

Nonlinear analysis to quantify human movement variability from time-series data

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@neuromatch #nmc3

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Why Movement Variability?

Few challenges when quantifying movement variability

Theoretical challenges

- Modelling human movement (tasks, environments, agent, perception, action)
- Modelling human variability (complexity vs predictability)
- ?

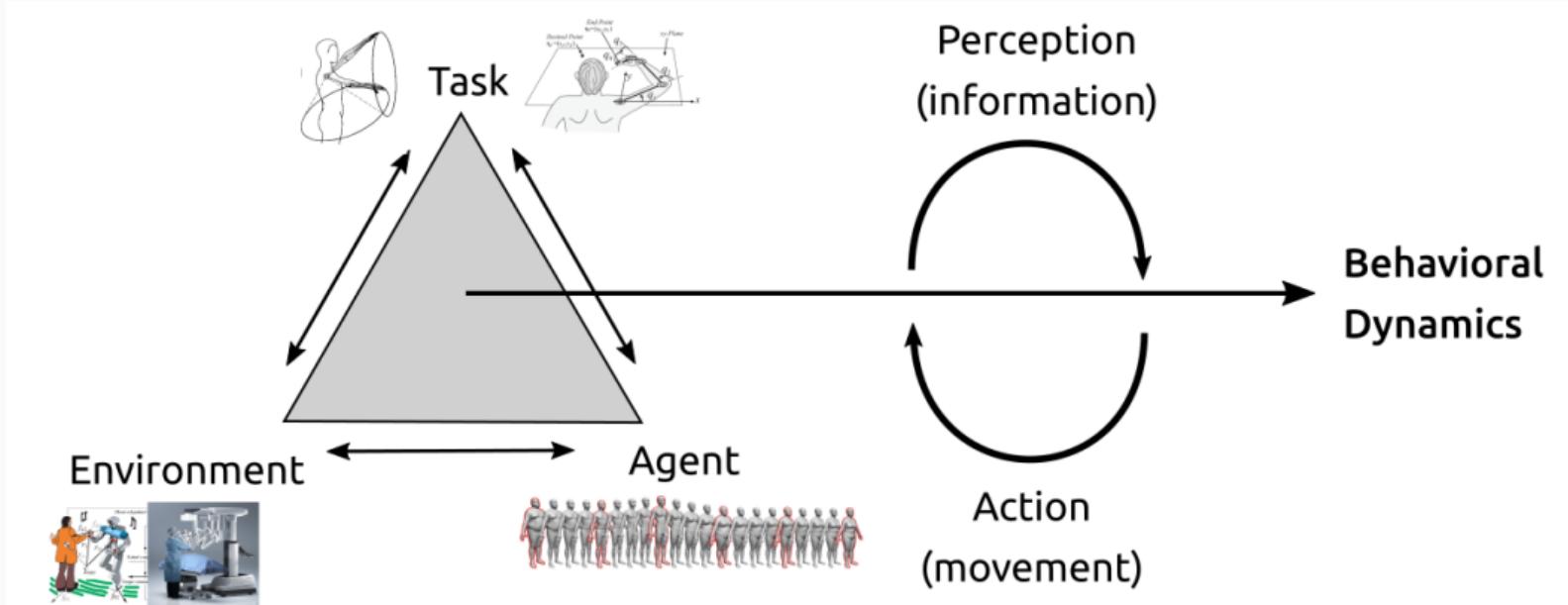
Choosing the right tools

- Time-based domain,
- Frequency-based domain
- Nonlinear dynamics
- ?

Technical challenges

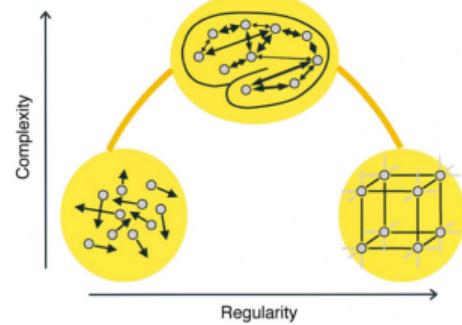
- non-stationarity,
- non-linearity,
- data length,
- sensor source,
- noise,
- ?

Modeling Human Movement

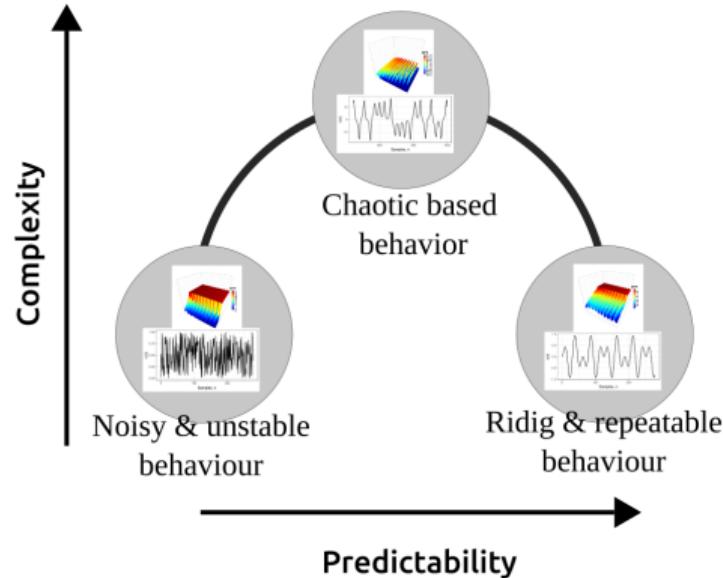


(Bernstein 1967 in The co-ordination and regulation of movements; Newell and Vaillancourt 2001 in Hum Mov Sci; Davids et al. 2003 in Sport Medicine; Warren 2006 in Psychological Review)

Modelling Movement Variability



Tononi et. al 1998

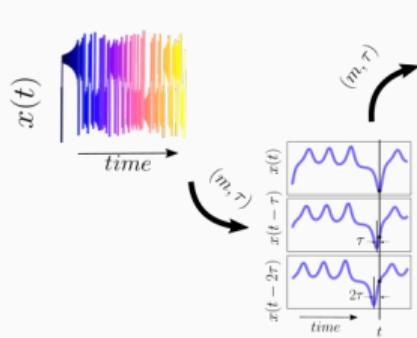


Stergiou et al. 2006

Nonlinear Methods

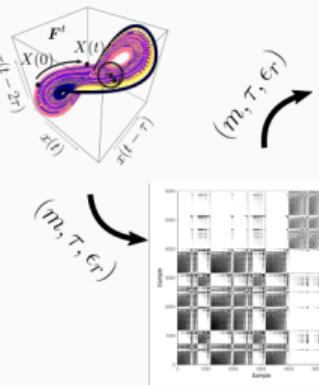
Nonlinear Analysis

Time Series



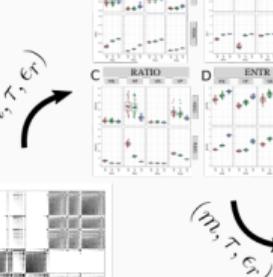
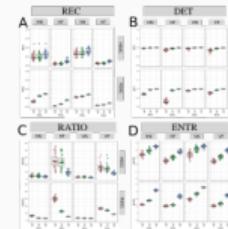
Uniform Time
Delay-Embedding

Taken's Theorem

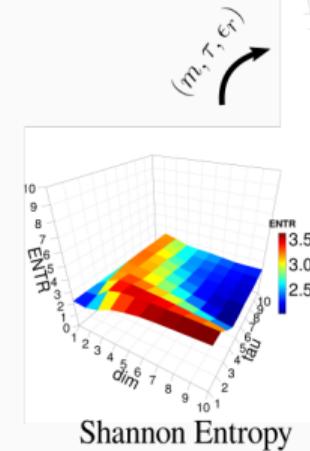


Recurrence Plots

RQA



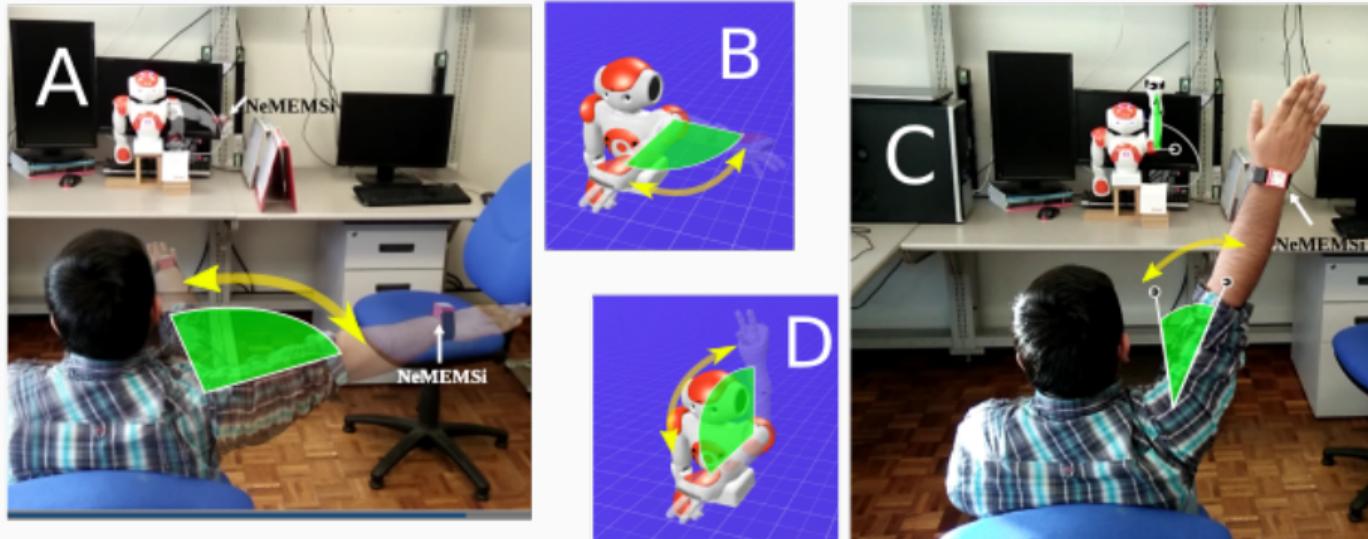
3D RQA-ENTR



Experiment

Human-Humanoid Imitation Activities

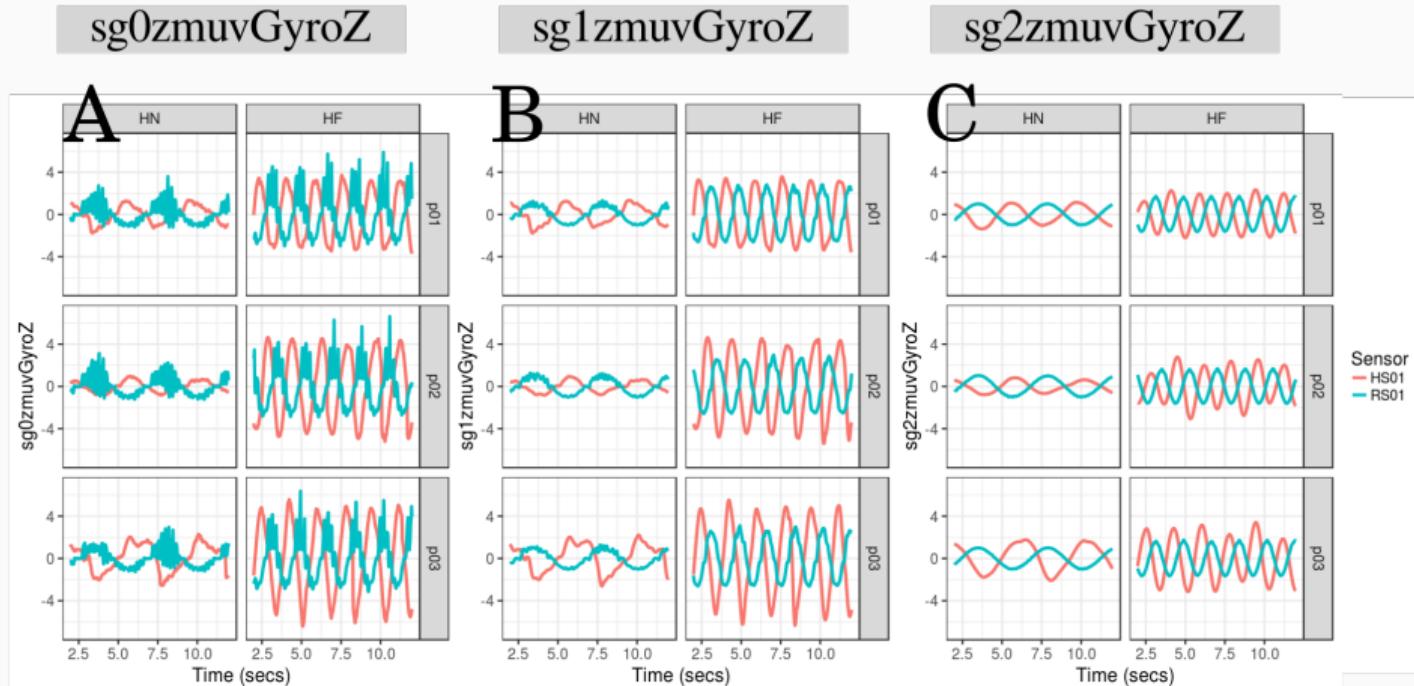
20 participants with mean and standard deviation (SD) age of mean=19.8 (SD=1.39) years, being four females and sixteen males.



(A/C) Front-to-Front Human-Humanoid Imitation Activities of Horizontal/Vertical Movements, (B/D) NAO, humanoid robot, performing Horizontal/Vertical arm movements.

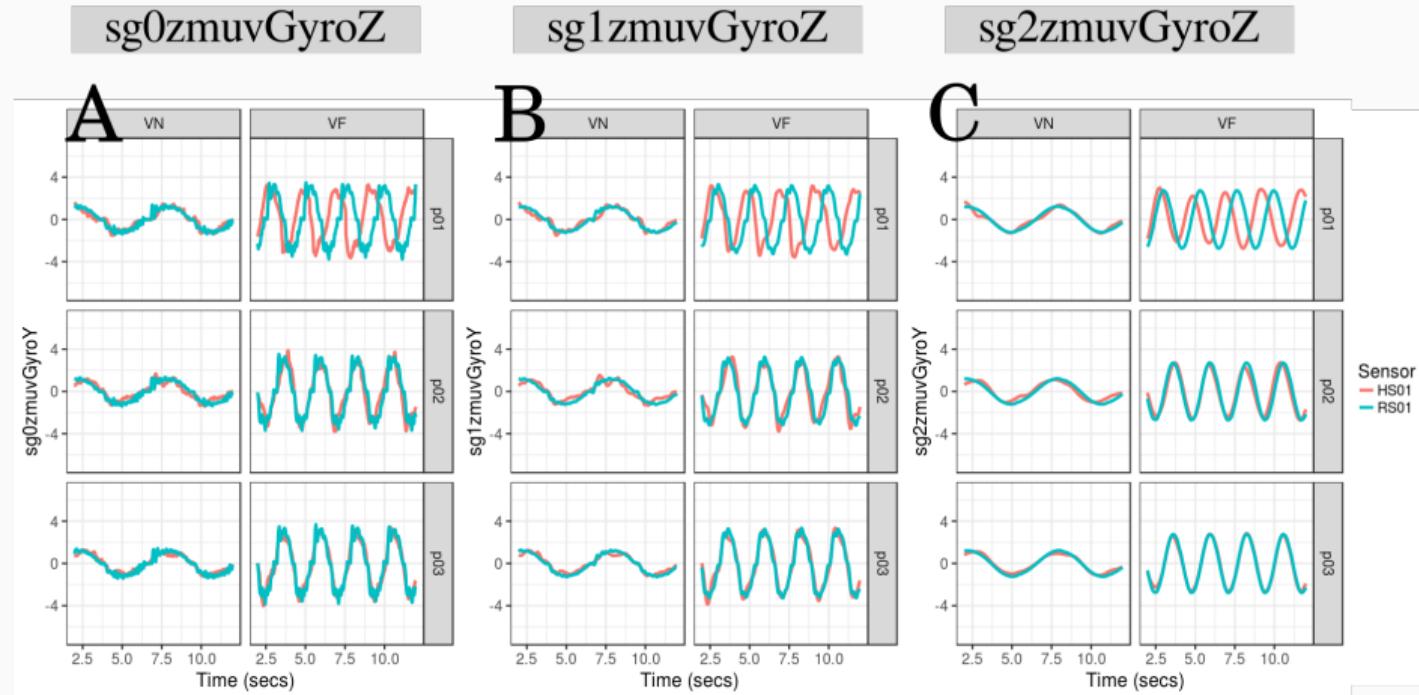
Results

From Raw to Smoothed Time Series



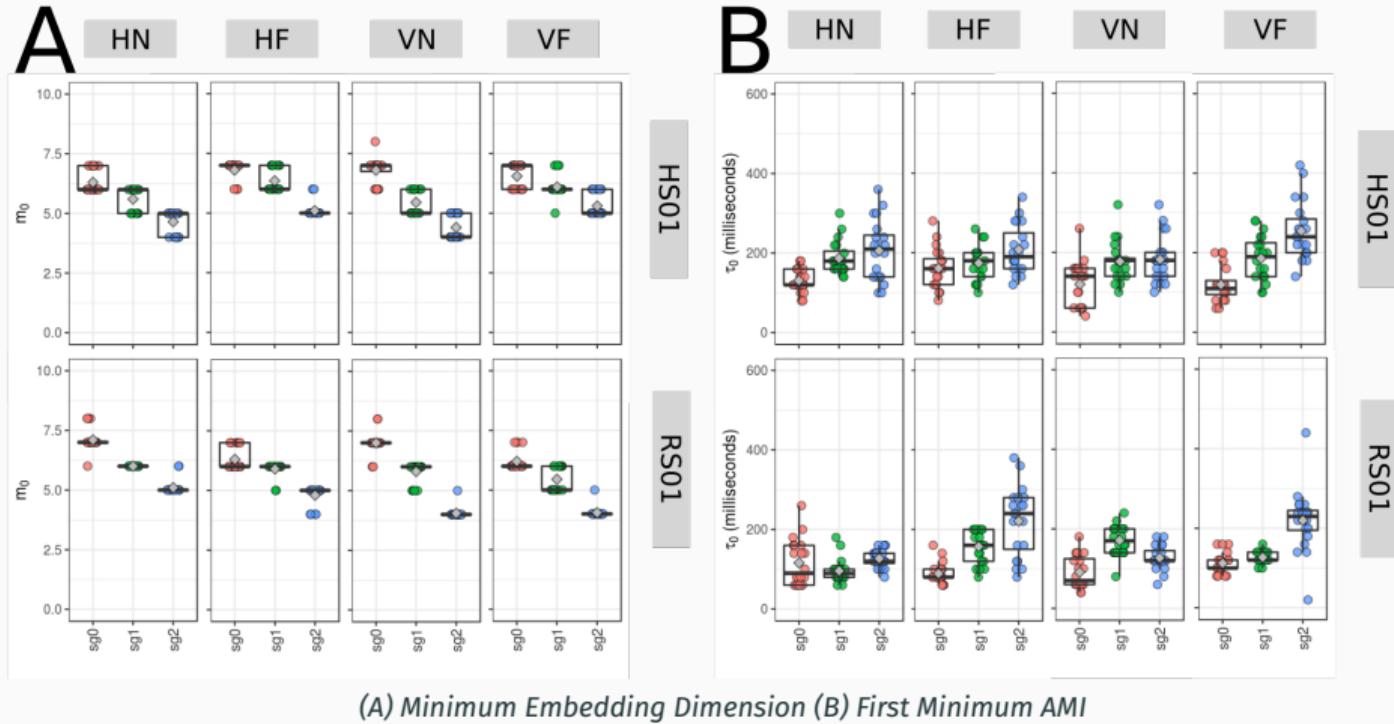
Time-series of horizontal movements for (A) normalised, (B) $sgolay(p=5, n=25)$, and (C) $sgolay(p=5, n=159)$.

From Raw to Smoothed Time Series

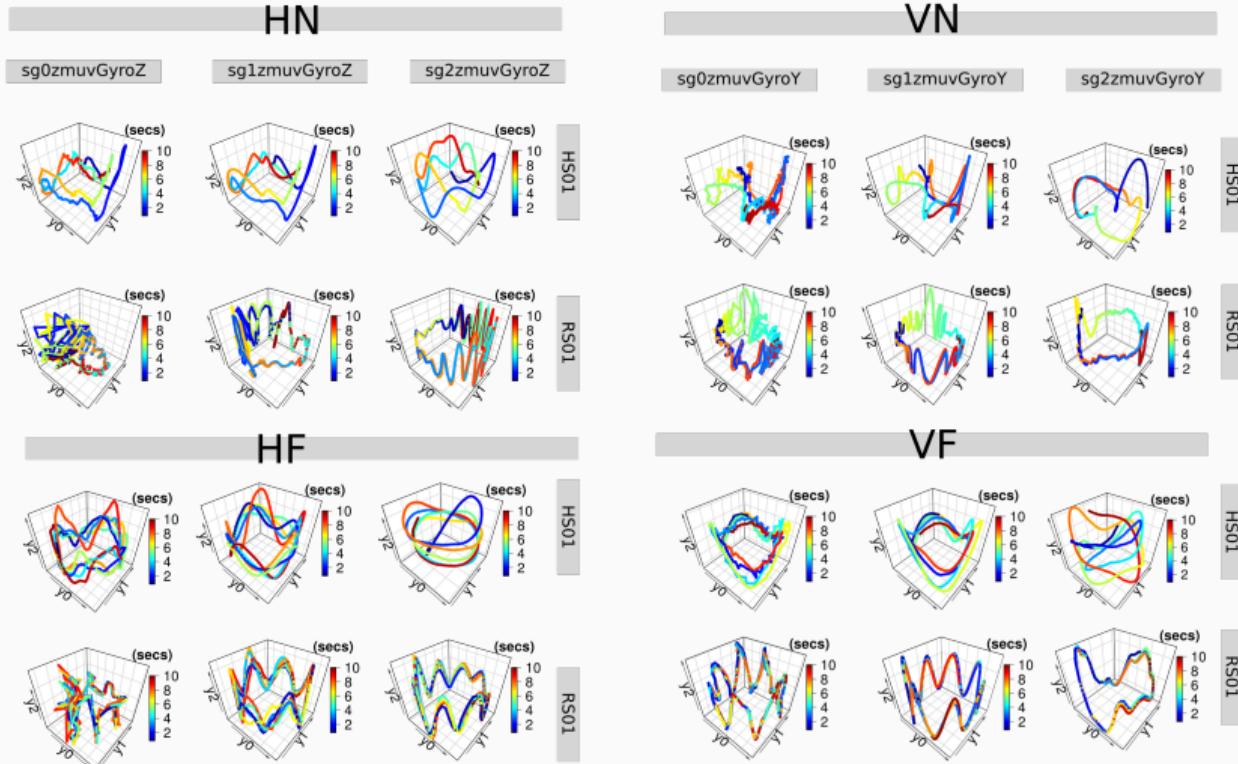


Time-series of vertical movements for (A) normalised, (B) **sgolay($p=5, n=25$)**, and (C) **sgolay($p=5, n=159$)**.

Minimum Embedding Parameters

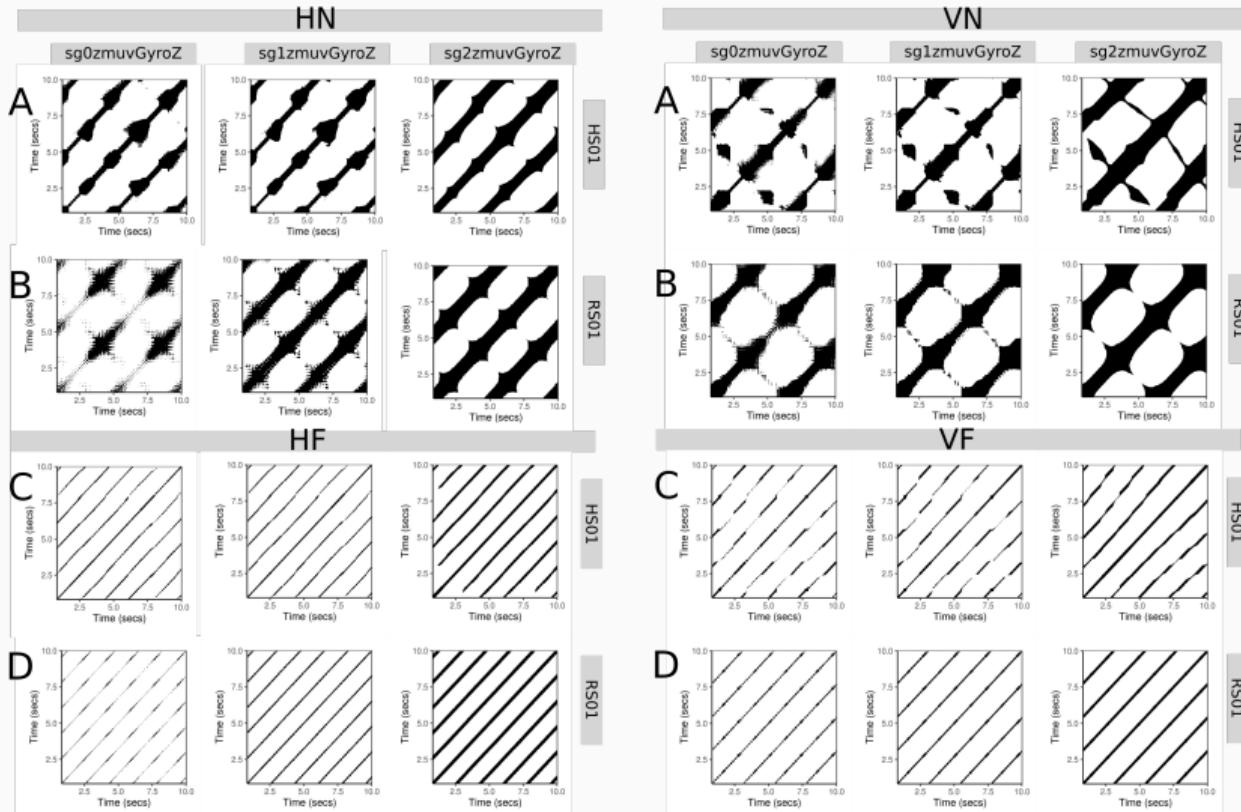


Reconstructed State Spaces



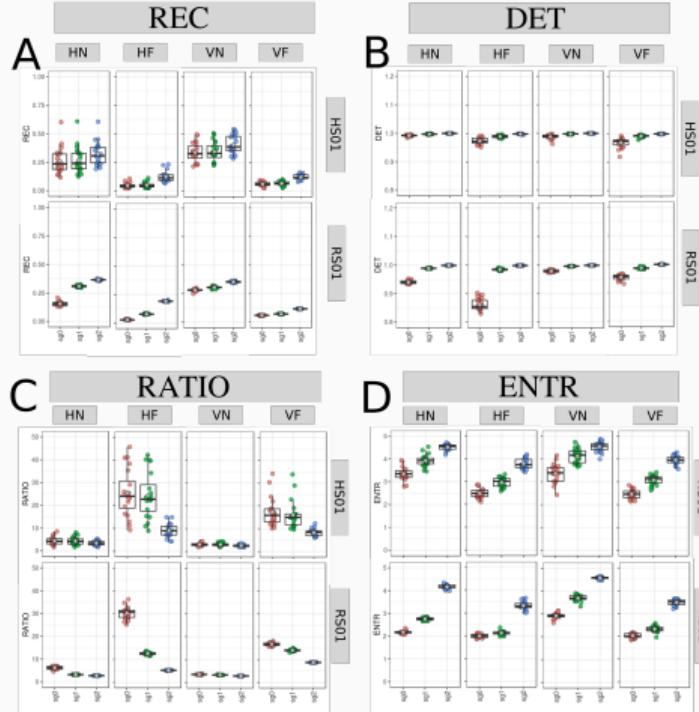
RSS for participant 01 computed with ($m = 6$, $\tau = 8$) for different activities, signals and source of time-series data.

Recurrence Plots



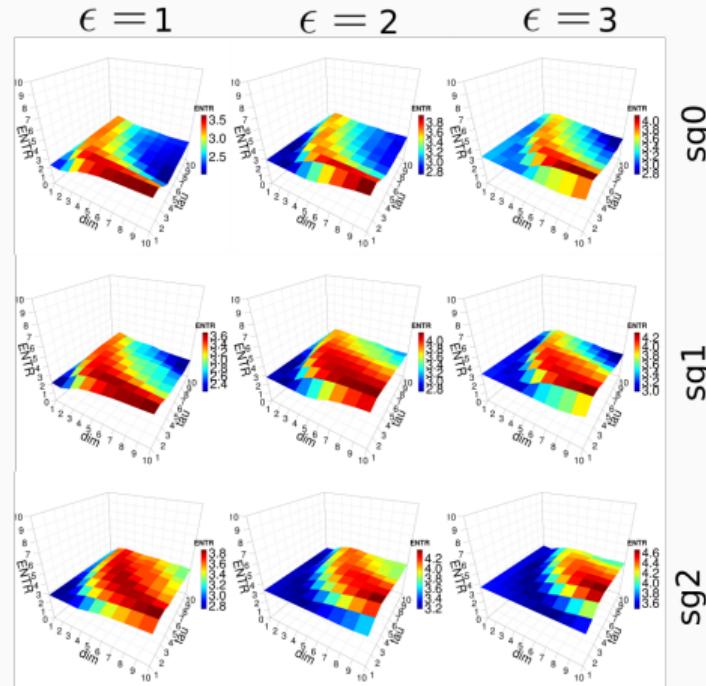
RP for participant 01 computed with ($m = 6$, $\tau = 8$, $\epsilon = 1$) for different activities, signals and source of time-series data.

Recurrence Quantification Analysis



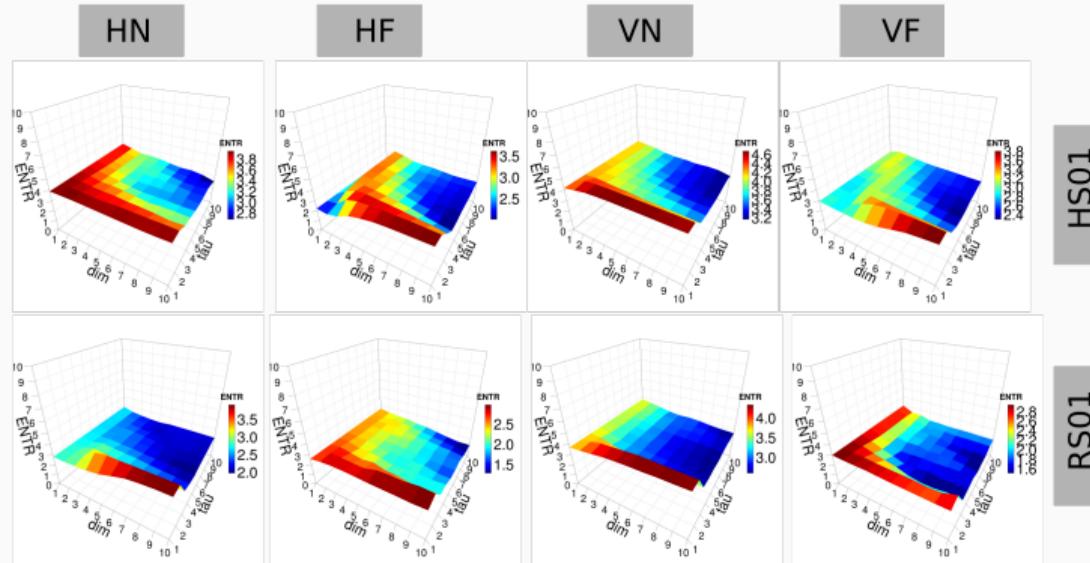
Box values of RQA computed with ($m = 7$, $\tau = 5$, $\epsilon = 1$). These values are for 20 participants.

RQA ENTR for ϵ thresholds & smoothness



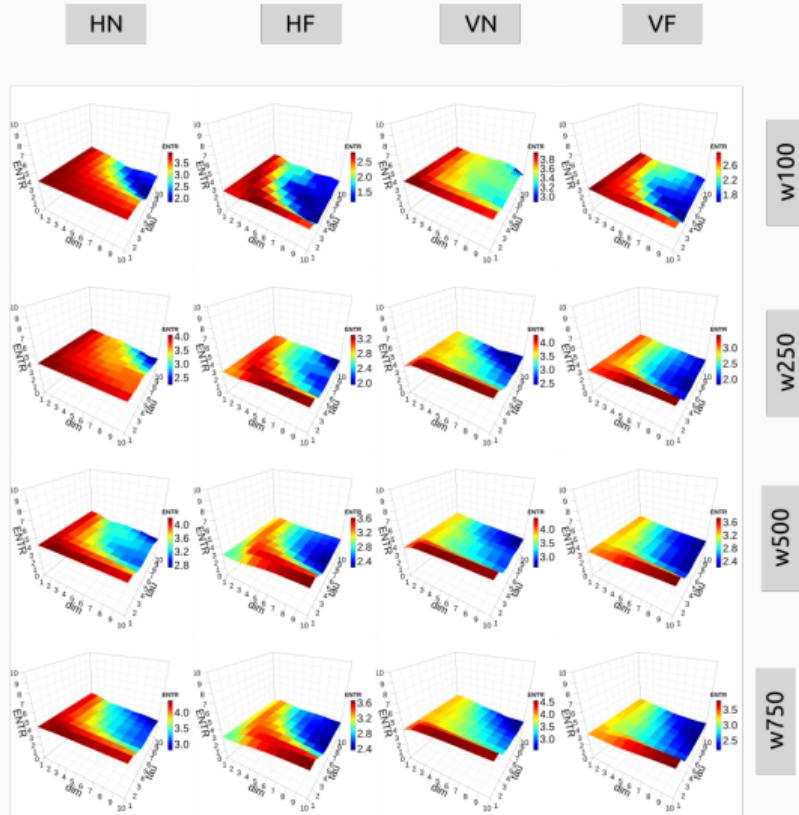
RQA ENTR values are for p03, sensor HS01, of a window size of 10-secs (500 samples).

RQA ENTR for sensors and activities

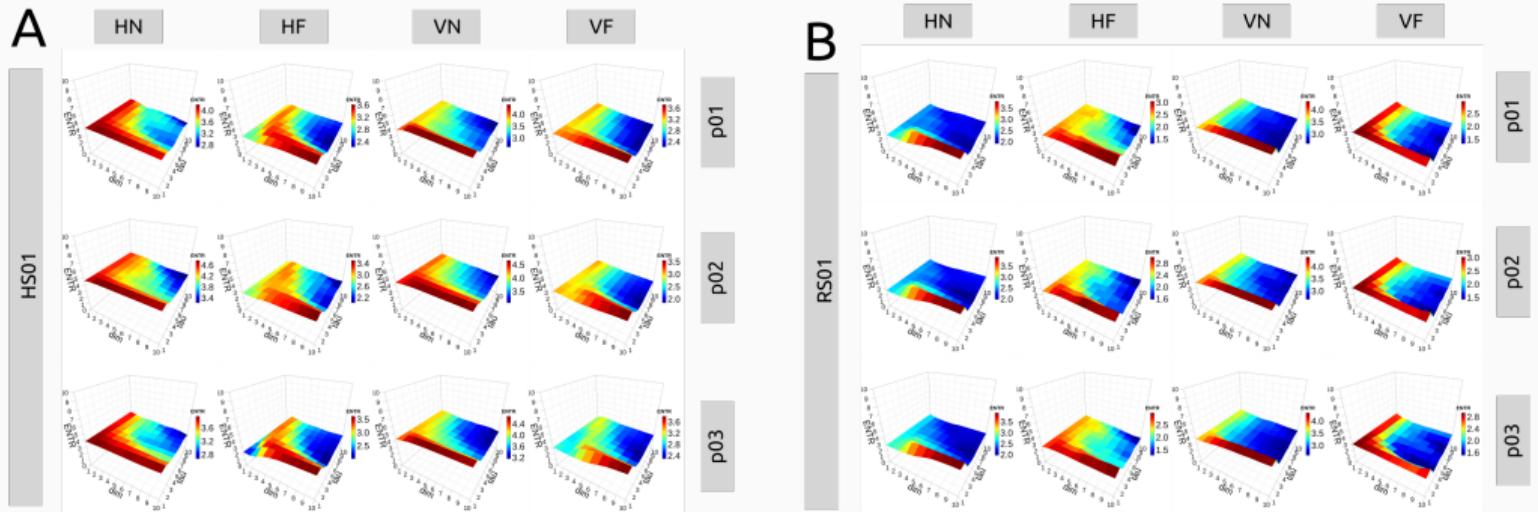


RQA ENTR values are for p03, sg0 and window size of 10-secs (500 samples).

Window size lengths



Participants



Participants differences of 3D surface plots of RQA.

Conclusions

Conclusions and future work

Take away messages

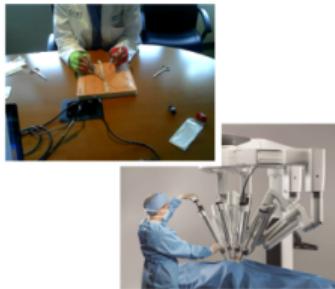
- Nonlinear analysis tools can quantify different data time-series.
- Shannon entropy with 3D plot surfaces of RQA appear to be robust for real-word data (i.e. different time series structures, window length size and levels of smoothness).
- Therefore, Shannon entropy would be a potential good tool to quantify complexity of movement.

Investigate

- other methodologies for state space reconstruction,
- the robustness of Entropy measurements with RQA, and
- variability in perception of velocity.

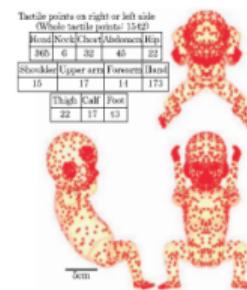
Applications of Nonlinear Dynamics

Quantification of skill learning



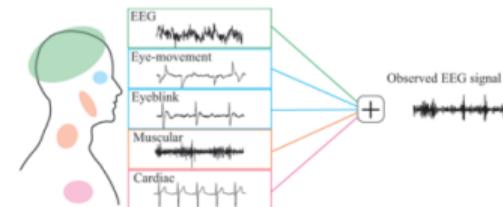
- * Surgical Skills Assessment
- * Robot-Assisted Surgery

Fetal behavioral development



- * General movements
- * Arm/Legs Movs
- * Hand/Face Contacts

Nonlinear Biomedical Signal Processing



- * EEG time series
- * Heart rate variability
- * Eye Movements

References



Xochicale Miguel

Nonlinear methods to quantify Movement Variability in Human-Humanoid
Interaction Activities

Submission in progress to Scientific Reports

<https://arxiv.org/abs/1810.09249>

Thanks!!! Questions?

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