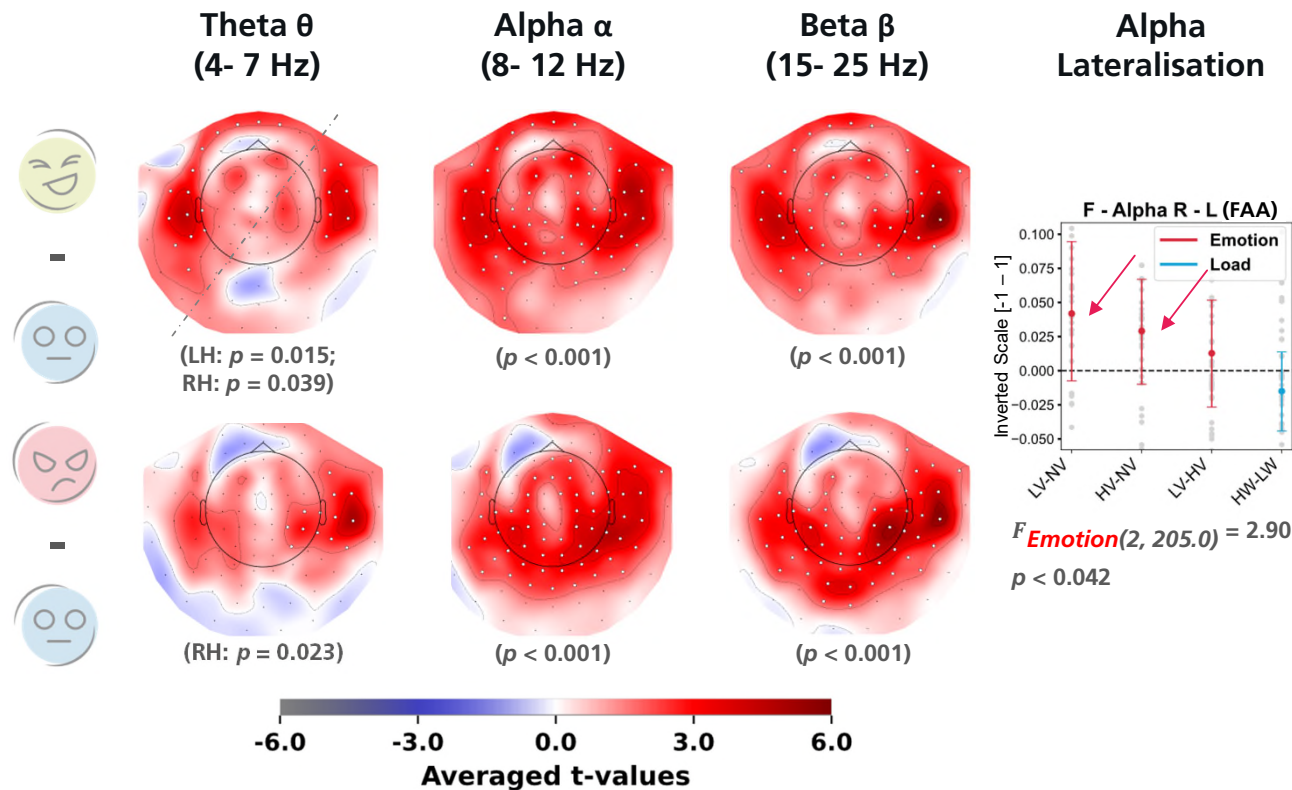**Within-Subject Block Design with N_{total} = 48 (M_{age}= 25.25 ± 4.01)**

Preprocessing and Analysis Pipeline

Bad Channel Detection (Manual + Automatic) → Head Movement Correction → Maxwell Filter (Default Settings) → Bandpass Filter IIR (4th order 0.1 - 42 Hz) → Automated ICA ECG/EOG

Stats with LME Models & MCS Bootstrapping ← Define ROIs & Indices ← PSD Calculation with Multitaper (Bandwidth 2) ← Epoching (0 – 5s)

Spatial Clustering F and T Statistic

Source: https://benediktehinger.de/blog/science/statistics-cluster-permutation-test/

CARL VON OSSIETZKY UNIVERSITÄT OLDENBURG
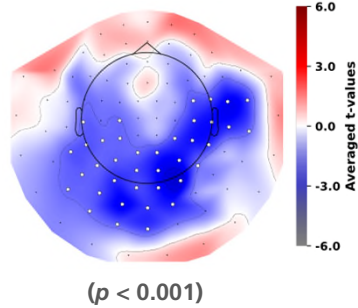
ANCP

Fraunhofer IAO

Oscillatory Signatures of Cognitive Load
Increased Visual Processing to Maintain Task Performance

↑ Cognitive Load

-

↓ Cognitive Load

Beta β (15- 25 Hz)

(*p* < 0.001)

Neuroergonomic Index

F - Theta / P - Alpha (WI)

Emotion
Load

Normalized Scale [-1 – 1]

0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03

LV-NV   HV-NV   LV-HV   HW-LW
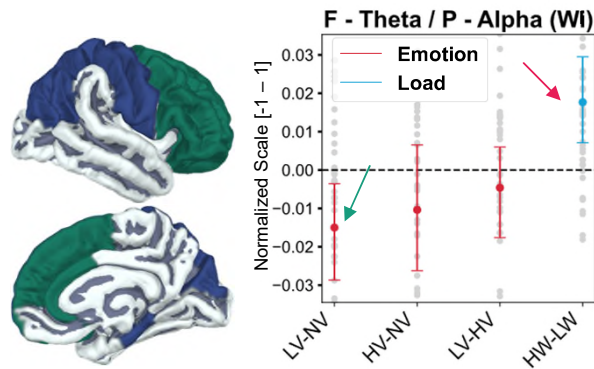
$F_{Load}(1, 205) = 10.21, p = 0.002$

$F_{Emotion}(2, 205) = 2.58, p = 0.078$ (n.s)

WHAT? WHERE? WHY? WHEN?

Is there an **Emotion-Cognition Interaction**?

↑ Cognitive Load

-

↓ Cognitive Load

↓ Occipito-parietal β

Enhanced Visual Processing
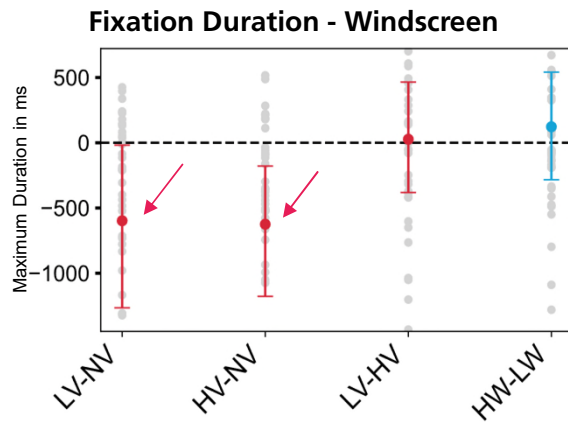**(Liu et al., 2023)**

Reduced Functional Inhibition
(Liu et al., 2023)

↑ Increased Load Index

but also

Emotion Effect: ↑ Increased Load Index

CARL VON OSSIETZKY UNIVERSITÄT OLDENBURG   ANCP   Fraunhofer IAO

Benefit of Measuring Multimodal
Insights from Fixations on Region of Interest

Fixation Duration - Windscreen

$F_{Emotion}(2, 203.98) = 4.64, p < 0.011$

Fixation Duration – Right Mirror
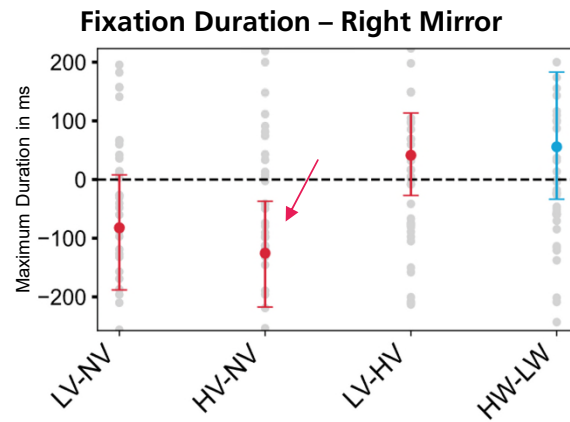
$F_{Emotion}(2, 199.18) = 4.84, p < 0.009$

↑ **Dynamic Gaze Behaviour**

vs.
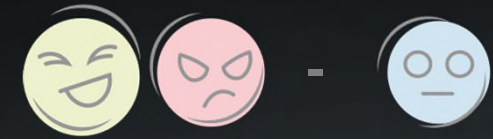
Sleepily Staring Ahead?

↑ **Cognitive Demand?**

Multimodal Evidence for the Interaction
Negative Emotional Conversations Matter

Emotion Effect   **Cognitive Load Effect**   **Interaction Effect**

≈   ↑ Cognitive Load

Pupil Dilation

Legend:
— Low Load (LW) - Valence Effect
— High Load (HW) - Valence Effect
— Load Effect (HW-LW)

y-axis: in mm (0.15, 0.10, 0.05, 0.00, -0.05, -0.10, -0.15)

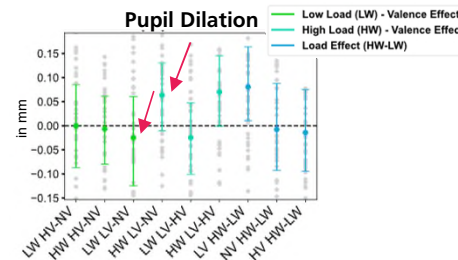x-axis: LW HV-NV, HW HV-NV, LW LV-NV, HW LV-NV, LW LV-HV, HW LV-HV, LV HW-LW, NV HW-LW, HV HW-LW

Duration Dashboard: $F_{Load(1, 205)}$ = 7.00, p < 0.009
Duration Left Mirror: $F_{Load(1, 201.21)}$ = 13.02, p < 0.001
Count Windscreen: $F_{Load(1, 203.94)}$ = 33.09, p < 0.001

$F_{Interaction(2, 205)}$ = 7.00, p < 0.027

↑ Cognitive Load

Valence   **Effort**

Normalized Scale [-1 – 1] (0.15, 0.10, 0.05, 0.00, -0.05, -0.10, -0.15, -0.20)
x-axis: LV-NV, HV-NV, LV-HV, HW-LW

General Frustration

Normalized Scale [-1 – 1] (0.2, 0.0, -0.2)
x-axis: LW HV-NV, HW HV-NV, LW LV-NV, HW LV-NV, LW LV-HV, HW LV-HV, LV HW-LW, NV HW-LW, HV HW-LW

$F_{Interaction(2, 235)}$ = 4.26, p < 0.015

Valence: $F_{Emotion(2, 235)}$ = 14.53, p < 0.001
$F_{Load(1, 235)}$ = 16.04, p < 0.001
Effort: $F_{Emotion(2, 235)}$ = 7.87, p < 0.001
$F_{Load(1, 235)}$ = 30.99, p < 0.001

VS.

↓ Dynamic gaze behaviour & ↑ Pupil Dilation indicates limited cognitive resources
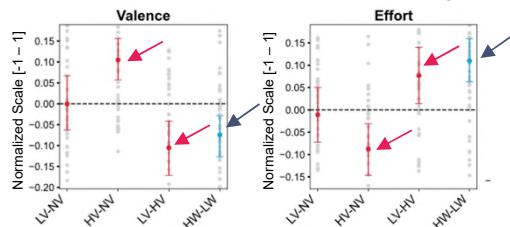
↓ Cognitive Load   ↑ Cognitive Load

When sufficient cognitive resources are available negative emotional speech is specifically processed and preferred over neutral speech!

Social Cognition (Keysers & Gazzola, 2006)

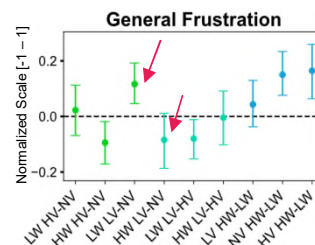Gathering Socio-Emotional Information (Rosnow, 2001; Peters et al., 2009)

CARL VON OSSIETZKY UNIVERSITÄT OLDENBURG   ANCP   Fraunhofer IAO

Take Home Message

Emotional speech trigger **specific processing modes** to optimize information processing and the demand on cognitive resources.
- α based gating mechanisms & lateralized processing
- fronto-temporal theta social cognition

When **cognitive resources** are **available**, task-irrelevant **emotional speech** is **preferred** to neutral speech because it may still contain potentially **valuable social information**. When cognitive resources are scarce, negative emotional conversation are more cognitively demanding compared due neutral speech.

Multimodal measures allow for coherent evidence and facilitate inference about underlying cognitive processes in naturalistic (less controlled) scenarios.

The End ;)

[1] Ahern, G. L., & Schwartz, G. E. (1985). Differential lateralisation for positive and negative emotion in the human brain: EEG spectral analysis. Neuropsychologia 23, 745–755.

[2] Dolcos, F., Iordan, A. D., & Dolcos, S. (2011). Neural correlates of emotion-cognition interactions: A review of evidence from brain imaging investigations. Journal of Cognitive Psychology (Hove, England), 23(6), 669–694.

[3] Fellrath, J., Mottaz, A., Schnider, A., Guggisberg, A. G., & Ptak, R. (2016). Theta-band functional connectivity in the dorsal fronto-parietal network predicts goal-directed attention. Neuropsychologia, 92, 20–30.

[4] Gevins, A., Leong, H., Du, R., Smith, M. E., Le, J., DuRousseau, D., Zhang, J., & Libove, J. (1995). Towards measurement of brain function in operational environments. Biological Psychology, 40(1-2), 169–186. https://doi.org/10.1016/0301-0511(95)05105-8

[5] Güntürkün, O., Ströckens, F., & Ocklenburg, S. (2020). Brain lateralization: a comparative perspective. *Physiological reviews*.

[6] Keysers, C., & Gazzola, V. (2006). Towards a unifying neural theory of social cognition. *Progress in brain research*, *156*, 379-401.

[7] Rosnow, R. L. (2001). Rumor and gossip in interpersonal interaction and beyond: A social exchange perspective. In R. M. Kowalski (Ed.), *Behaving badly: Aversive behaviors in interpersonal relationships* (pp. 203–232). American Psychological Association.

[8] Peters, K., Kashima, Y., & Clark, A. (2009). Talking about others: Emotionality and the dissemination of social information. *European Journal of Social Psychology*, *39*(2), 207-222.

[9] Pavlov, Y. G., & Kotchoubey, B. (2022). Oscillatory brain activity and maintenance of verbal and visual working memory: A systematic review. *Psychophysiology*, *59*(5), e13735.

[10] Kam, J. W. Y., Lin, J. J., Solbakk, A. K., Endestad, T., Larsson, P. G., & Knight, R. T. (2019). Default network and frontoparietal control network theta connectivity supports internal attention. Nat Hum Behav 3, 1263–1270.

[11] Klimesch, W., Sauseng, P., & Hanslmayr, S. (2007): EEG alpha oscillations: the inhibition-timing hypothesis. In: Brain research reviews 53 (1), S. 63–88. DOI: 10.1016/j.brainresrev.2006.06.003.

[12] Lettieri, G., Handjaras, G., Ricciardi, E., Leo, A., Papale, P., Betta, M., Pietrini, P., & Cecchetti, L. (2019). Emotionotopy in the human right temporo-parietal cortex. Nature communications, 10(1), 5568. https://doi.org/10.1038/s41467-019-13599-z

[13] Lin, C. T., Chen, S. A., Chiu, T. T., Lin, H. Z., & Ko, L. W. (2011). Spatial and temporal EEG dynamics of dual-task driving performance. Journal of neuroengineering and rehabilitation, 8, 11.

[14[Lingelbach, K., Vukelić, M., & Rieger, J. W. (2023). GAUDIE: Development, validation, and exploration of a naturalistic German AUDItory Emotional database. Behav Res.

[15] Liu, R., Qi, S., Hao, S., Lian, G. & Luo, Y. (2023) Using electroencephalography to analyse drivers' different cognitive workload characteristics based on on-road experiment. Front. Psychol. 14:1107176. doi: 10.3389/fpsyg.2023.1107176

[16] Lowe, C. J., Manocchio, F., Safati, A. B., & Hall, P. A. (2018). The effects of theta burst stimulation (TBS) targeting the prefrontal cortex on executive functioning: a systematic review and meta-analysis. Neuropsychologia, 111, 344-359.

[17] Schweizer, S., Satpute, A. B., Atzil, S., Field, A. P., Hitchcock, C., Black, M., Barrett, L. F., & Dalgleish, T. (2019). The impact of affective information on working memory: A pair of meta-analytic reviews of behavioral and neuroimaging evidence. Psychological Bulletin, 145(6), 566–609.

[18] Smith, E. E., Reznik, S. J., Stewart, J. L., & Allen, J. J. B. (2017). Assessing and conceptualizing frontal EEG asymmetry: An updated primer on recording, processing, analyzing, and interpreting frontal alpha asymmetry. Int J Psychophysiol 111, 98–114.

[19]Zekveld, A. A., Koelewijn, T., & Kramer, S. E. (2018). The pupil dilation response to auditory stimuli: Current state of knowledge. *Trends in hearing*, 22.

Interested in Collaborating? Just Get in Touch!

Contact

—

Katharina Lingelbach
Applied Neurocognitive Systems & Psychology
Fraunhofer IAO, University of Oldenburg
katharina.lingelbach@iao.fraunhofer.de