

Posters

Bahar Hamzehei (University of Bologna, Italy)

Spatial Decoding of Lateralized Pain Anticipation from EEG Using Deep Temporal Neural Networks

OBJECTIVES

We present a deep learning framework to decode spatially specific pain anticipation from electroencephalography (EEG) signals recorded during a Pavlovian threat conditioning paradigm. Beyond binary classification of threat versus safety, our primary objective is to determine whether anticipatory neural activity contains sufficient information to distinguish the predicted spatial location of pain (left vs. right arm) prior to stimulus delivery. This approach aims to characterize lateralized anticipatory brain dynamics and evaluate whether data-driven temporal models can capture structured, spatially organized predictive states in cortical activity.

MATERIALS

Thirty healthy adult participants underwent a threat conditioning paradigm comprising acquisition and reversal phases. During acquisition, two visual cues predicted a painful shock to either the left (CS+L) or right (CS+R) arm, while a third cue (CS-) signaled safety. In the reversal phase, contingencies were swapped, requiring flexible updating of spatial predictions. This design enabled assessment of both stability and adaptability of anticipatory neural representations. Peripheral physiological measures (SCR, MEPS) were recorded but analyzed separately.

METHOD

EEG was recorded from 64 scalp electrodes at 5 kHz. Data were artifact-corrected, filtered (0.5–50 Hz), downsampled (500 Hz), baseline-corrected, and z-scored per participant. Epochs included a pre-cue baseline (–1–0 s) and cue interval (0–4.5 s). We trained a Temporal Convolutional Network (TCN) with stacked 1D convolutional layers and global pooling for multi-class classification (CS+L, CS+R, CS-). In parallel, time–frequency representations (STFT spectrograms) were evaluated as model inputs. Training followed a participant-level split (70/15/15%) to ensure generalization across individuals.

RESULTS

Model optimization is ongoing. Preliminary analyses indicate above-chance classification of lateralized pain anticipation during the cue period, suggesting that EEG signals encode spatially organized predictive states prior to nociceptive input. Comparative analyses across raw and time–frequency inputs are in progress.

DISCUSSION

These findings support the hypothesis that anticipatory brain states exhibit structured, lateralized dynamics detectable through deep temporal modeling. The paradigm further allows investigation of neural flexibility during contingency reversal, linking predictive coding and adaptive learning mechanisms.

CONCLUSIONS

This framework demonstrates the feasibility of decoding spatial pain anticipation from EEG and provides a foundation for integrating explainable AI approaches to identify neural features underlying pre

Jobst Heitzig (Potsdam Institute for Climate Impact Research, Germany)

AI systems that empower humans in a complex world

We present results from experiments where AI systems are tasked to empower human agents in multi-agent environments with complex dynamics.

Johanne Hizanidis (University of Crete, Greece)

TBA

Philipp Hövel (Saarland Universität, Saarbrücken, Germany)

Do you remember? Latency effects in time-delay feedback control of chaos

Once upon a time... Unstable periodic orbits can be controlled by time-delay feedback methods. We present a stability analysis in the case of extended time-delay autosynchronization. Our analysis includes effects of non-zero latency time, i.e., the time associated with the generation and injection of the feedback signal. We derive a theoretical explanation for experimentally observed, nontrivial features of the domain of control, e.g., gaps, maximum latency times. The explanation is done in the background of Floquet theory and we take both the unstable eigenmode and a single stable eigenmode into account... and they lived happily ever after.

Ali Rana Atilgan (Sabanci University, Istanbul, Turkey)

Trajectory Ensembles to Elucidate Mutant-Induced Kinetic Modulation of Proteins

Many experiments and coarse-grained models of protein conformational change report only a single rate, while the underlying dynamics are high-dimensional, contact-structured, and heterogeneous. We develop a two-layer sequence–structure framework that uses Maximum Caliber (MaxCal) to lift such coarse kinetic information into an explicit trajectory ensemble on a structurally defined path, and to quantify how mutations reshape that ensemble.

In the first layer, a compact sequence–structure theory estimates mutation-induced changes in gating rates. A Potts model inferred from a multiple-sequence alignment (MSA) is blended with a Gaussian Network Model built on the closed conformation; Potts couplings modulate effective spring constants, deforming the Kirchhoff matrix in a sequence-dependent manner. A gating contribution is extracted from the lowest-frequency mode that best aligns with the closed \rightarrow occluded displacement, and an Arrhenius-like barrier factor accounts for non-harmonic reorganization. Applied to E. coli DHFR, this layer predicts mutant-to-wild-type rate ratios in close agreement with experiment and yields a target closed \leftrightarrow occluded rate for each sequence.

In the second layer, we use two endpoint structures and the target rate to construct a one-dimensional structural path, a contact-breaking barrier profile, and an effective free-energy landscape. MaxCal then infers nearest-neighbor transition rates that obey local detailed balance and reproduce the prescribed mean first-passage time (FPT), yielding the maximum-entropy Markov dynamics consistent with the structural and kinetic constraints. From the resulting ensemble we obtain dwell-time maps, state-resolved fluxes, path-length and FPT distributions, and path entropies that quantify route diversity, kinetic bottlenecks, and gating robustness. Whenever two structures, an MSA, and a few kinetic observables are known, the framework furnishes a minimally biased non-equilibrium process on a constrained graph.

Wolfgang Renz (University of Applied Sciences, Hamburg, Germany)

Sepsis prediction by combining dynamic network models with machine-learning

Georg Reich (TU Berlin, Germany)

TBA

Rossella Rizzo (University of Palermo, Italy)

Stationary and oscillatory patterns in a FitzHugh-Nagumo model with anomalous diffusion

Anomalous diffusion phenomena frequently occur in natural systems. Interesting examples include autocatalytic chemical reactions on porous media, the preferential movement of species driven by safety or hunting strategies, and long-range interactions in ion channels within the plasma membrane. Cross-diffusion is a kind of nonlinear diffusion used to describe population dynamics where the gradient of one species induces the flux of the other species [1, 2]. On the other hand, super-diffusive processes, such as Lévy flights, can describe the mass diffusion in plasmas or foraging dynamics of birds and oceanic predators for randomly located resources and lead to fractional derivative modeling [3, 4].

In this talk, we investigate how anomalous diffusion influences the formation of stationary patterns in the FitzHugh-Nagumo model, which represents the paradigm system to describe excitable dynamics both in chemical reactions and population dynamics [5, 6]. We find that introducing anomalous diffusion terms allows for pattern formation in both short-range activation/long-range inhibition or long-range activation/short-range inhibition, relaxing the typical requirement for a rapidly diffusing inhibitor in the case of classical diffusion [7]. Moreover, in the presence of cross-diffusion, the spatial structures induced by long-range activation/short-range inhibition mechanisms are always out of phase (cross-Turing patterns) and subcritical in most of the instability regions [8]. Finally, using the formalism of amplitude equations, we derive the asymptotic profiles of the stationary solutions and classify the bifurcation, distinguishing between super- and subcritical transitions. Moreover, we investigate the dynamics near a co-dimension 2 Turing-Hopf bifurcation point, and find the conditions under which we can have oscillatory Turing patterns.

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Merten Stender (TU Berlin, Germany)

Evolution strategies for optimal minimal reservoir computers

Ronja Strömsdörder (TU Berlin, Germany)

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Simon Vock (Charité Berlin, Germany)

Criticality governs deep learning: enhancing performance, enabling continual learning, mitigating model collapse

The rapid advances in artificial intelligence (AI) have largely been driven by scaling deep neural networks (DNNs) - increasing model size, data, and computational resources. However, performance is ultimately governed by network dynamics. The lack of a principled understanding of DNN dynamics beyond heuristic-based design has contributed to challenges with their robustness, suboptimal performance, high energy consumption and pathologies in continual and AI-generated content learning. Increasing evidence suggests that the human brain may avoid these problems by operating at a critical phase transition. Inspired by this principle, we here propose that criticality may provide a unifying framework linking structure, dynamics, and function also in DNNs. First, by analyzing more than 80 state-of-the-art DNN models and well established benchmark datasets (ImageNet, MNIST), we report that a decade of AI progress has implicitly driven successful

networks towards criticality, as measured by largest Lyapunov exponents λ_0 (Spearman $r = -0.5$, $p < 10^{-4}$), explaining why certain architectures succeeded while others failed. Second, incorporating criticality explicitly into training improves even highly optimized models by more than 0.4 percentage points ($p < 0.001$) and establishes robustness across weight initializations, preventing key limitations of current models. Third, we show that catastrophic AI pathologies, including continual learning degradation and model collapse from AI-generated training data, constitute a loss of critical dynamics. By keeping networks critical, we provide the first principled solution to these fundamental AI problems by mitigating performance degradation and model collapse. This work confirms criticality as substrate-independent principle of intelligence, connecting AI advancement with core principles of brain function. For systems neuroscience, this work offers a link between optimal function in biological and artificial neural networks. For AI, it provides profound theoretical insights along with immediate practical value solving major challenges to ensure long-term DNN performance and resilience as models grow in scale and complexity.

Yu Wang (Potsdam Institute for Climate Impact Research, Germany)

Universal dynamic phenomena in delay systems: fundamentals and applications

The majority of delay differential equations (DDEs) with one delay have only a few bifurcation scenarios, which can be explicitly described. We explore absolute stability and universal bifurcation scenarios in DDEs using asymptotic continuous spectrum (ACS) theory. We then combine the Master Stability Function (MSF) method for discussing the dynamics of active-agent systems. First, we present how universality classes and Hopf bifurcation sequences in single-delay DDEs can be characterized through the ACS, reveal general transversality results in the large-delay regime, and consider the three most common universality classes. For each of them, we explicitly describe the sequence of stabilizing and destabilizing bifurcations. Then, we apply the above framework to active-agent systems with inertia and delayed feedback, analyzing stability conditions for formation patterns in both uncoupled and coupled settings. These results provide a unified perspective on stable coordination, pattern formation, and universal delay-induced dynamics in complex systems. Additionally, we investigate interactions in the large-delay limit, where delays affect inter-agent coupling, while local feedback remains instantaneous. In this limit, we prove rigorously that the stability region in the complex plane of the eigenvalues of the Laplacian matrix converges to a circle centered at the origin, a phenomenon previously observed in delay-coupled networks. Our findings provide a universal framework for understanding stable formations and motions of active agents with delayed interactions.

Matthias Wolfrum (WIAS Berlin, Germany)

Topologically protected incoherent spots in coupled oscillator systems

We describe the emergence of specific synchronization patterns in an array of coupled active rotators. They are characterized by self-organized regions of coherently rotating and coherently quiescent units. We show that at the interfaces between these regions the topology of the solutions induces localized spots of chaotic motion, which causes the pattern as a whole to perform an irregular motion in space.

Serhiy Yanchuk (University College Cork, Ireland)

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