Analyzing Group HRV Complexity Matching via Attractor State-Space Geometry

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Motivation

Problem

- Do the HRV patterns of a group become more alike in a shared session?
- Group HRV patterns are not easy to see in raw recordings

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Analysis

- HRV is rebuilt as 2D attractors (the shape of the rhythm)
- A CNN autoencoder and K-means sort them into 3 shape types

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Goal

- Do more participants share the same attractor type as the session goes on?
- Check whether this is consistent with group-level complexity matching

Introduction

Complexity matching helps explain how interacting physiological systems may become coordinated during shared experiences. Our earlier study of a distant healing protocol used a derived complexity index of the RR intervals (H-rank). Here the attractor is rebuilt directly from the RR intervals of each participant. This lets us ask whether the attractor shapes of the group become more alike as a guided session goes on.

Data and session

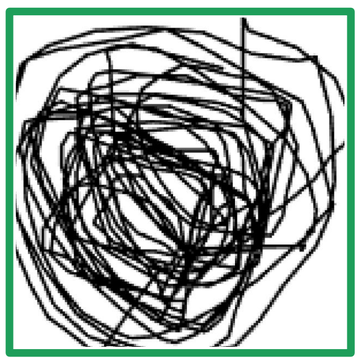
- 20 adults, aged 31-75 (7 women, 13 men)
- PPG pulse signal, 256 Hz; session about 26 min
- Six guided intervals, 120 attractors in total

#	Time	Guided activity
1	0-290 s	Video (baseline)
2	293-470 s	Heart-focused breathing, gratitude
3	480-780 s	Appreciation toward the person next to you
4	789-1020 s	Appreciation toward the whole group
5	1040-1310 s	Visualizing wider humanity with care
6	1330-1554 s	Unconditional love and compassion

Method

1. **Signal** Pulse (PPG) gives beat-to-beat RR intervals, cleaned and resampled at 2 Hz.
2. **Attractor** Each RR series is plotted against a shifted copy of itself (2D). The delay is chosen for each participant and interval.
3. **Shape types** A CNN autoencoder turns each 104 × 104 px attractor image into 2048 numbers. PCA and K-means (K = 3, chosen in advance) give 3 types.
4. **Test** Cochran's Q across the 6 intervals; exact McNemar tests between intervals (main focus: Interval 1 vs 6); Holm correction.

Three attractor types



Type 1
circular or loop-like
10% → 60%



Type 2
distorted circular
55% → 25%



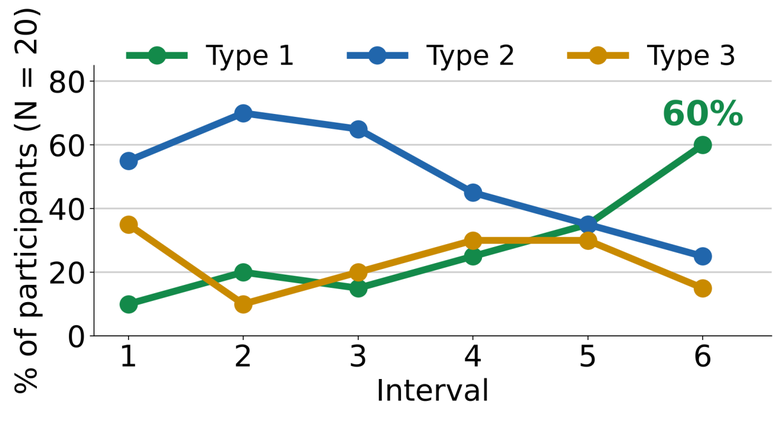
Type 3
distorted concentrated
35% → 15%

Share of participants, Interval 1 → Interval 6

Results

10% → 60%

of participants had Type 1 attractors (Interval 1 → 6). Cochran's Q(5) = 19.46, Holm p = 0.0047. Type 2 was the most common type in Intervals 1–3; Type 1 was the most common in Interval 6.



Type	I1	I2	I3	I4	I5	I6	Q(5)	Holm p
Type 1	10	20	15	25	35	60	19.46	**0.0047**
Type 2	55	70	65	45	35	25	12.94	**0.0478**
Type 3	35	10	20	30	30	15	5.92	0.3142

% of participants (I = Interval). Q(5): Cochran's Q; Holm p < 0.05 in bold. Type 1 (I1 vs I6): McNemar Holm p = 0.0293.

Conclusion

- → Type 1 increased from 10% to 60%, suggesting greater similarity across participants.
- → This fits group-level complexity matching. It does not mean the HRV signals became identical.
- → Fixed order, no control group: an association, not proof that appreciation or compassion caused it.
- → Attractor reconstruction with CNN-autoencoder clustering can show shared organization that is not visible in raw HRV.

Limits and extra check: only 20 participants; breathing not recorded; K = 3 chosen beforehand; not compared with conventional HRV indices. Subgroup of 15 participants whose type changed: Type 1 6.67% → 66.67%, Q(5) = 20.00, Holm p = 0.00375; Interval 1 vs 6 alone, Holm p = 0.0586. Not independent confirmation.

References

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