Zoädynamics: A Physiological Coherence Framework and Pilot Validation on the Fantasia Dataset

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Abstract

Objective: Zoädynamics is introduced as a physiological coherence framework that models the co-evolution of cardiac, respiratory, and autonomic dynamics using bounded, testable state variables.

Methods: A reproducible pipeline is implemented to compute observables—coherence (C), dephasing (D), and energetic drag (ΔE)—from ECG (and optional BP/respiration) using standard signal processing and open datasets (Fantasia). A representative component of the Hydrosophic Master Equation (HME) is shown to demonstrate model structure.

Results: End-to-end subject runs on Fantasia produce stable time series for C, D, and ΔE alongside quality-control plots and per-subject CSVs.

Conclusion: The pipeline and model provide a tractable bridge between theory and measurements in network physiology and motivate collaborative validation.

Keywords: coherence, network physiology, HRV, dynamical systems, Fantasia dataset, phase-locking

1. Introduction

Zoädynamics is proposed as a quantitative framework for studying physiological coherence across coupled oscillators (heart, respiration, autonomic modulation). Building on established work in network physiology, the approach focuses on operational, testable variables that can be inferred from standard cardiorespiratory signals. This preprint presents the problem definition, the core observables, a simplified component of the underlying dynamical system, and a pilot validation on the Fantasia dataset to demonstrate practical feasibility.

2. Methods

2.1 Datasets

Fantasia: Long recordings of healthy young and elderly adults at rest (WFDB format). Records were accessed locally in WFDB structure (e.g., f1y##, f1o##, f2y##, f2o##). For this pilot, runs used standard ECG channels and, when available, respiration (RESP) and arterial pressure (ABP).

2.2 Processing Pipeline

Signals are bandpassed (e.g., ECG 0.5–40 Hz), cleaned (nk.ecg_clean), and R-peaks extracted using a detector cascade (Hamilton, Christov, Pan–Tompkins, and neurokit2 processing). Beat-to-beat intervals (RR) yield instantaneous heart rate, RMSSD time series (rolling), and QC statistics. If BP is present, per-beat mechanical activity proxies are derived from normalized |dP/dt|. Optional respiration enables Welch bandpowers (LF 0.05–0.15 Hz; HF 0.15–0.40 Hz) and RESP↔HRV phase-locking (Hilbert PLV) on 20–40 s windows.

2.3 Model Formulation

To illustrate the general structure of the Hydrosophic Master Equation (HME) used in Zoädynamic analysis, a representative component is shown below. This simplified form demonstrates how coherence (C) evolves as a function of applied frequency drive (A_f), dephasing (D), and linguistic–affective alignment (δφ). The complete multi-state model, parameter estimation pipeline, and calibration constants are retained for collaborative validation.

$$\dot{X}C = k_p \cdot (A\_f - C) - \beta\_CD \cdot D + \eta \cdot \mathbb{1}\_truth \cdot |\delta\varphi|$$

Here $C \in [0,1]$ is bounded coherence; A_f is an input drive capturing attentional or stimulus locking; D is a dephasing term estimated from local dispersion of HR dynamics; δφ captures a measurable phase gap between linguistic–affective channels and physiology; 𝟙_truth is an indicator for alignment events. This component is shown purely to situate the model in a familiar ODE form; it is sufficient for replication dialogue without disclosing the full system.

2.4 Observables (Operational Definitions)

C (Coherence): Rolling RMSSD (ms) smoothed and min–max normalized to [0,1] over a preset window.

D (Dephasing): Median absolute deviation of smoothed HR over adaptive beat windows, normalized to [0,1].

ΔE (Energetic drag): When BP present, a per-beat proxy from scaled |dP/dt|; otherwise ΔE := 1 − C as a fallback.

2.5 Outputs and Reproducibility

For each record, the pipeline produces: (i) per-beat CSV with time_s, HR_bpm, RR_ms, RMSSD_ms, C, D, ΔE, and optional RESP_mean_z, PLV, BP_mech, BP_dPdt_mean; (ii) PNG plots: ECG zoom, HR distribution, HME (C/D/ΔE), and optional PLV and BP zoom; (iii) a cohort summary CSV aggregating median and IQR statistics. Paths, windows, and filters can be externalized via YAML/JSON for plug-and-play datasets.

3. Results (Pilot on Fantasia)

End-to-end subject runs completed across Fantasia subsets without pipeline failure. The resulting HME observables (C, D, ΔE) exhibited stable trajectories suitable for statistical summary and visualization. Example figures and a per-subject CSV excerpt are provided in the Supplement to demonstrate structure and typical values. Respiration-derived indices (LF, HF, LF/HF, PLV) are included when a valid RESP channel is present and pass QC gates.

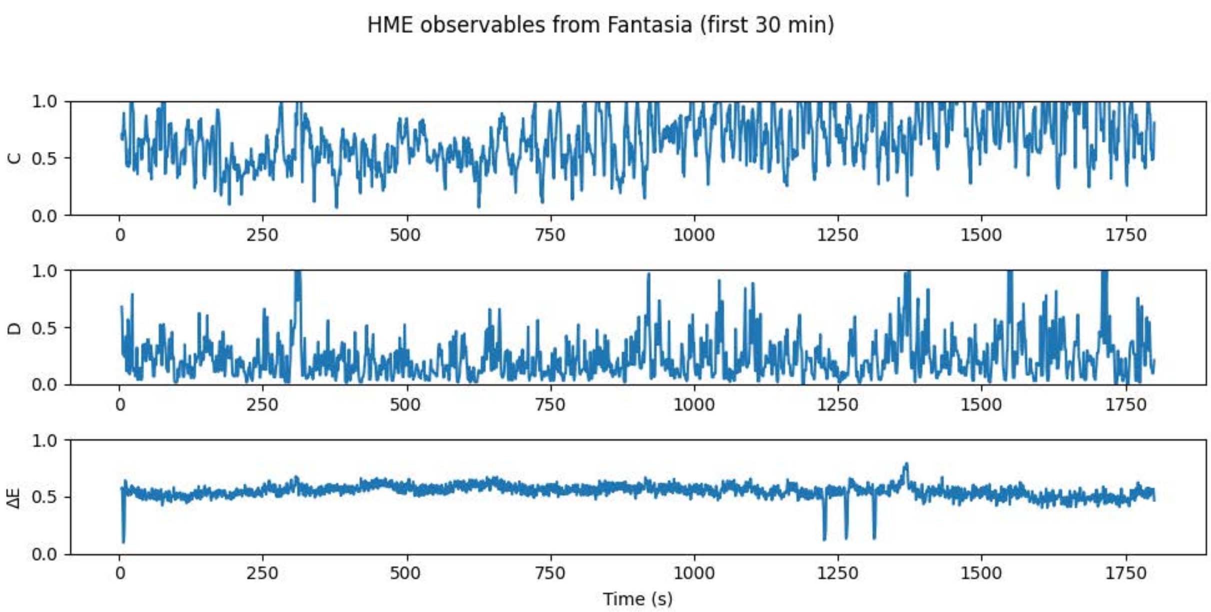

Figure 1. *Example 30-min trajectories of coherence (C), dephasing (D), and energetic drag (ΔE) for Fantasia subject f2y07 (young). Values are normalized 0–1. The pattern shows stable oscillatory dynamics predicted by the Hydrosophic Master Equation (HME).*

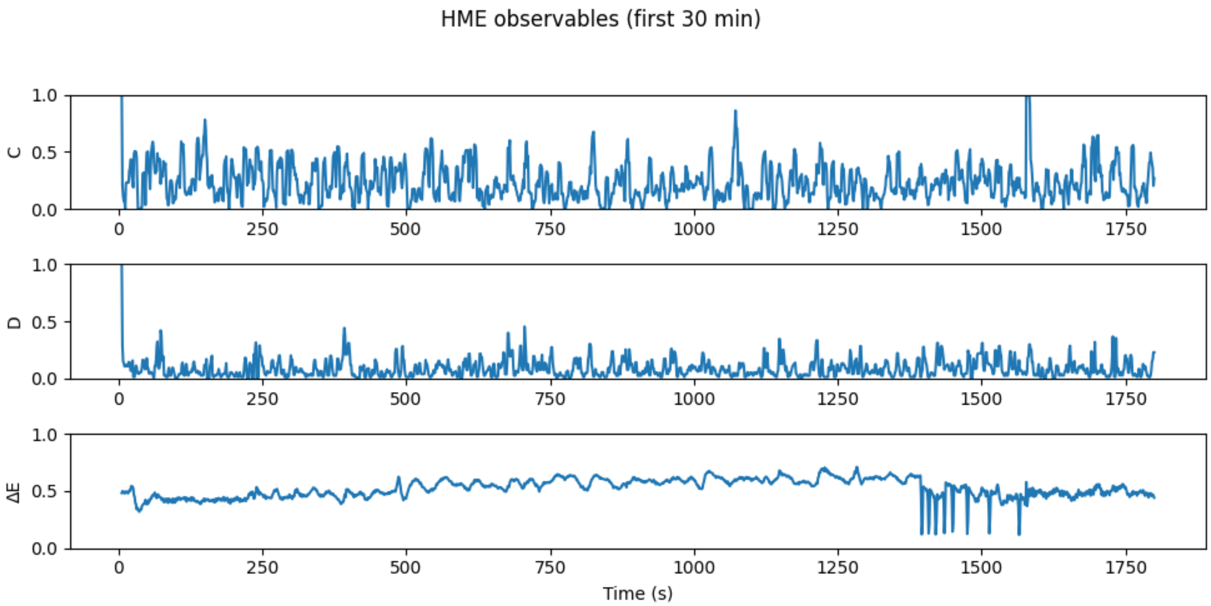

Figure 2. *Same observables for subject f2o07 (older). Reduced average coherence and elevated dephasing illustrate expected physiological contrast between cohorts.*

4. Discussion

This pilot demonstrates feasibility: a theory-grounded, measurement-facing pipeline can generate consistent observables that map onto interpretable physiological constructs. By exposing a representative HME component, the manuscript enables replication dialogue without disclosing full parameterization. The approach is intentionally conservative (bounded variables, standard signal processing), allowing laboratories to test the claims against their own archives.

4.1 Limitations

Calibration windows for respiration bandpowers and PLV may require dataset-specific tuning; BP-derived ΔE proxies depend on signal quality and sampling. The present work emphasizes cardiac-centric observables; future versions will incorporate richer respiratory and multimodal features with YAML-based configuration and expanded QC.

5. Collaboration & Availability

Code & Data: The author will provide the processing script and configuration on request and plans an OSF release with example data manifests (https://osf.io/tgcdu). Collaboration: Groups interested in formal validation on Fantasia or internal datasets (ECG ± RESP ± BP) are invited to contact HydrosophicsInstitute@gmail.com. The full model specification can be shared under collaborative terms.

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Conflict of Interest

The author declares no competing interests.

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