Intensity of pain-related facial activity linked to distinctions in neural network engagement in the early stages of sensory processing in full-term neonates

Oana Bucsea*[1], Mohammed Rupawala*[2], Ilana Shiff[1], Steven Wang[1], Judith Meek[3], Maria Fitzgerald[2], Lorenzo Fabrizi[2], Rebecca Pillai Riddell*[1,4,5], Laura Jones*[2]

[1]York University, Toronto, Canada, [2]University College London, London, UK, [3]University College London Hospital, London, UK, [4]Hospital for Sick Children, Toronto, Canada, [5]University of Toronto, Toronto, Canada

YORK UNIVERSITÉ UNIVERSITY | UCL | NHS University College London Hospitals NHS Foundation Trust | SickKids | UNIVERSITY OF TORONTO

Background & Objective

Noxious stimulation elicits pain-related changes in facial expression and distinct brain activity as measured by electroencephalography (EEG).

Facial expressions are a critical indicator for caregivers to decipher infant pain responses[1], and although positively correlated with cortical activity, this relationship can be disrupted.

Cortical processing of a noxious stimulus requires the parallel and sequential activation of a distributed network of brain regions, with different regions linked to distinct cortical processes engaged hierarchically[2,3].

We do not know which level of nociceptive cortical processing is related to the immediate expression of pain-related facial activity in neonates.

The main objective of this study was to describe the relationship between sequential network engagement from whole-head EEG recording (microstates) and pain-related facial activity following a heel lance in full-term neonates.

Methods

Participants:

The sample consisted of 37 full-term neonates ranging from 0-14 days postnatal age recruited from the postnatal ward, special care, or intensive care wards at the Elizabeth Garett Anderson Obstetric Wing, University College London Hospital (UCLH) in London, England.

Methodology:

Cortical activity (EEG) and facial actions (video) were recorded following a clinically-required heel lance in the neonatal unit.

Measures:

Pain-related facial actions (NFCS). Pain-related facial actions were coded using 3 versions of Neonatal Facial Coding System (NFCS). A cluster based on brow bulge, eye squeeze, and nasolabial furrow best captured the variability in facial activity. Each facial action was coded second-by-second as either 0 (not present) or 1 (present) and summed over the first 10s post heel-lance. Groups displaying lower NFCS scores (N = 21) vs. higher NFCS scores (N = 16), reflecting distinct intensities of behavioural expressions of pain-related distress, were created based on a clinically significant natural dichotomy in NFCS scores.

Electroencephalography (EEG). EEG responses time-locked to the heel lance were recorded from 18 electrodes placed across the scalp over the first second post heel-lance. Differences in total cortical power (Global Field Power; GFP) and patterns of neural network engagement (onset, duration, and power of microstates) between the lower vs. higher NFCS groups were investigated.

Results

Total Cortical Power Post-Lance Not Related to NFCS Scores

There was no significant difference in the total pain-related cortical power between the lower and higher NFCS groups of full-term neonates (p = .22).

Lower vs. Higher NFCS Scores Related to Distinct Microstates in the First 500ms

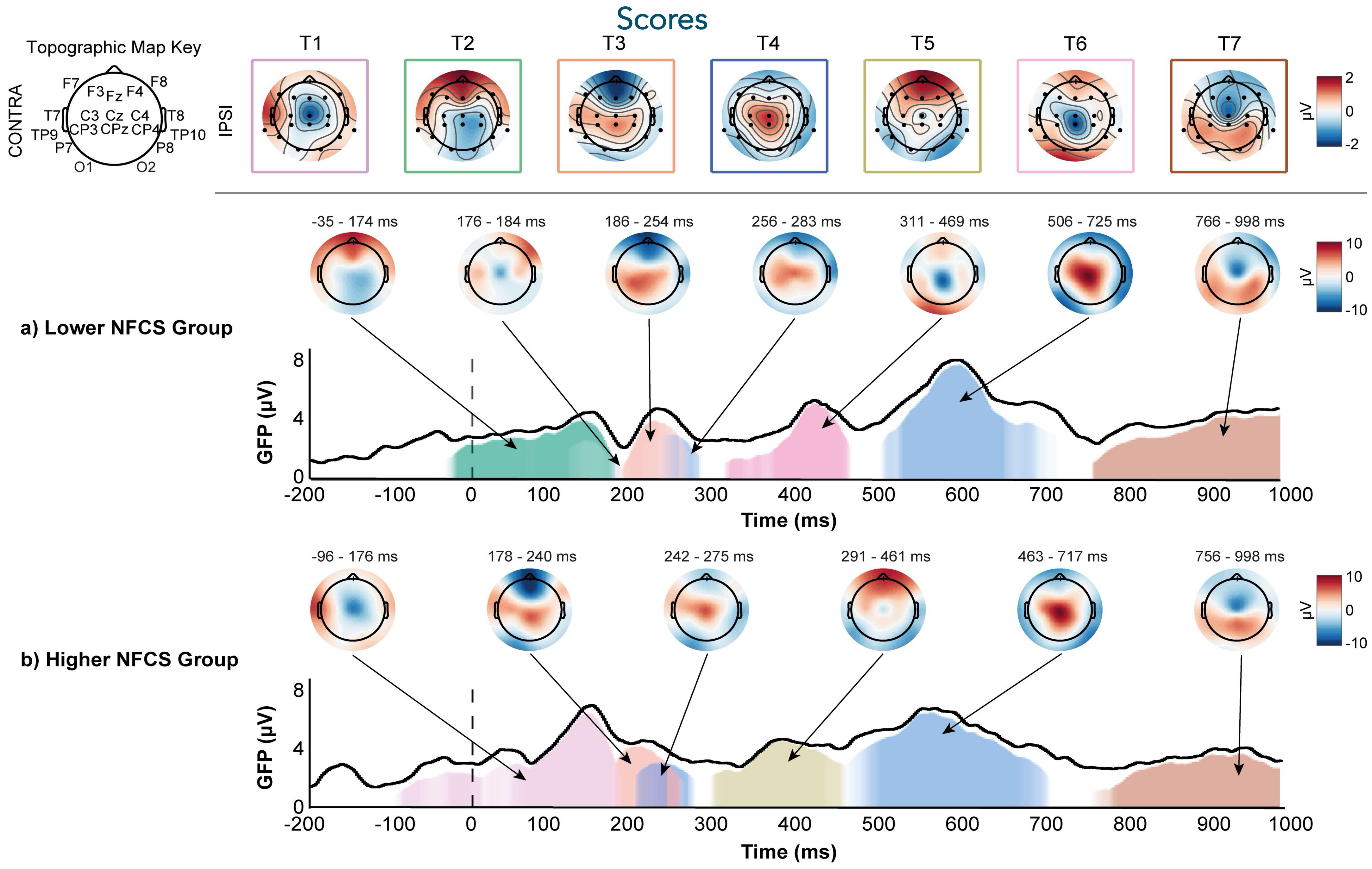
Neonates in the lower vs. higher NFCS groups engaged a distinct microstate at the start of the cortical response (lower NFCS: T2, green; higher NFCS: T1, purple). At approx. 400ms, the two groups again engaged distinct microstates (lower NFCS: T6, pink; higher NFCS: T5, olive).

Heel Lance Elicits Common Microstate Sequence Independent of NFCS Group

The heel lance evoked the sequential engagement of four microstates common to both the lower and higher NFCS groups (T3, orange; T4, blue; T7, brown). These microstates were mainly engaged to the same degree in both groups, with one difference. T4 was engaged 50.78ms earlier in the higher NFCS group (p = .00).

Results

Patterns of Microstate Engagement in Full-term Neonates with Lower vs. Higher NFCS Scores



Note. The microstates in the top row display the average representations of the seven microstates calculated across all 37 participants. Graph a) represents the lower NFCS group microstates while b) depicts the higher NFCS group microstates. The black curve represents the total cortical power (GFP) across the whole electrode array. Gaps in the microstate sequence represent periods in which no significant event occurred in that respective group. The dashed vertical line at 0ms represents the release of the heel lance.

Discussion & Conclusions

This study aimed to determine which stage in the cortical nociceptive processing is related to changes in pain-related facial activity in full-term neonates. Three microstates were similarly engaged by both the lower and higher pain-related facial activity groups, indicating a sequence of pain-related neural networks, independent of variations in facial expressions.

However, neonates displaying different intensities of facial activity engaged distinct neural networks on two occasions in the first 500ms post heel-lance (including the first microstate reflecting initial thalamocortical input[2]). These differences in neural network engagement during this initial early latency period may reflect the common input from the spinal cord which subsequently initiates facial responses via the pons and early sensory/discriminative processes via thalamocortical projections [4,5].

Interestingly, variations in the intensity of pain-related facial expressions were not linked to either 1) differences in total cortical power measured across the whole scalp between the groups or 2) differences in individual microstates' power across groups. Taken together, these results suggest that it is not the degree of pain-related cortical activity driving differences in neonatal pain-related facial expressions intensity. To further our understanding of pain-related brain-behaviour relationships in full-term neonates, future research should instead focus on examining patterns of neural network activation, particularly in the initial sensory/discriminative stages of nociceptive cortical processing.

References

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