

Frontal Alpha Activity And Its Dynamic Modulation During Cognitive Pain Processing and In Chronic Pain

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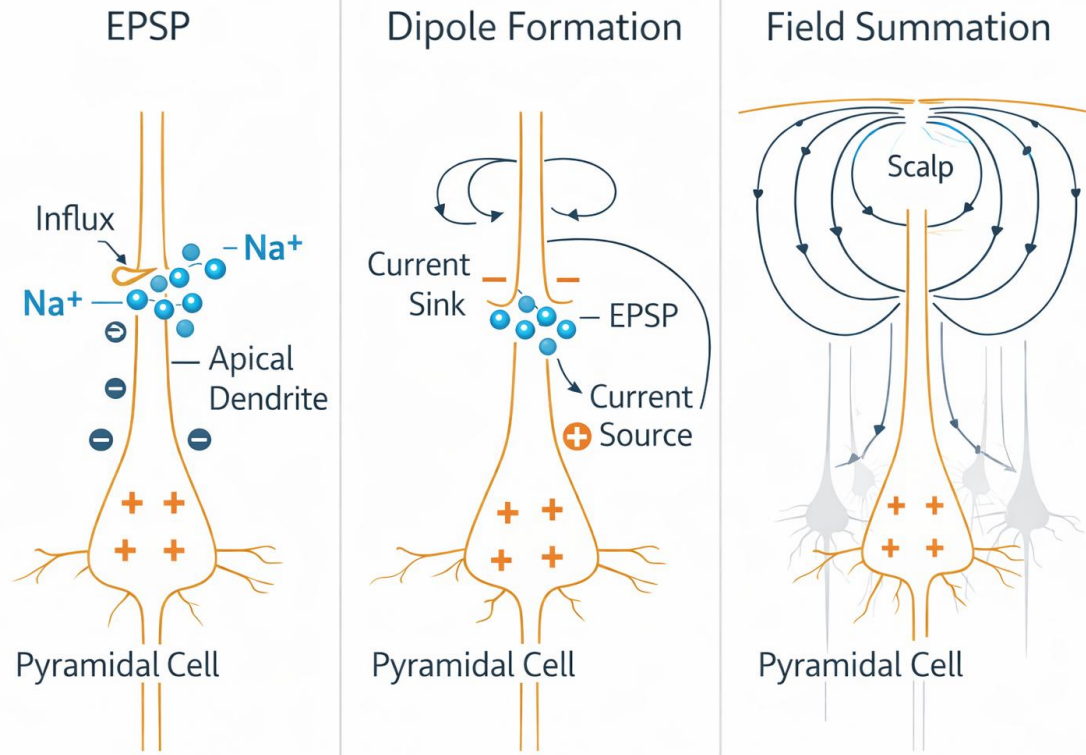
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Role of EEG in Multimodal Pain Investigation



Electroencephalography (EEG) reflects large-scale synchronization of cortical postsynaptic currents.

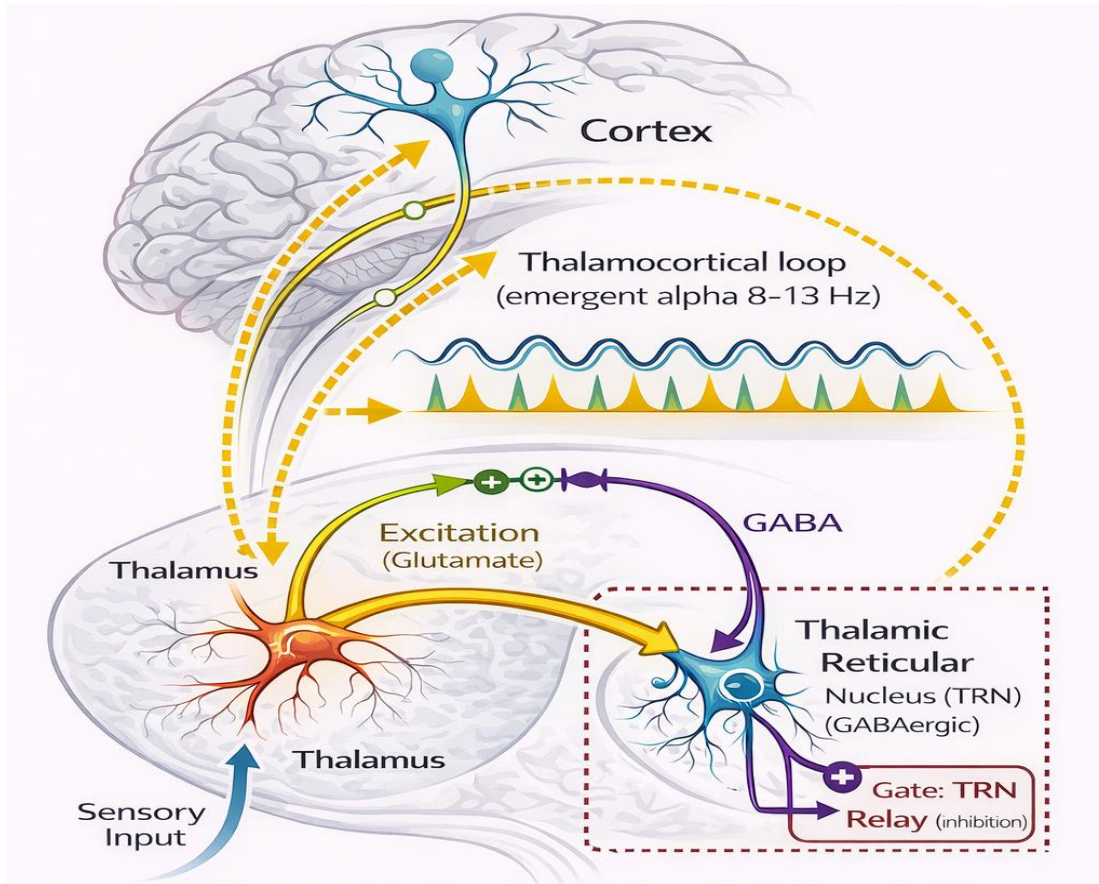
EEG-detectable brain waves

GAMMA WAVES ~30–100 Hz		Binding, high-level processing
BETA WAVES ~13–30 Hz		Active cognition
ALPHA WAVES ~8–12 Hz		Inhibitory gating, relaxed wakefulness
THETA WAVES ~4–8 Hz		Memory encoding, drowsiness
DELTA WAVES ~0.5–4 Hz		Slow-wave sleep, cortical downstates

Low-frequency oscillations, particularly alpha (8–13 Hz) are consistently implicated in pain processing.

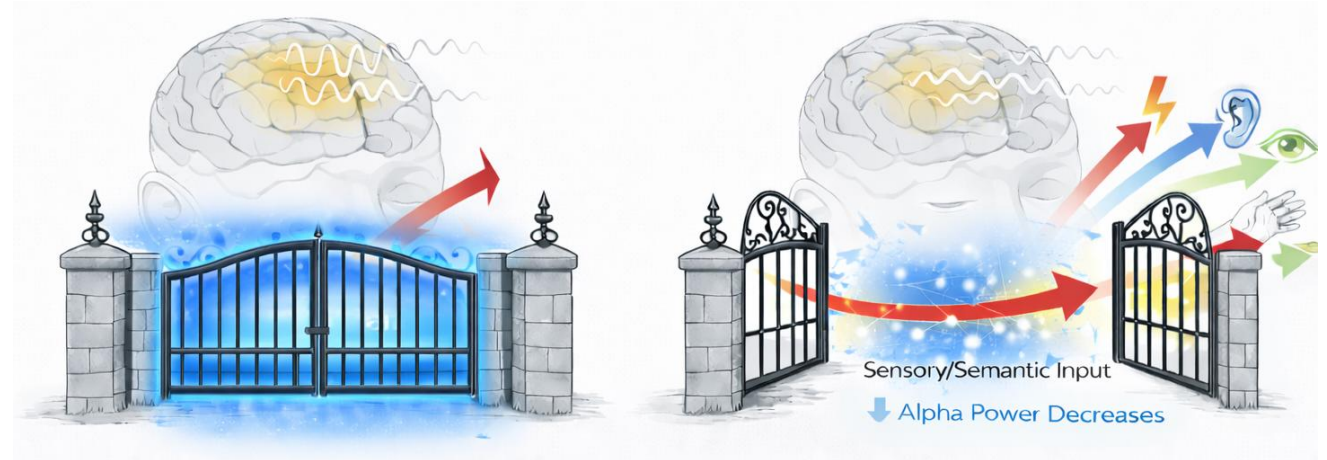
Role of alpha (8-13 Hz) in Pain Processing

Thalamocortical gating network



Alpha emerges from reciprocal interactions between thalamic relay neurons and cortex, regulated by rhythmic inhibition from the Thalamic reticular nucleus.

Alpha Power as a Gate



High alpha = Functional inhibition

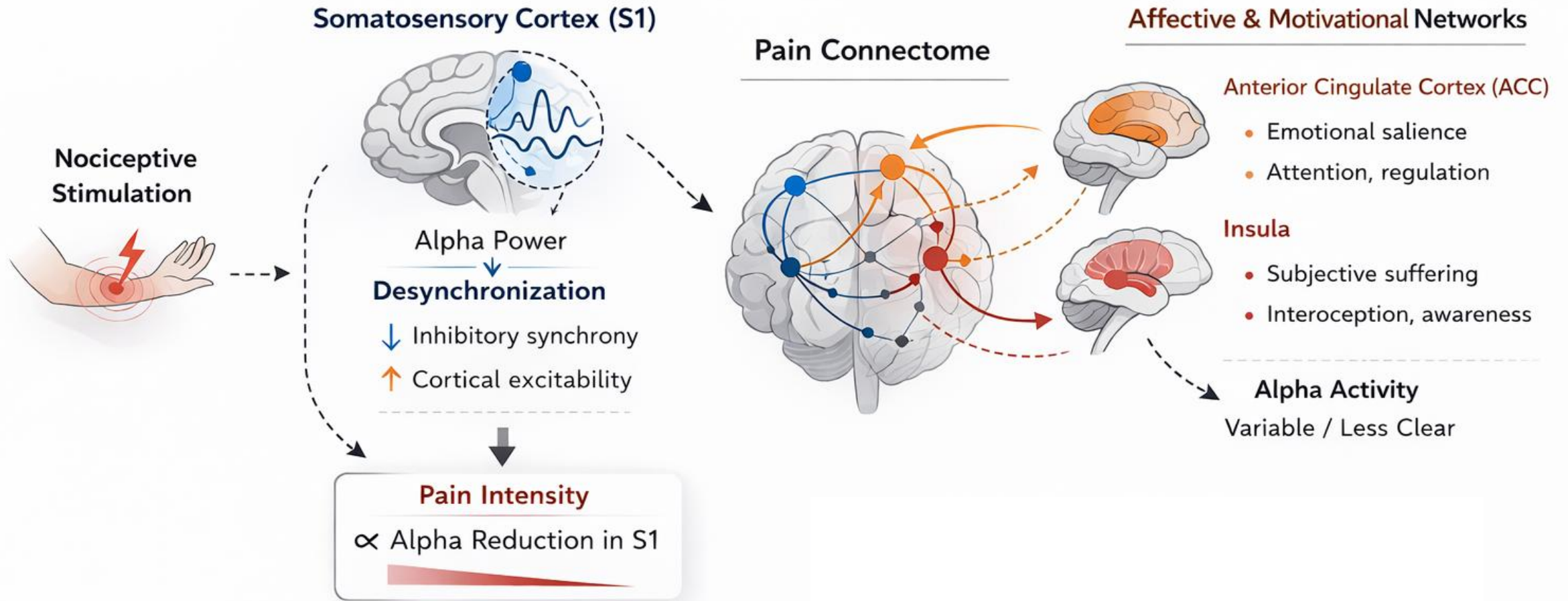
- Gate closed
- External input suppressed
- Internal processing stabilized
- Sensory gain controlled

Low alpha = Cortical excitability

- Gate open
- Auditory, visual and tactile information input processed
- Information flow sustained

Functionally, alpha operates as an inhibitory gating mechanism.

Role of Alpha: From Sensory Input to Subjective Experience

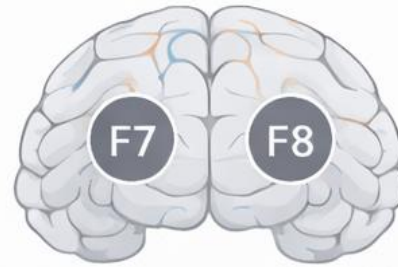


Hypothesis

Frontal alpha is differentially modulated in sensory–discriminative and affective–motivational pain processing.

Specific aim 1

To characterize alpha oscillations in isolated conditions of sensory–discriminative and affective–motivational dimensions of pain, and their interaction.



Frontal Alpha
(8–13 Hz)
(F7/F8)

Specific aim 2

To examine frontal alpha modulation across these conditions in chronic pain (knee osteoarthritis) and control populations

Sensory–Discriminative

Cold / Nociceptive Input

Affective–Motivational

Sensory and Affective Words

Control

vs

Osteoarthritis

High-Density EEG Acquisition and Frontal Alpha Analysis

Participants

- Knee osteoarthritis (OA): $n = 9$, Healthy control: $n = 20$

EEG Acquisition

- 256-channel EEG (Magstim EGI)
- Continuous recording in **four time-bins**

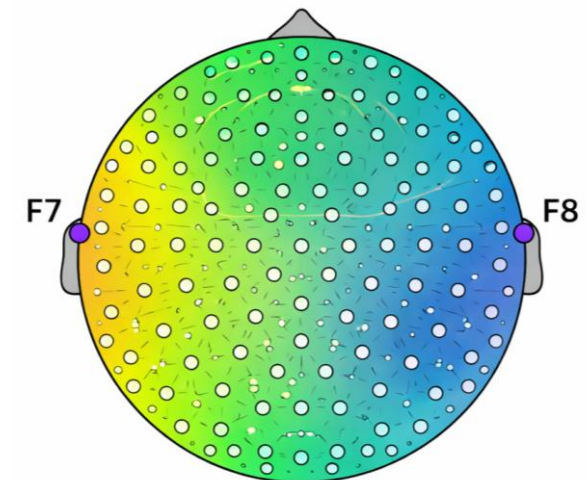
Signal Processing

- Preprocessing and artifact rejection conducted in NetStation.
- Alpha power (8–13 Hz) extracted using wavelet-based time–frequency decomposition.

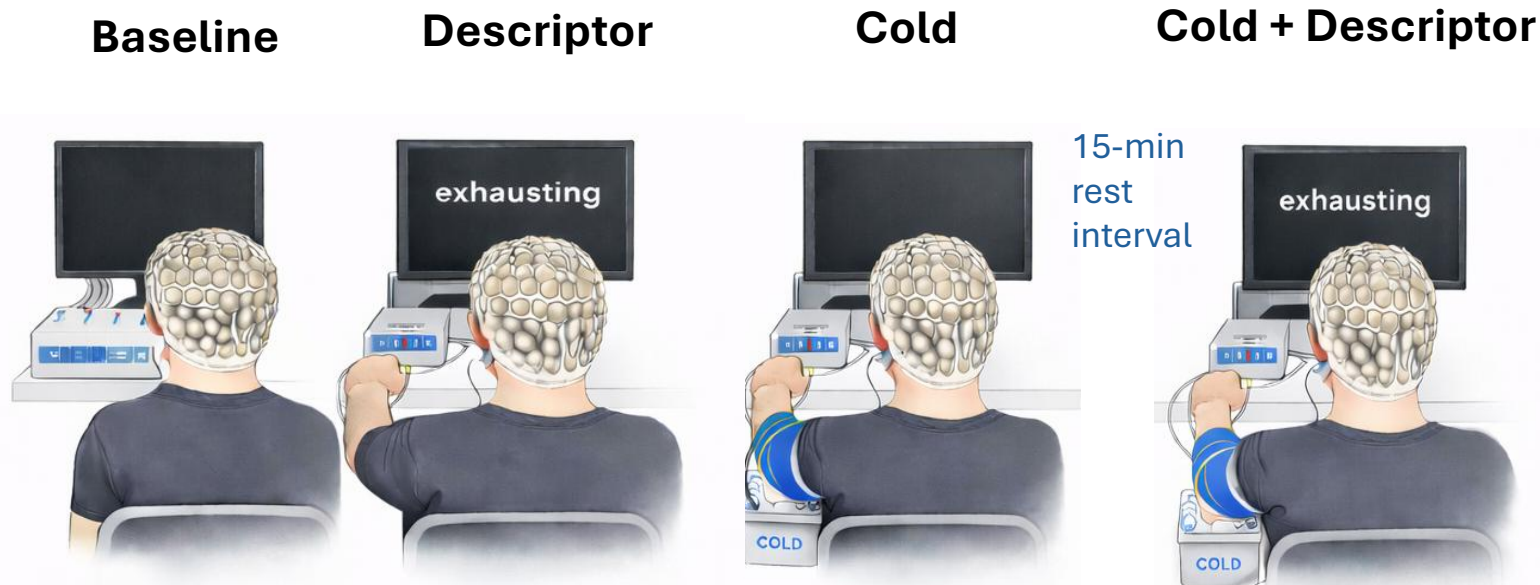
Regions of Interest: F7 and F8

Statistical Analysis

- Mixed-model repeated-measures Anova
Within-subject factor: Time bins
Between-subject factor: group (OA vs control)



Experimental Design: Cold Pain × Pain Descriptor Manipulation



Continuous high-density EEG acquisition across four conditions/Time bins



McGill-derived Pain Descriptors

Sensory (n = 5)

- Gnawing
- Aching
- Throbbing
- Shooting
- Sharp

Perceptual quality



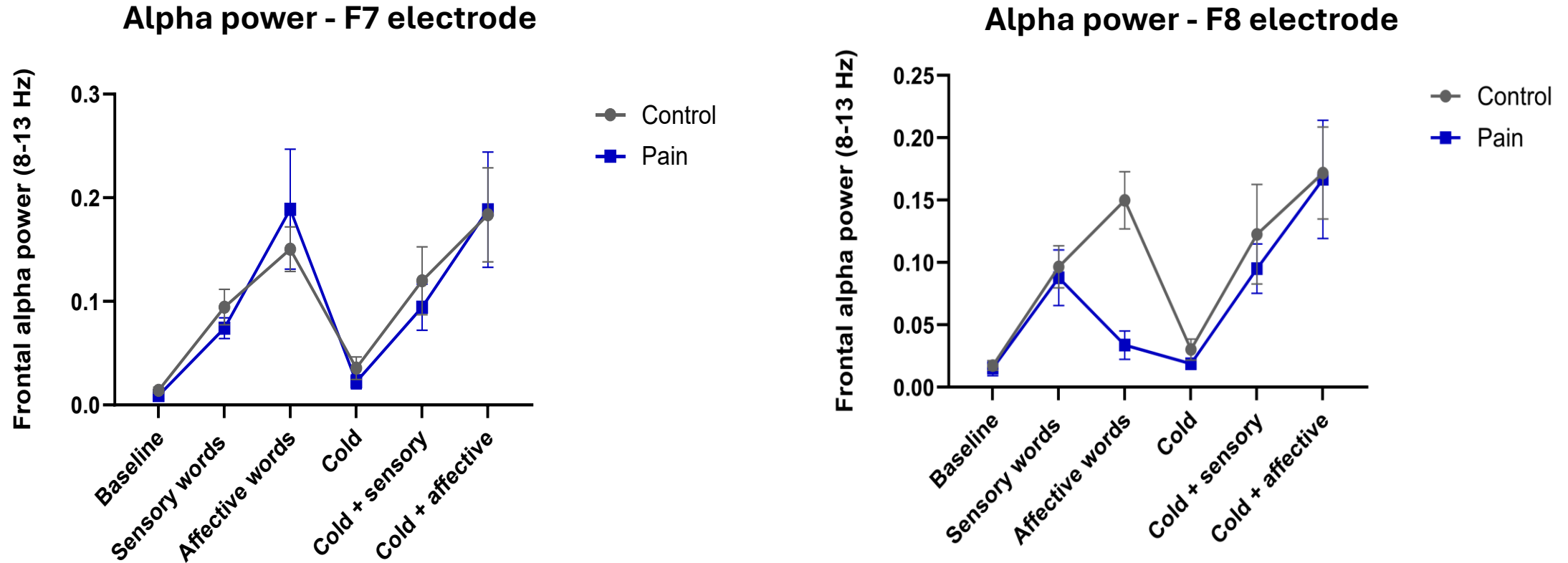
Affective (n = 4)

- Sickening
- Punishing
- Exhausting
- Fearful

Emotional salience



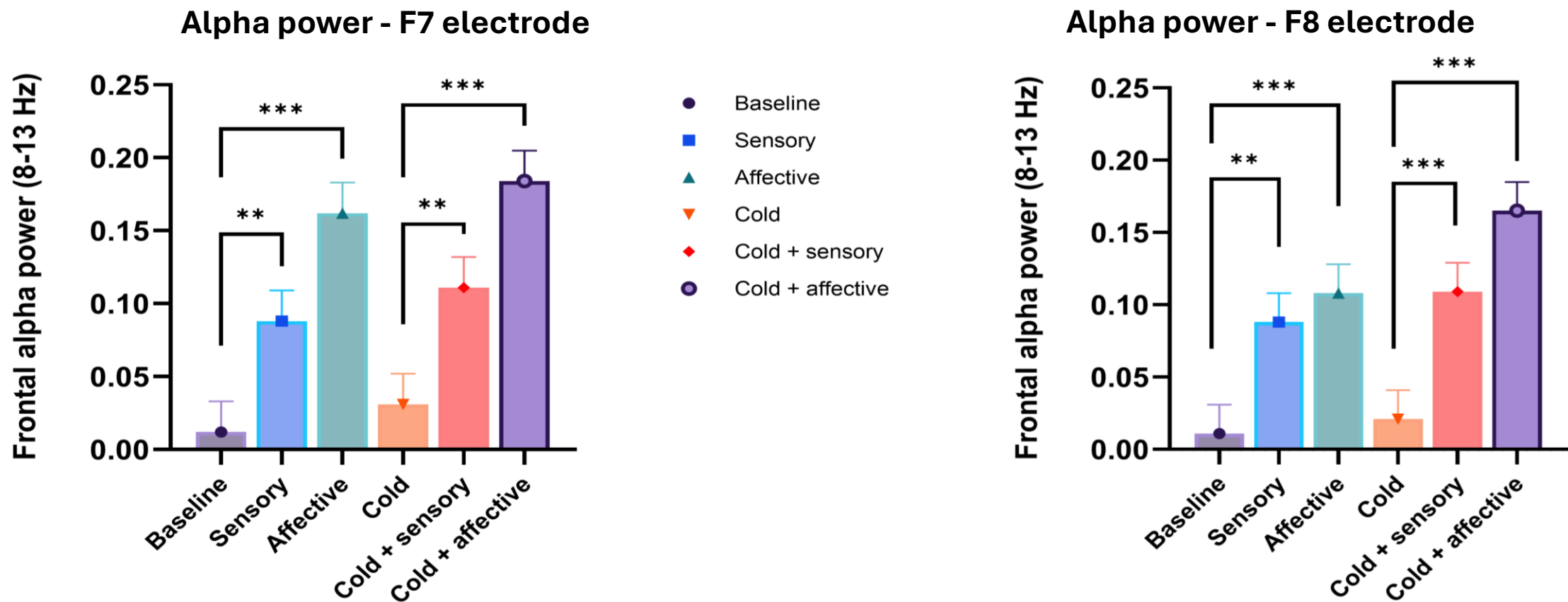
Alpha power was not differentially modulated in chronic pain



No significant main effect of group or group × condition interaction at F7 or F8.

Gray = Control | Blue = Chronic pain | Error bars = SEM

Cognitive Evaluation of Pain Descriptors Drives Frontal Alpha Modulation

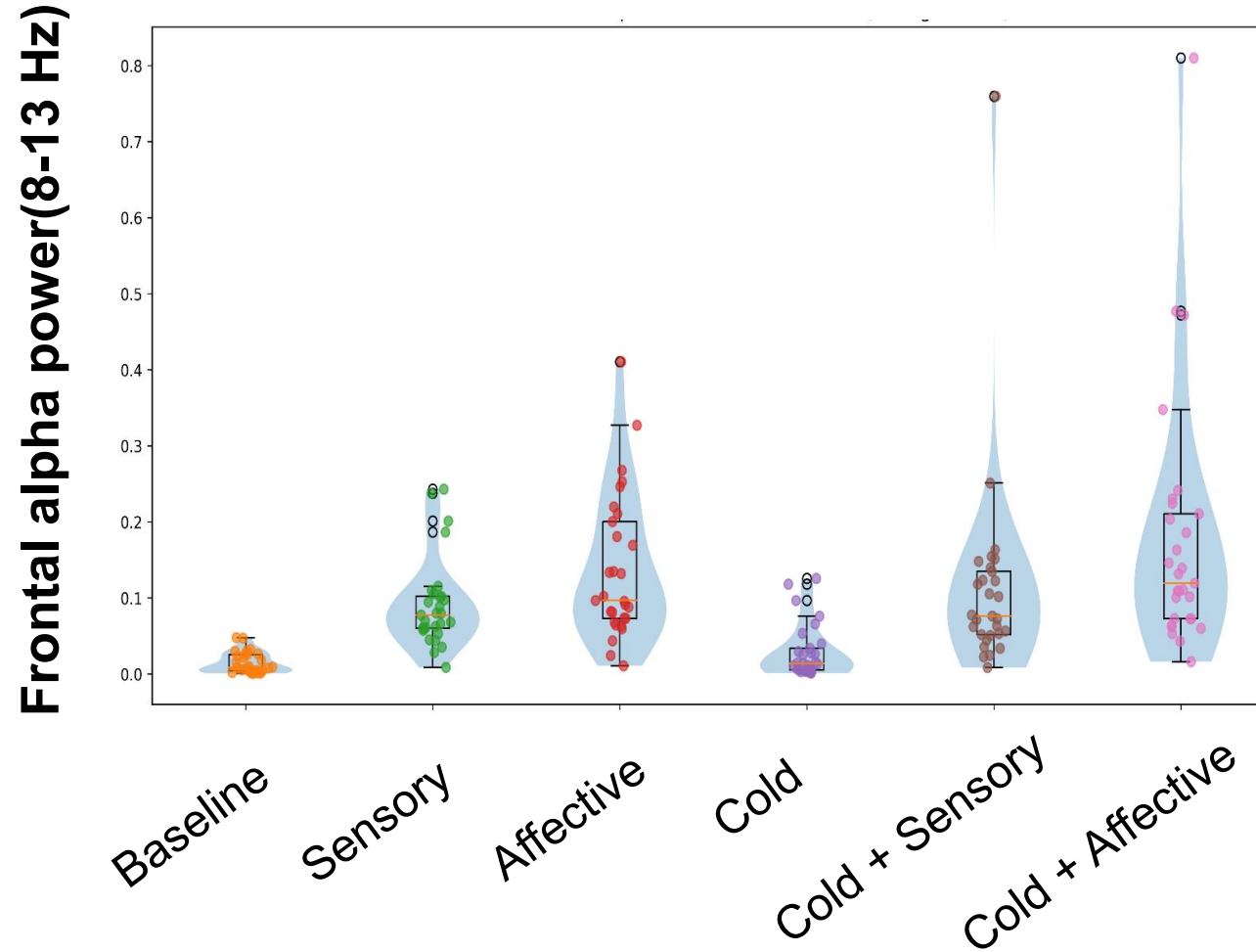


Frontal alpha (8–13 Hz) increases during descriptor evaluation, with maximal modulation during cold + affective conditions.

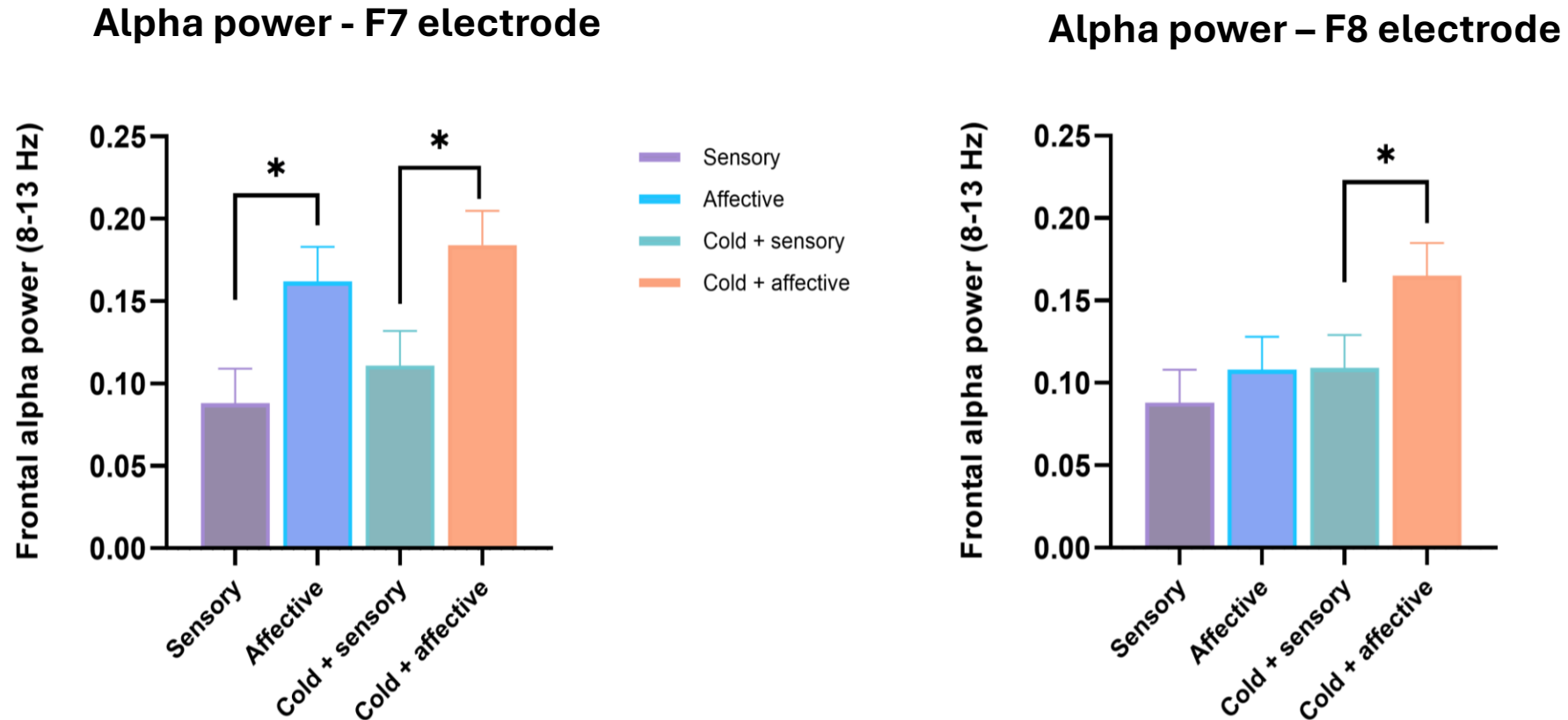
Mean ± SEM alpha power at F7 (left) and F8 (right) across conditions.
Within-subject contrasts: ** $p < .01$, *** $p < .001$

Distribution of frontal alpha across conditions

Distribution of frontal alpha power across conditions (Averaged F7/F8 electrodes)



Affective descriptors elicit highest alpha modulation

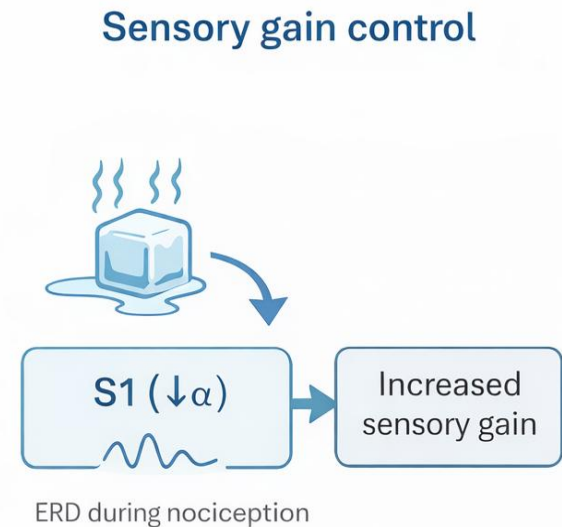


Affective descriptors produced significantly greater alpha power than sensory descriptors in neutral and cold conditions ($p < .05$, Bonferroni-corrected).

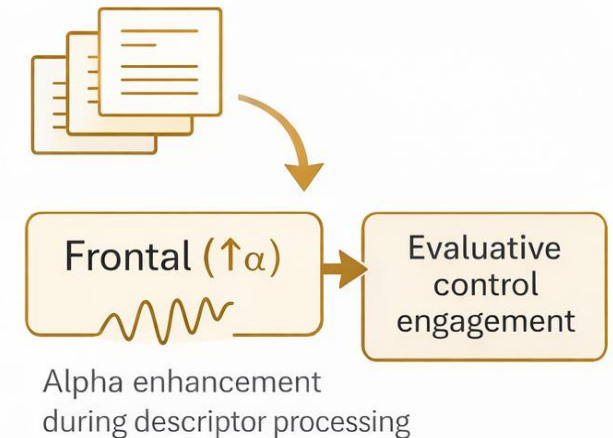
Statistics reflect within-subject planned contrasts from linear mixed model

Summary and interpretation

- Cold alone $\approx$ no frontal alpha change
 - Alpha $\uparrow$ during descriptor evaluation (affective > sensory)
 - Consistent with **top-down gating / controlled access** during internally directed appraisal
 - Stabilization of task-relevant evaluation
- **Contrast:** S1 alpha often reflects **sensory gain control**
- **Frontal alpha may index engagement control.**

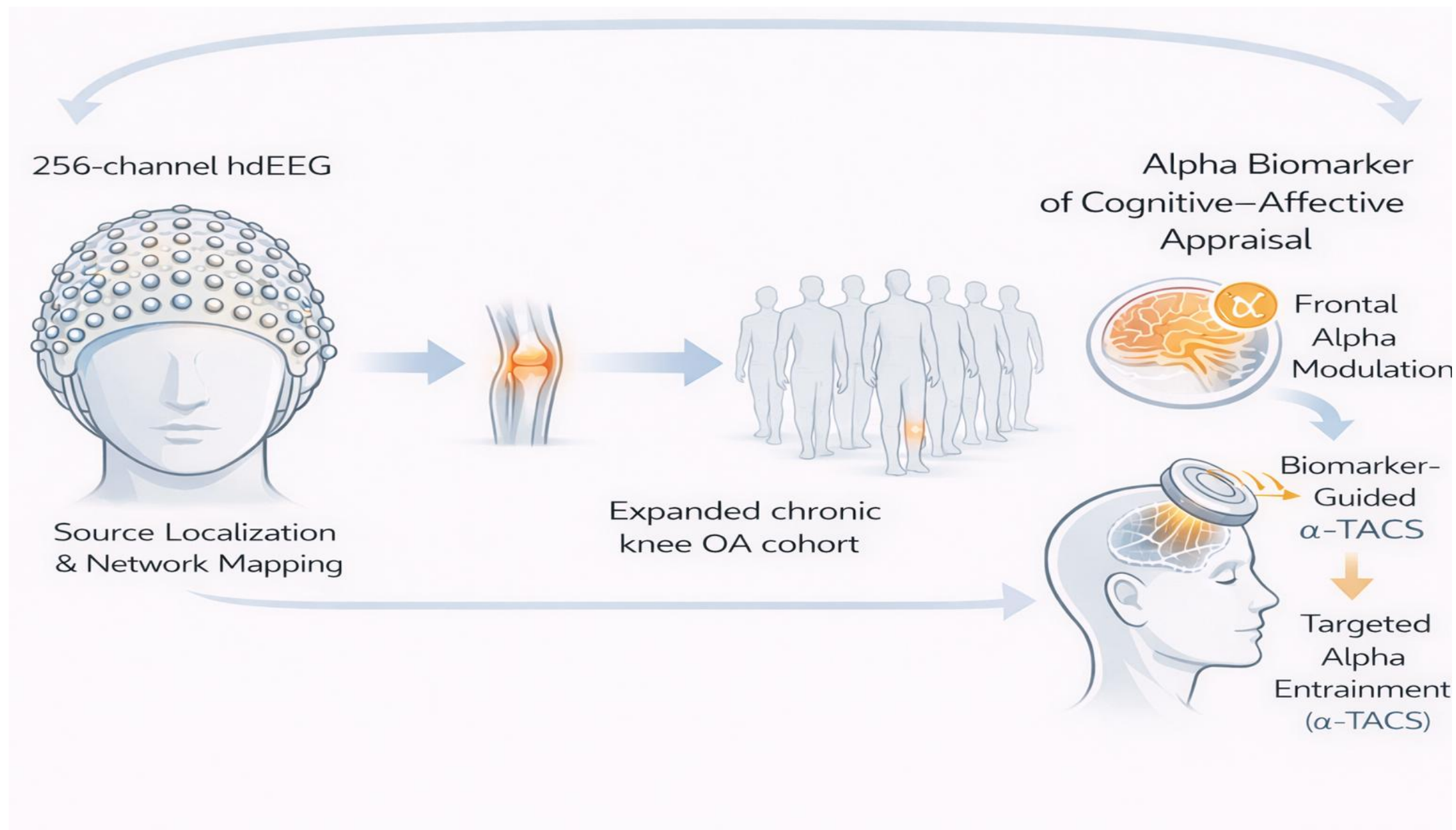


Evaluative control engagement



Frontal alpha here likely indexes cognitive and affective appraisal of pain-derived meaning

Future directions and application



Thank you!

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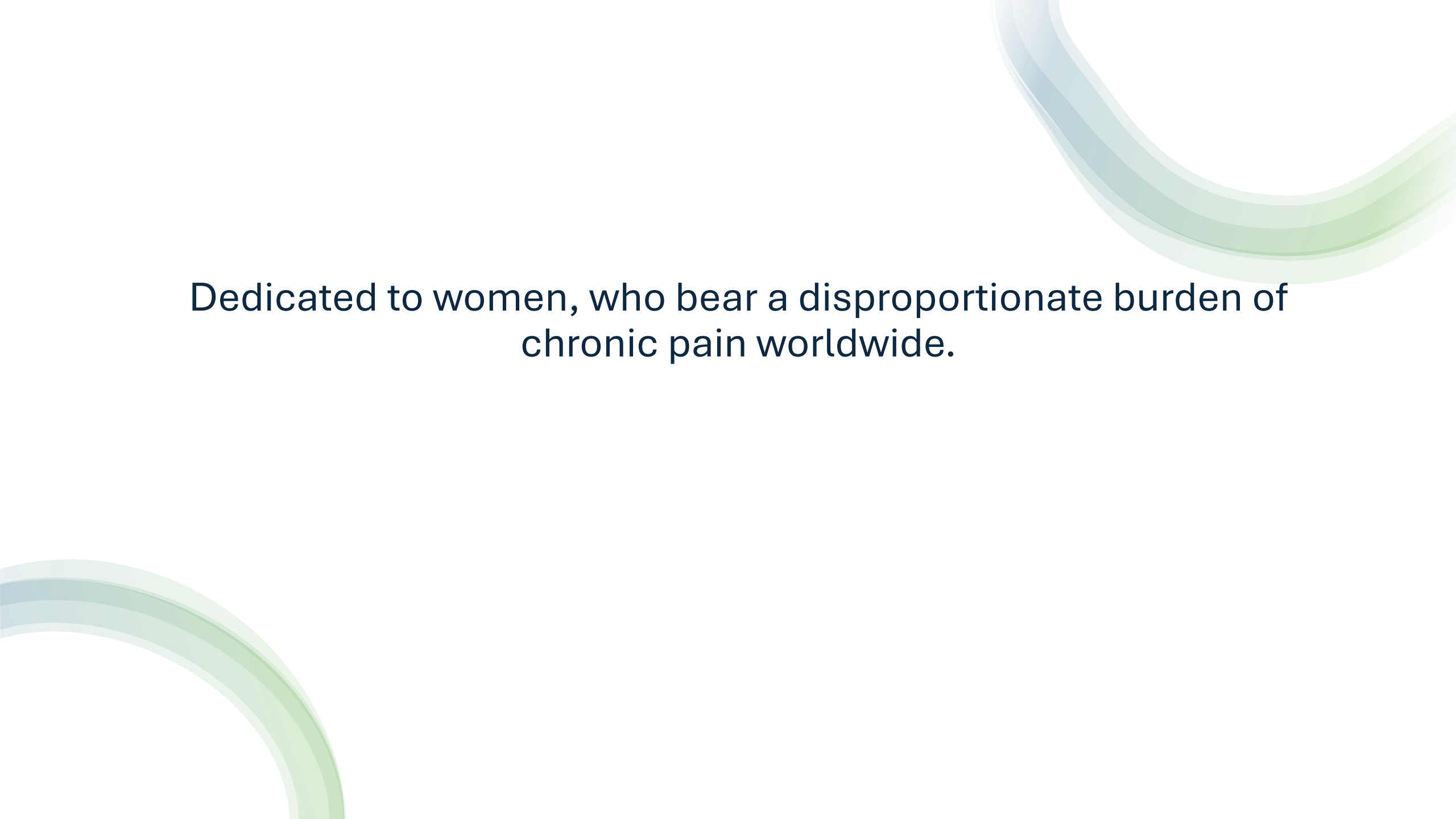
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Thank YOU for your attention !



The image features two decorative curved lines. One line is in the top right corner, curving from the top edge towards the right, with a color gradient from light blue to light green. The other line is in the bottom left corner, curving from the bottom edge towards the left, with a color gradient from light green to light blue.

Dedicated to women, who bear a disproportionate burden of
chronic pain worldwide.