The complexity of improvisation: brain, sound, movement and experience

Acknowledgements

東京工業大学
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GUILD SCHOOL HALL

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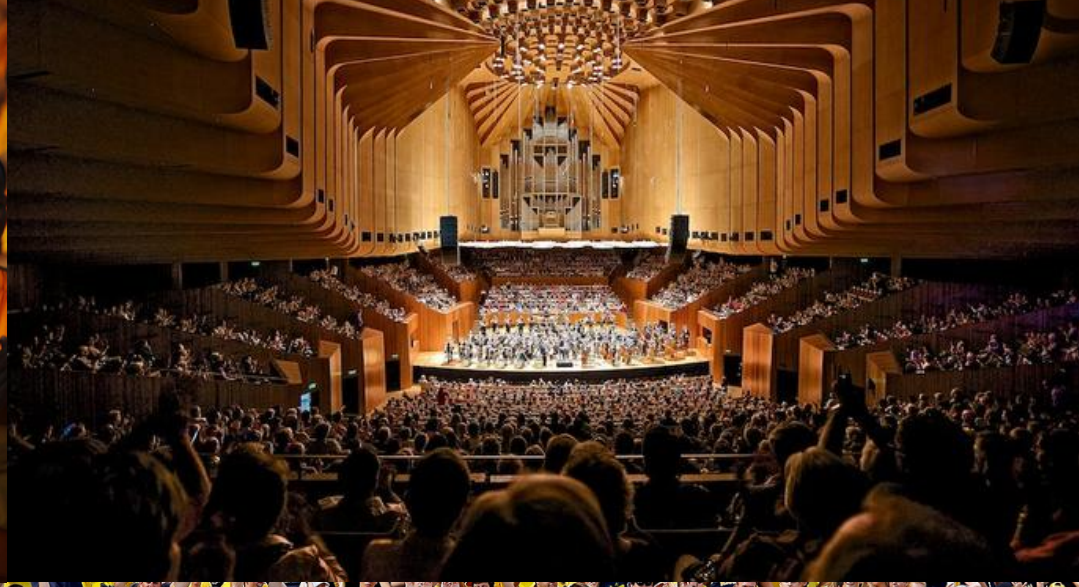
Dr Pedro AM Mediano
Dr Fernando E Rosas

I. EMERGENCE, COMPLEXITY, ENTROPY

Everywhere in nature, we see
complex collective behaviour of the **group** arising
from the **simple interactions** between **individuals**.

This behaviour is **emergent**.

"The whole is more than the sum of its parts."

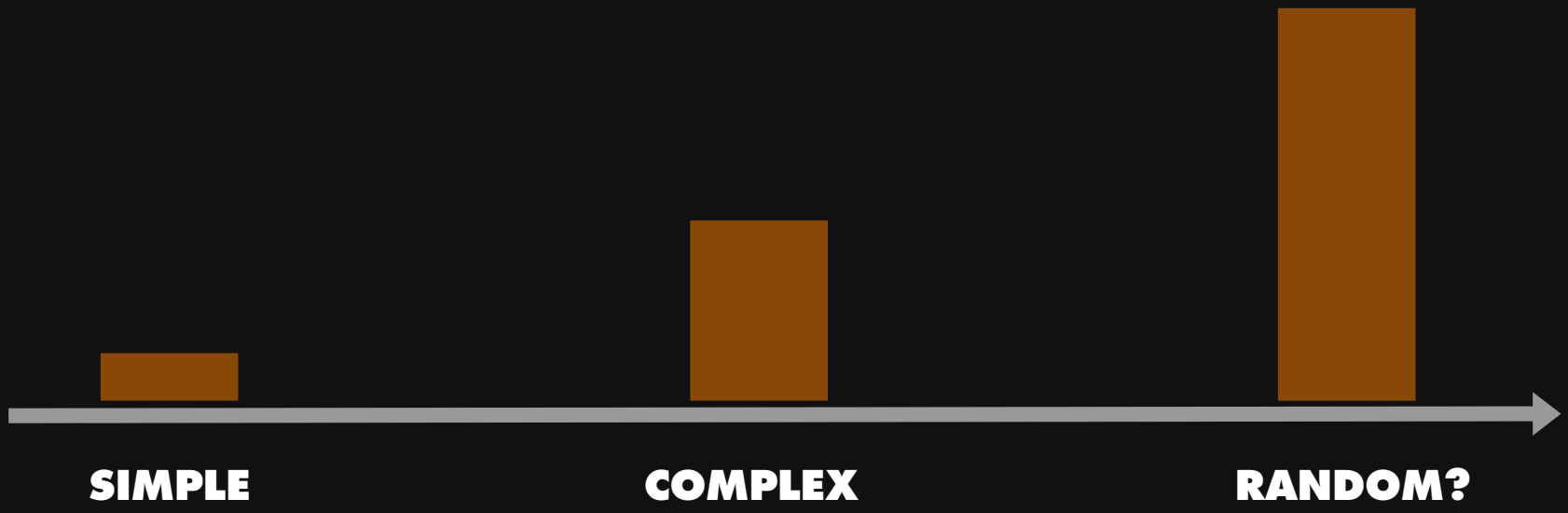


QUANTIFYING COMPLEXITY

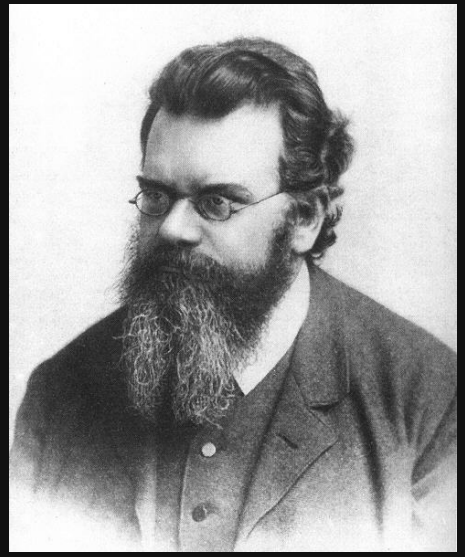
abababababa
bababaababa

To be or not to be?
this is the question…

mEYug&34tr973tr8i43t*XJu
wetv3YWw76fle@



ENTROPY

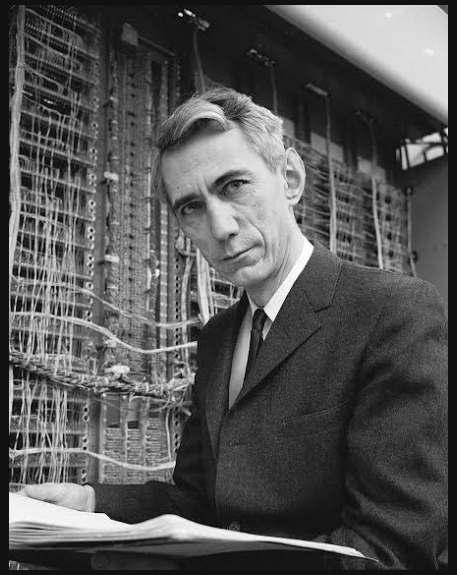


Ludwig Bolzmann (1875)

$$\mathrm{S} = \mathrm{k_B}\, log\, \Omega$$

'statistical disorder'

'average surprise'



Claude Shannon (1949)

$$\mathrm{H(X)} = \sum \mathrm{p_X}\, log\, \mathrm{p_X}$$

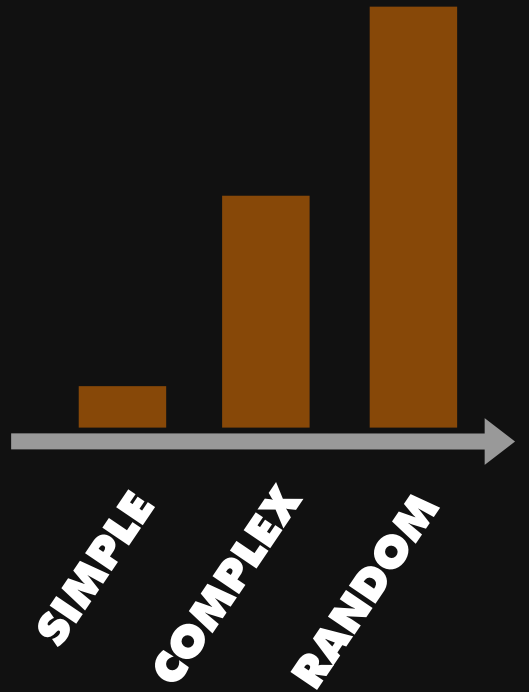
ENTROPY & COMPRESSION

abababababa
bababaababa

“abab”, “a”

To be or not to be?
this is the question…

“to be”, “or not”, “this”,
“is”, “the”, “question”



mEYug&34tr973tr8i43t*XJu
wetv3YWw76fle@

mEYug&34tr973tr8i43….

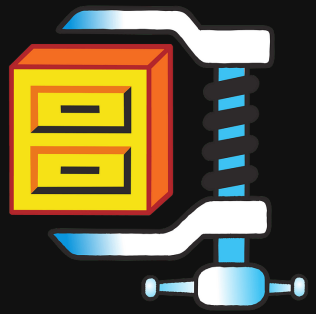
Welch (1984), Ziv & Lempel (1978)

ENTROPY & COMPRESSION

abababababa
bababaababa

To be or not to be?
this is the question…

mEYug&34tr973tr8i43t*XJu
wetv3YWw76fle@



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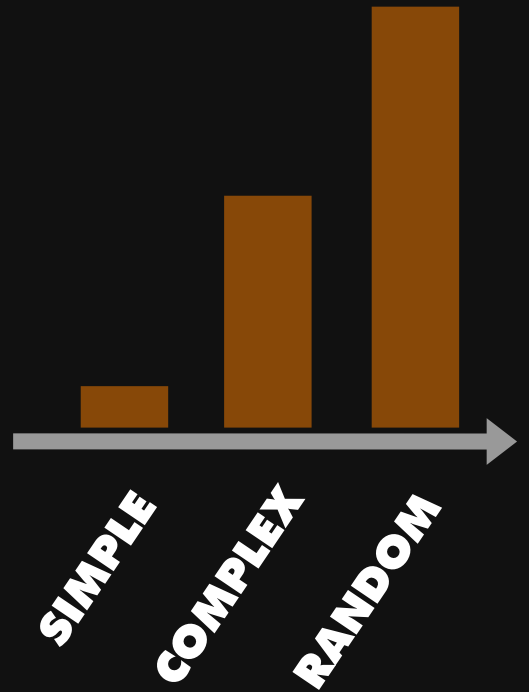
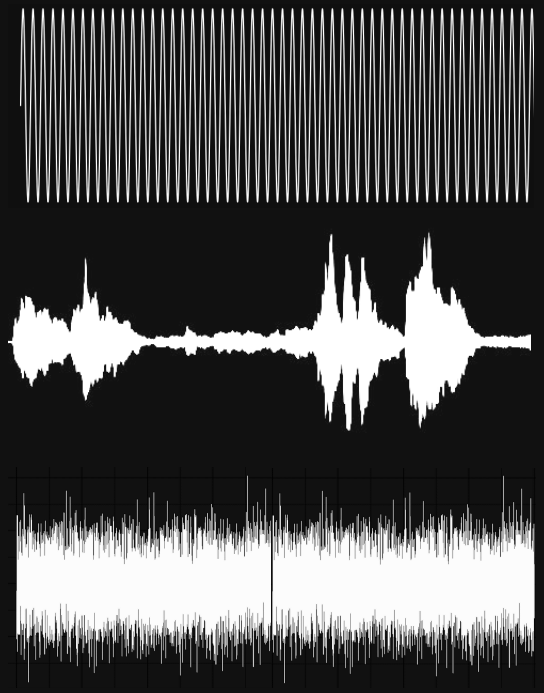
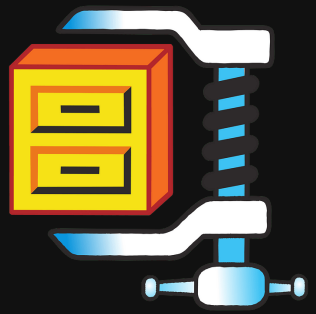


ENTROPY & COMPRESSION





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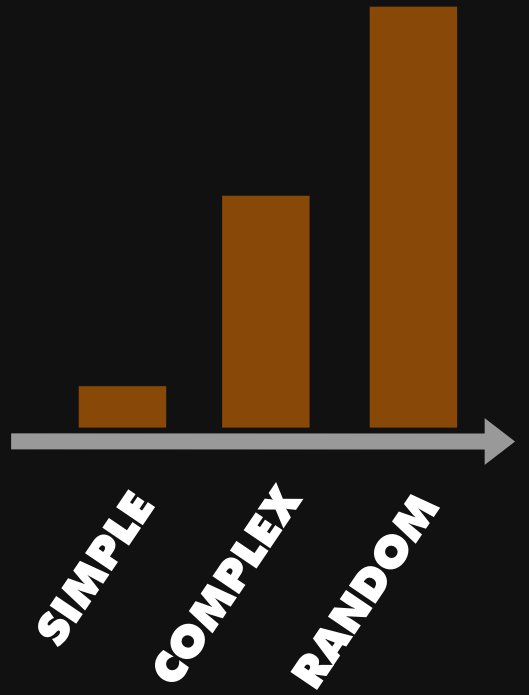
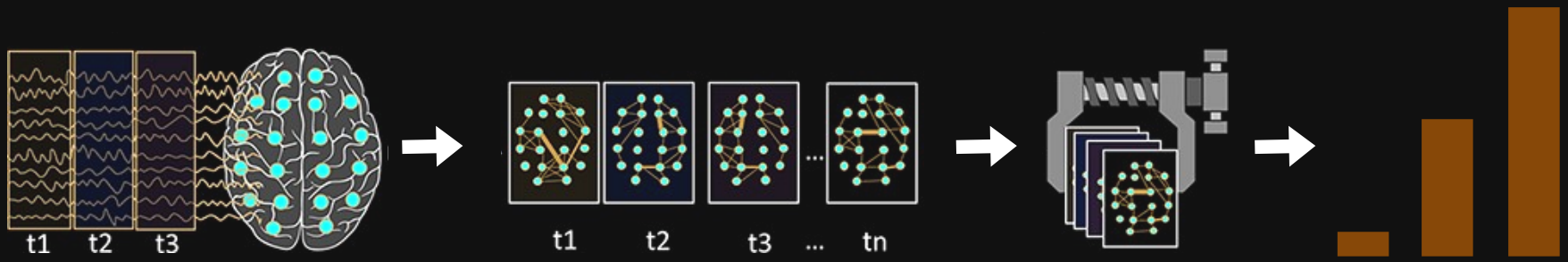


Pinkerton (1956)

ENTROPIC BRAIN HYPOTHESIS

The **entropy** of spontaneous brain activity indexes
the **richness** of **states of mind**.



Carhart-Harris et al (2014), Sarasso et al (2021)

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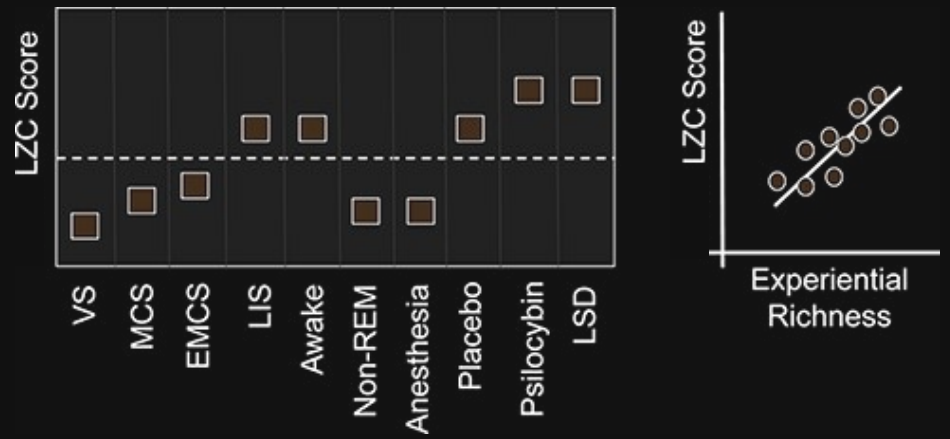


Rankaduwa & Owen (2023)

II. MUSICAL IMPROVISATION

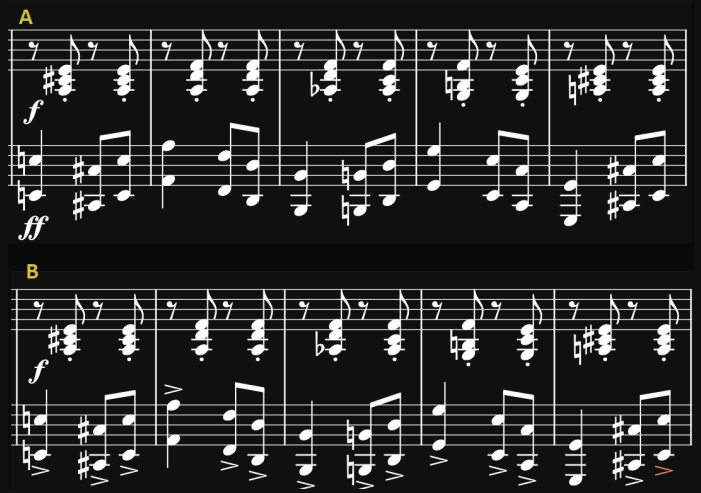
IMPROVISATION

1800s

1900s

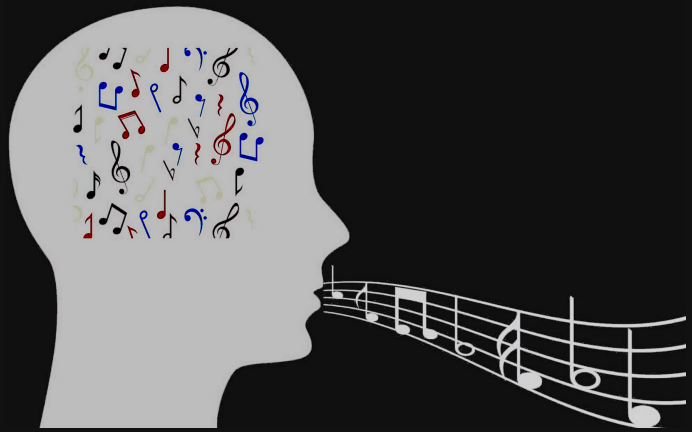
2000s

MODES OF PERFORMANCE



Strict

control technical precision, timing and accuracy of the score's details and avoiding risks, while at the same time creating the most convincing and expressive performance possible



Let-go

play freely, spontaneously, not putting an imperative focus on "no wrong notes", take risks, may deviate from the written text in an unplanned coordination with the other ensemble partners

Dolan et al (2013)

MUSIC COMPLEXITY & CREATIVITY

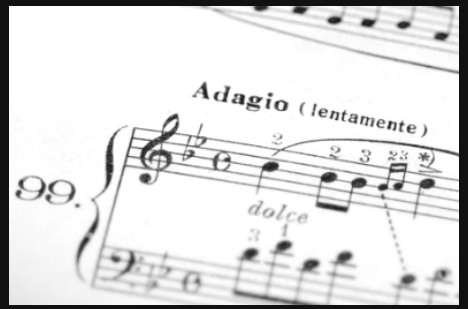
MUSIC ANALYSIS

- Musicology: focus on symbolic music (sheet music or MIDI)
- Music information retrieval: focus on a single piece, using only one recording
- Music performance analysis: performance-centric comparisons of the same piece

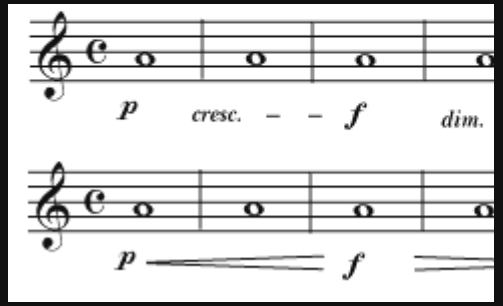
Lerch et al (2020)

PERFORMANCE PARAMETERS

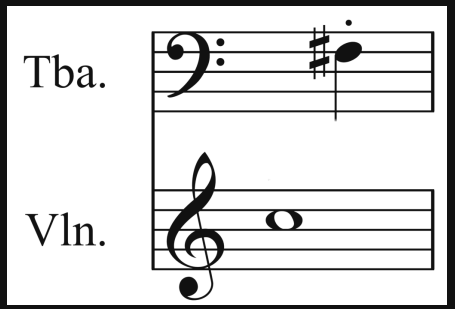
tempo



dynamics

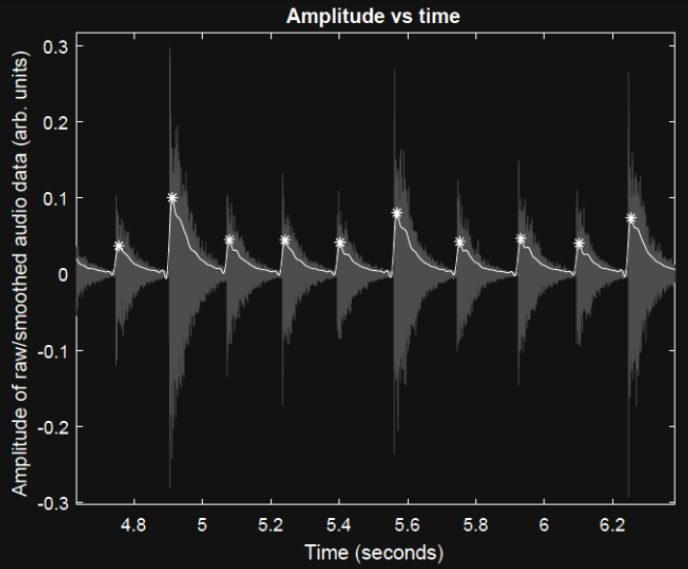


timbre

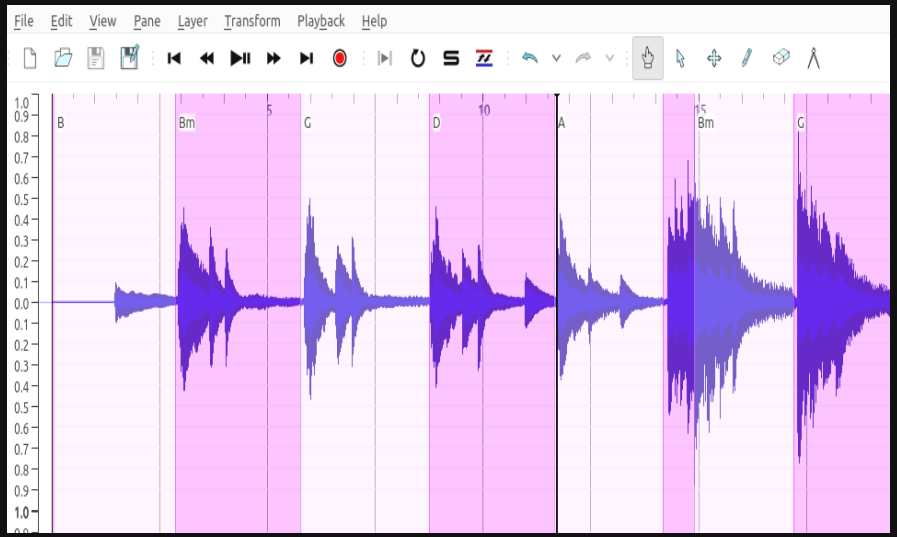


Bowen (1996); *Lerch et al* (2020)

TEMPO MAP



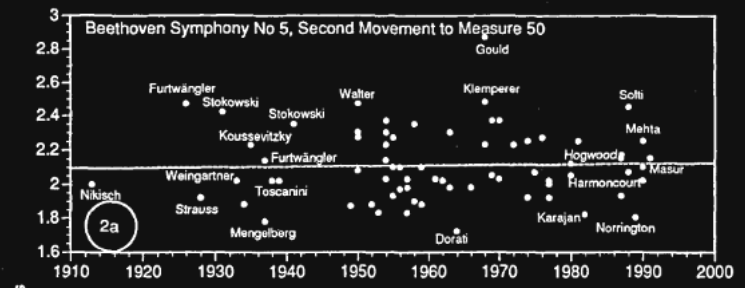
Automated peak detection
(best for drums)

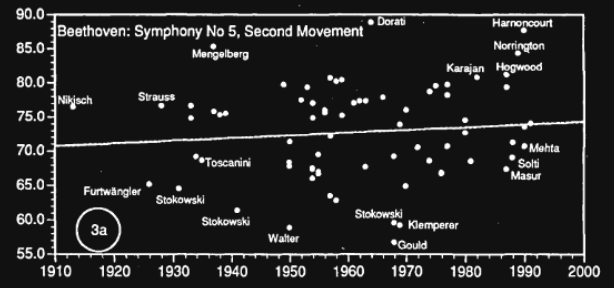


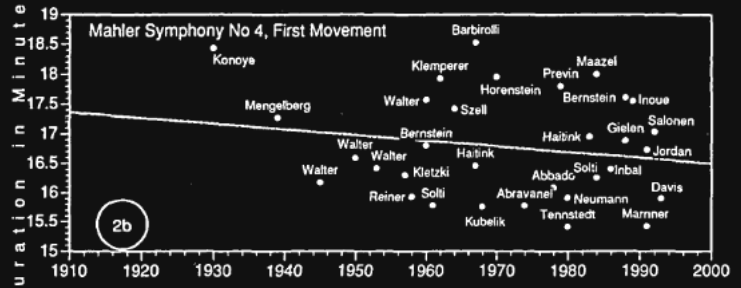
Manual tempo annotations in
Sonic Visualiser

Gordon et al (2019)

DURATION & TEMPO







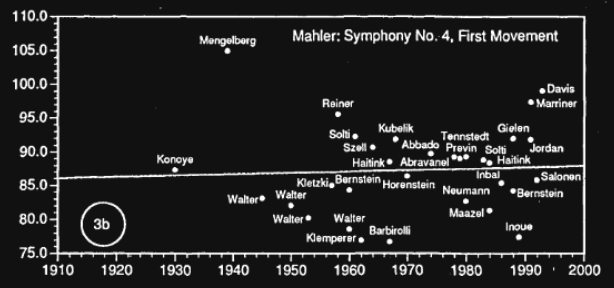
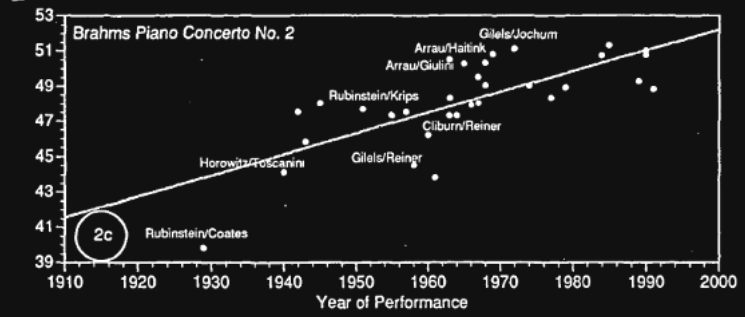


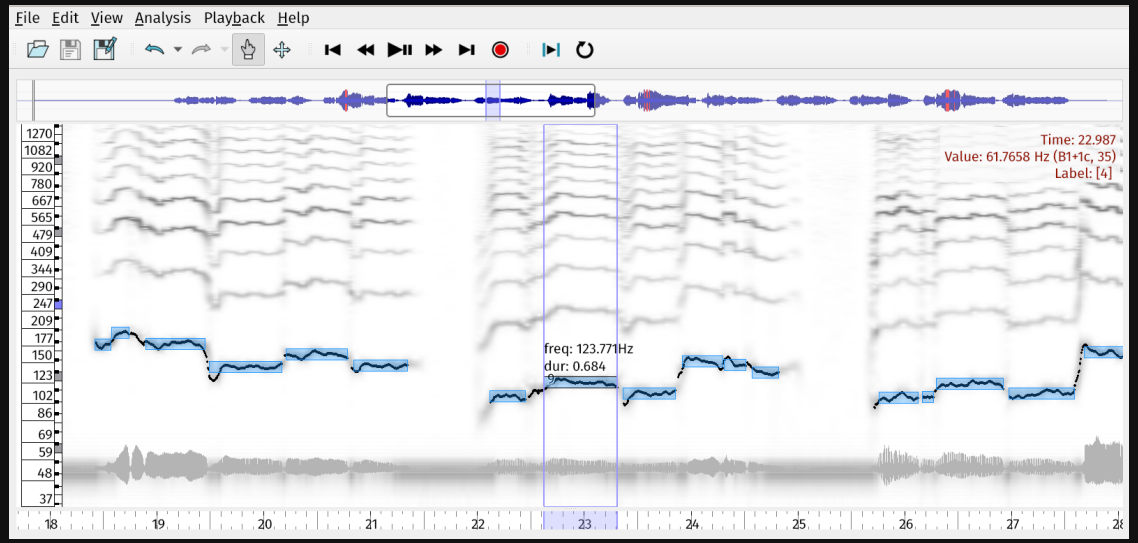
Figure 3. Average Initial Tempos



Bowen (1996)

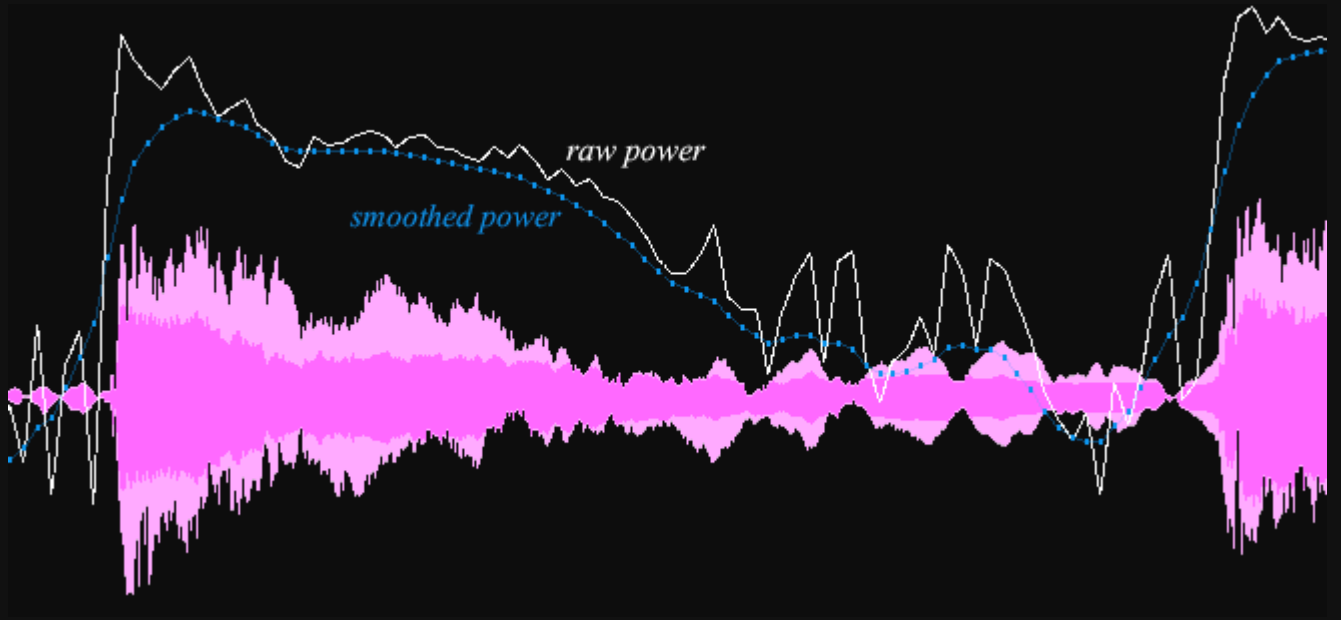
TIMBRE

Spectral analysis using wavelet transform (spectrogram).
Spectral entropy can reveal timbral complexity.



DYNAMICS

Loudness Units relative to Full Scale (LUFS) is a standardised unit for perceptual loudness used for digital audio normalisation.



ITU-R BS.1770 (2006); EBU R 128 v 4.0 (2020), Mazurka Plugin Documentation

DYNAMICS

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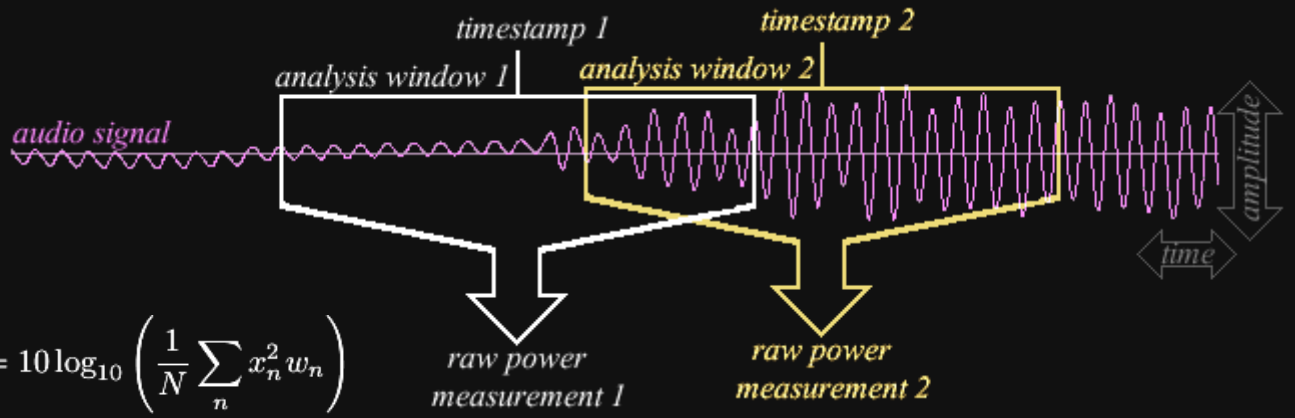
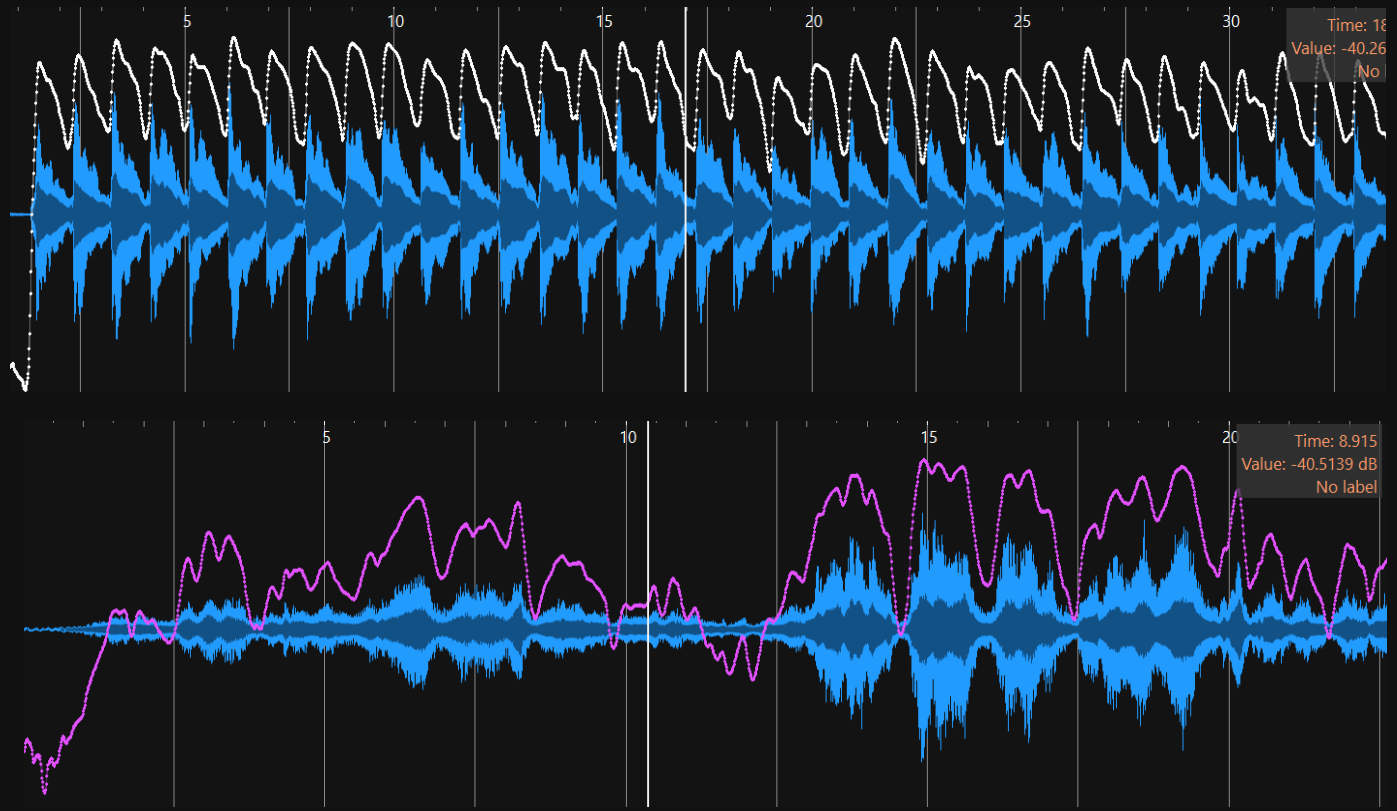


$$P_{\text{wavg}} = 10 \log_{10} \left(\frac{1}{N} \sum_{n} x_n^2 w_n \right)$$

computed as a weighted RMS over time windows

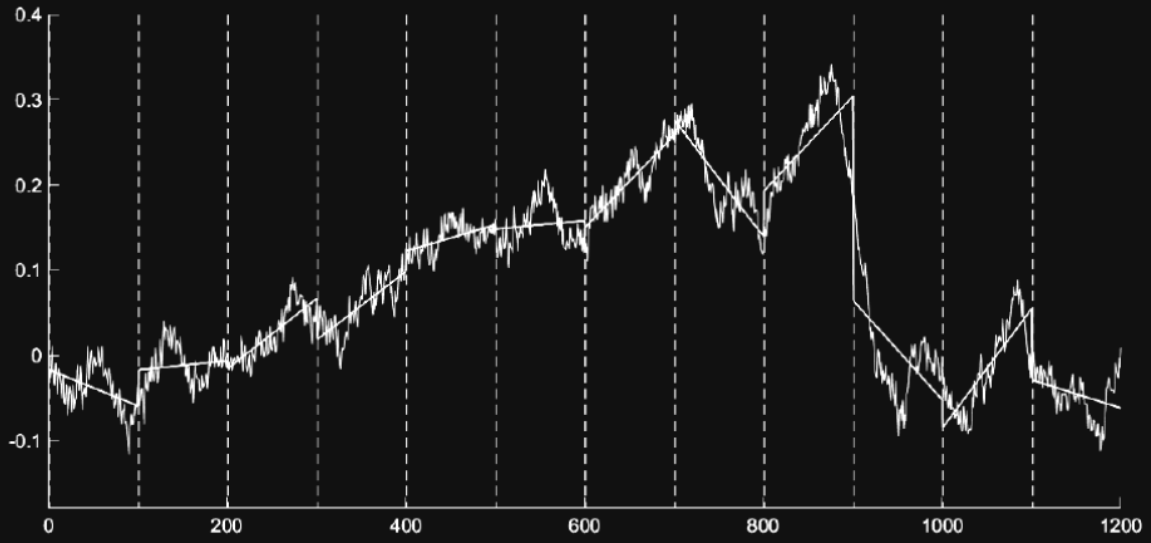
ITU-R BS.1770 (2006); EBU R 128 v 4.0 (2020), Mazurka Plugin Documentation

DYNAMICS & COMPLEXITY



DETRENDED FLUCTUATION ANALYSIS

For each window size, fit a line over the power curve within each window, compute linear regression residuals and average to get fluctuations $F(w)$



Fit a power law

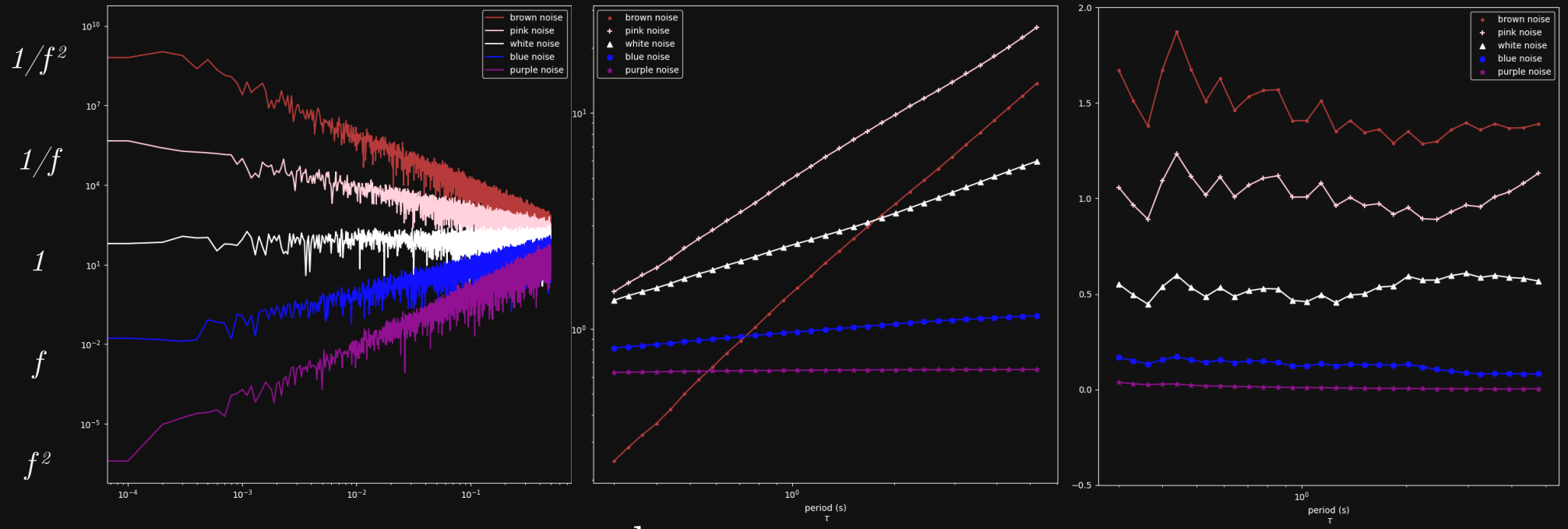
$$F(w) \propto w^{\alpha}$$

to analyse fluctuations

Jennings *et al* (2003), Streich & Herrera (2005), Räsänen et al (2015), Gordon et al (2019)

DETRENDED FLUCTUATION ANALYSIS

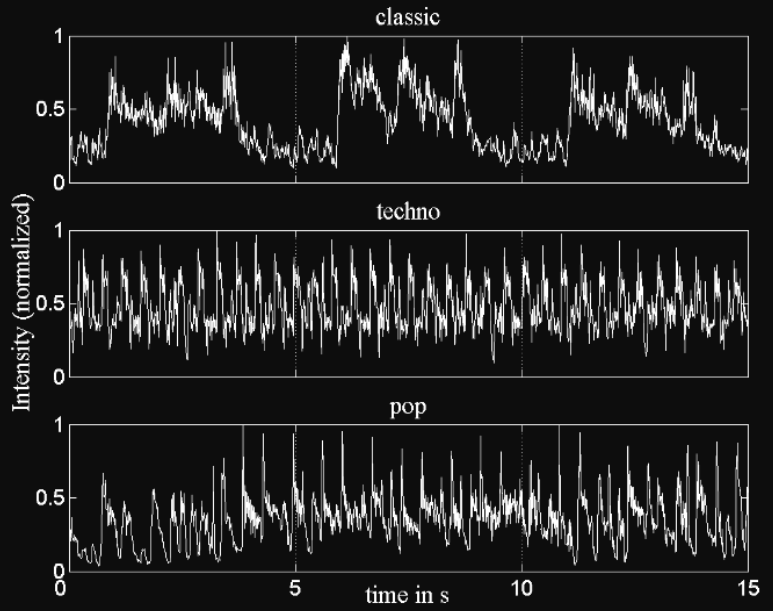
Estimates a ‘fractal dimension’ of the signal

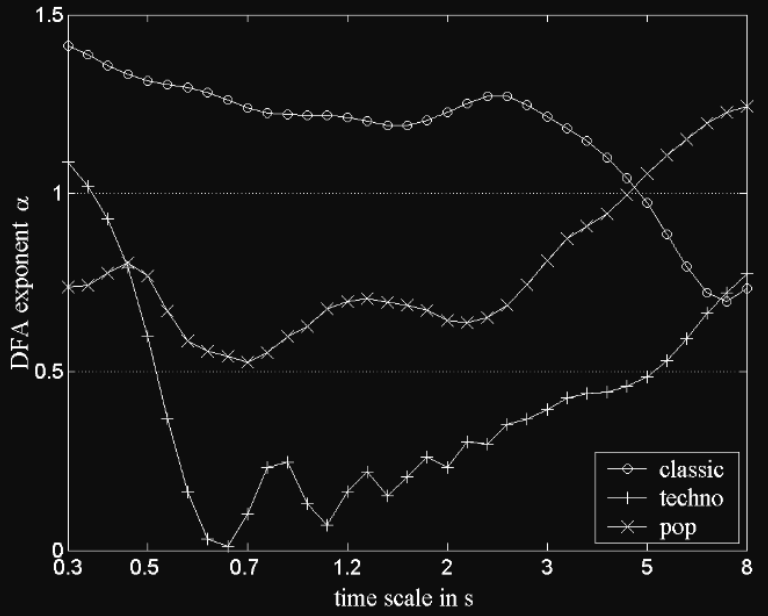


$y = ax + b$

$F(\tau) \propto \tau^{\alpha}$

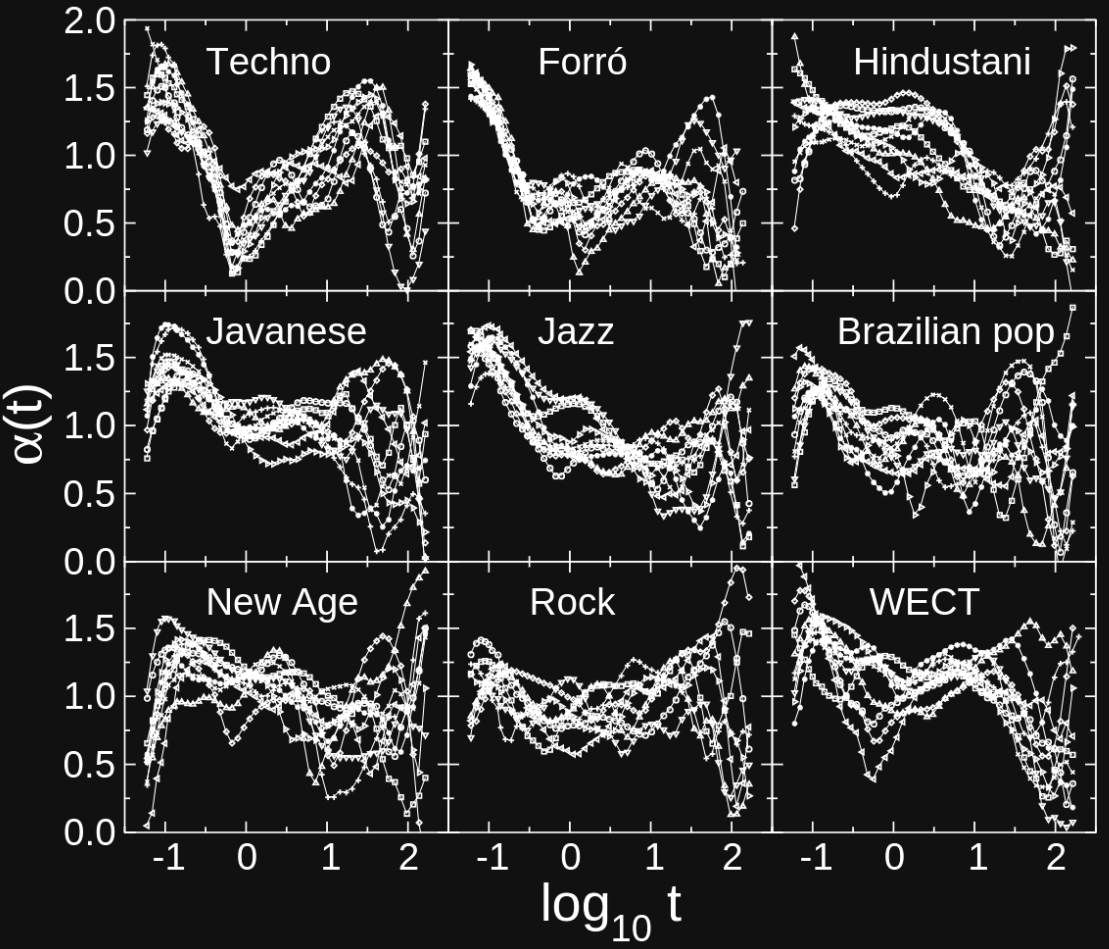
DETRENDED FLUCTUATION ANALYSIS





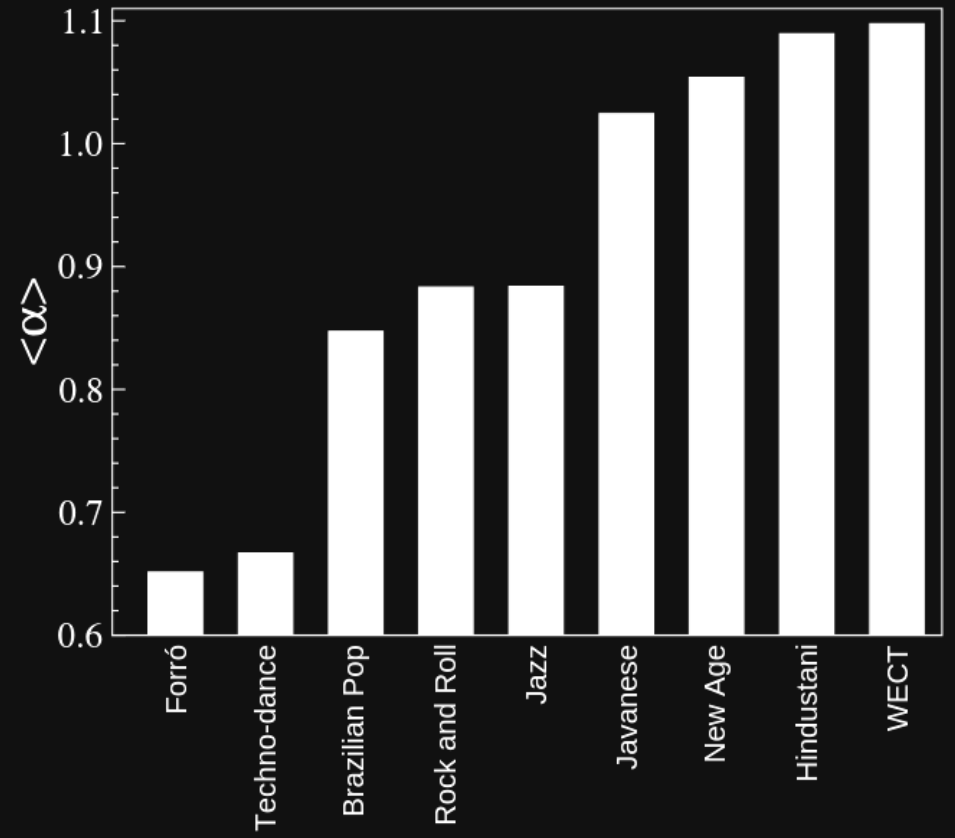
Streich & Herrera (2005)

GENRE DISCRIMINATION



Jennings *et al* (2003)

GENRE DISCRIMINATION



Jennings *et al* (2003)

EXPERIMENTAL RESULTS

THE CONCERT EXPERIMENT

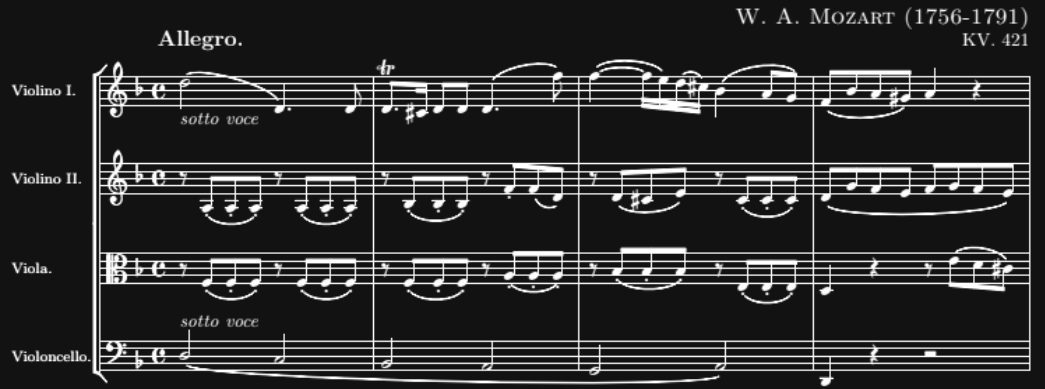
Playing a repertoire piece **strict** or **let-go** allows direct comparisons of performance parameters, audience behaviour and the performers' and audience's brain signals.

Dolan et al (2013)

REPERTOIRE PERFORMANCES

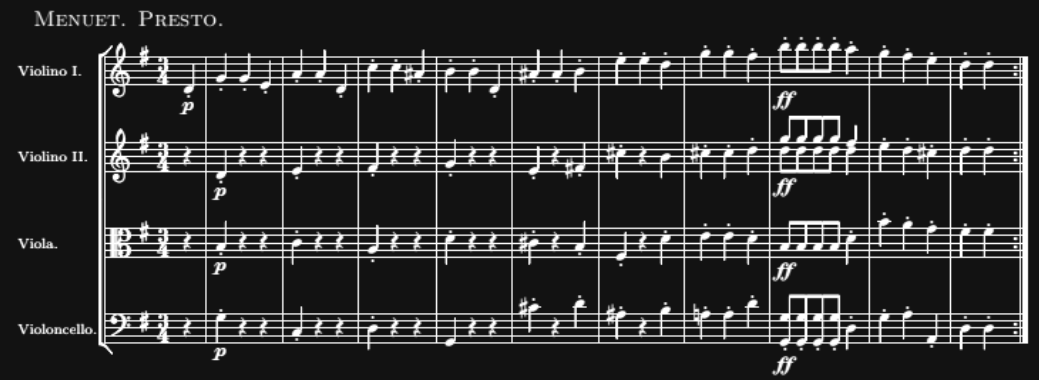
Mozart String Quartet KV. 421 no. 15

- Let-go first (piece 1)
- Strict second (piece 2



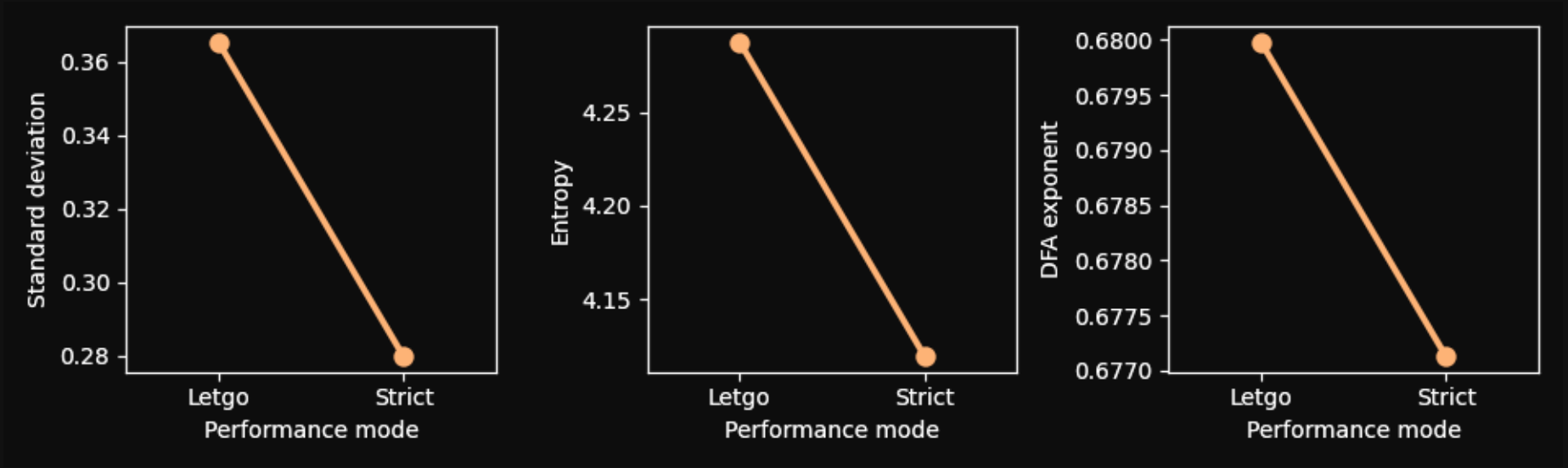
Haydn String Quartet Op. 76 no. 1, III

- Strict first (piece 7)
- Let-go second (piece 8)



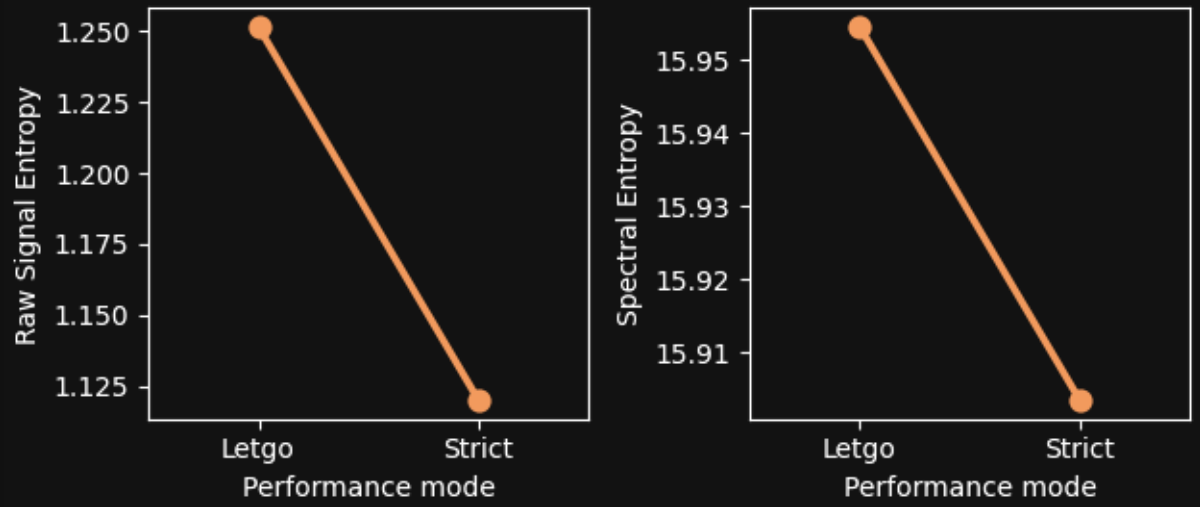
TEMPO COMPLEXITY

Compute inter-beat intervals from tempo map then calculate metrics on the resulting signal.

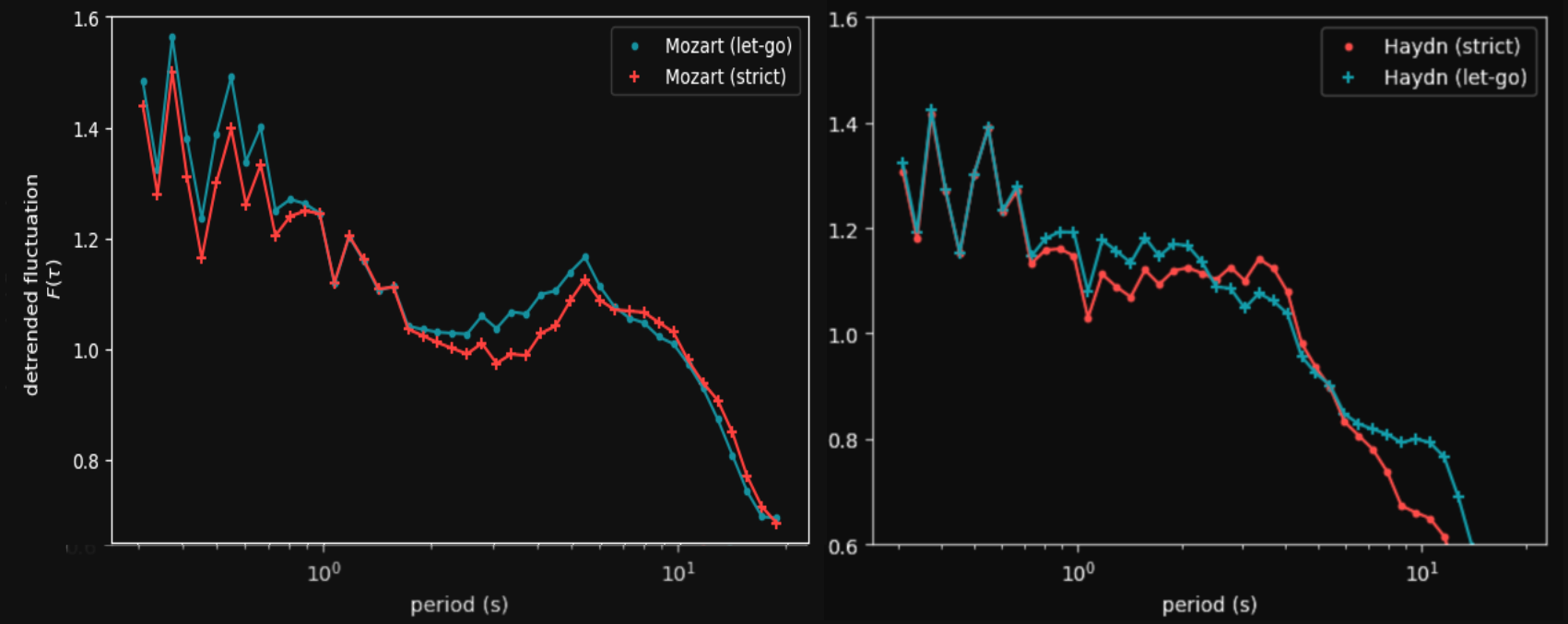


methods by Räsänen et al (2015), Gordon et al (2019)

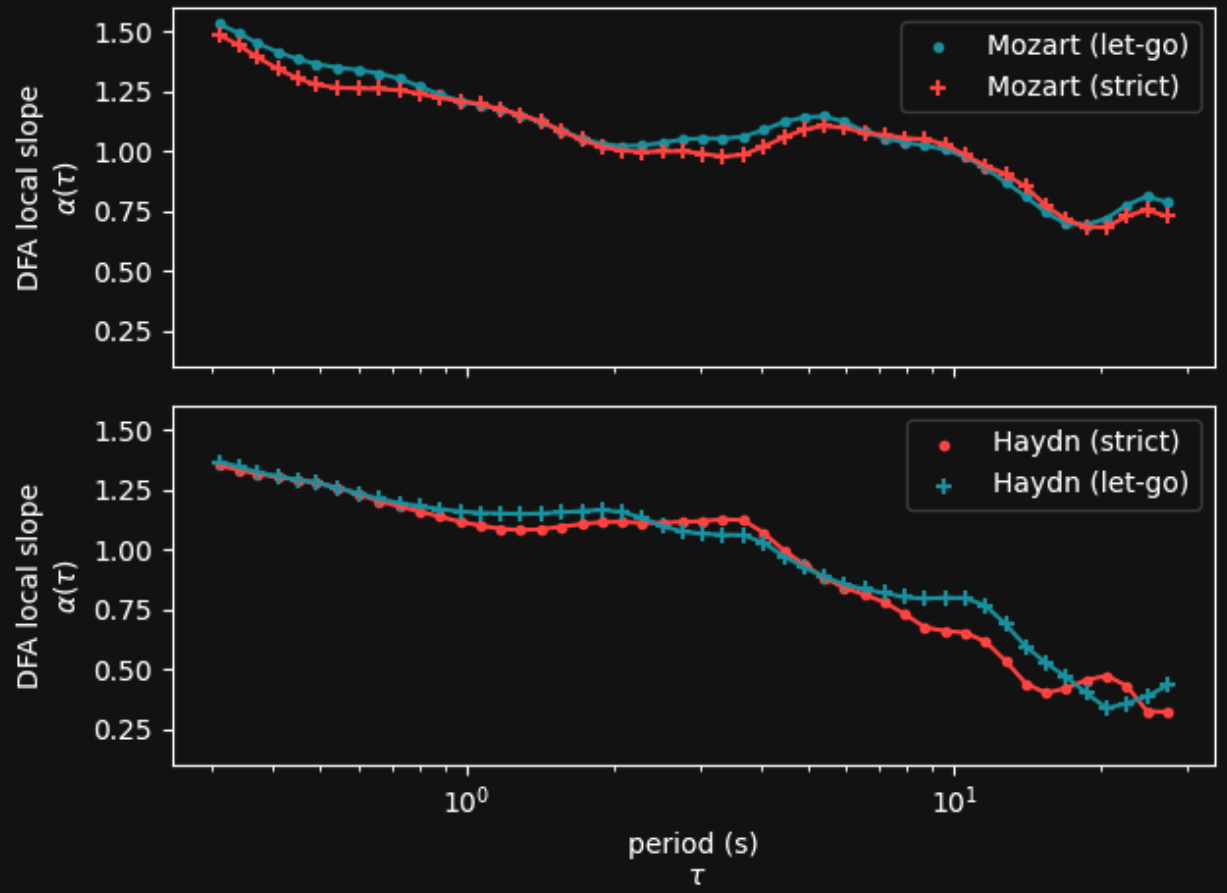
DYNAMIC & SPECTRAL COMPLEXITY



DETRENDED FLUCTUATION ANALYSIS



DETRENDED FLUCTUATION ANALYSIS



III. COLLECTIVE EXPERIENCE

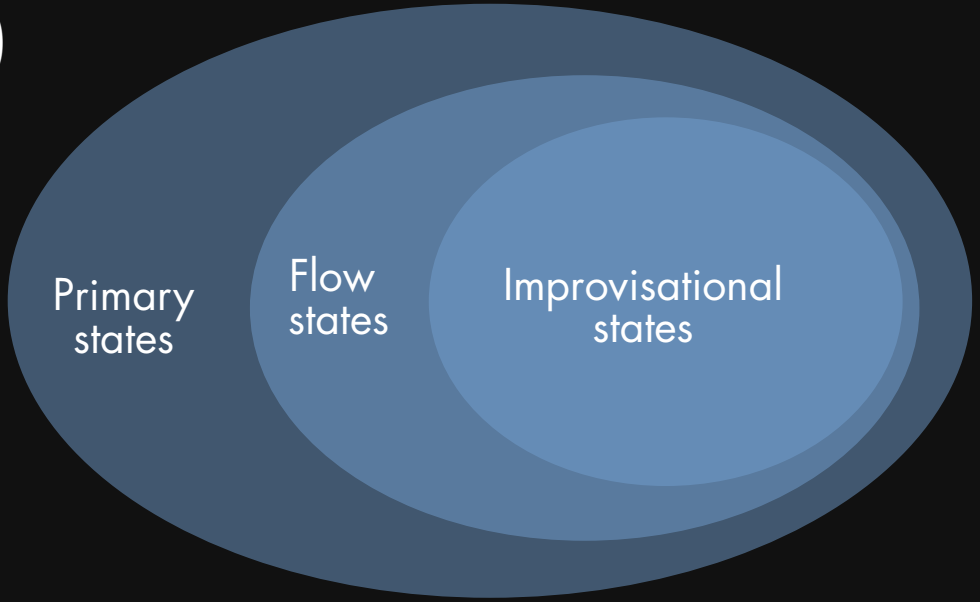
“

In all societies, a primary function of music is collective and communal, to bring and bind people together. People sing together and dance together in every culture [...] in such a situation, there seems to be a binding of nervous systems accomplished by rhythm.

— Oliver Sacks

IMPROVISATIONAL STATE OF MIND

- a **primary state** (*Carhart-Harris et al*, 2014)
- a type of **flow state** (*Csikszentmihalyi*, 1990)
- a type of **team flow**? (*Shehata et al*, 2020)



THE CONCERT EXPERIMENT

Liardi*, Sas* et al (*in prep.*)

IMPROVISATIONAL STATE OF MIND

Performers and **audience** show increased
Lempel-Ziv **complexity** during **let-go** and **improvisation**.

Dolan et al (2018)

THE MUSICIANS' PERSPECTIVE

… the let-go version puts us on an awareness edge, and suddenly we are able to see past the music and look out for these spontaneous cues for the changes in both the music itself and the way we perform it…

… a very high level of mind-reading and synchronicity …

THE AUDIENCE'S PERSPECTIVE

Classical music audiences show higher synchrony of movements, heart rate and arousal when listening.

Synchrony facilitates many prosocial behaviours.

But synchrony decreases as enjoyment of the piece increases?

Czepiel et al (2021), Tschacher et al (2023)

Cognitive processing of a common stimulus **synchronizes** brains, hearts, and eyes.

Physical synchrony between humans facilitates rapport and learning.

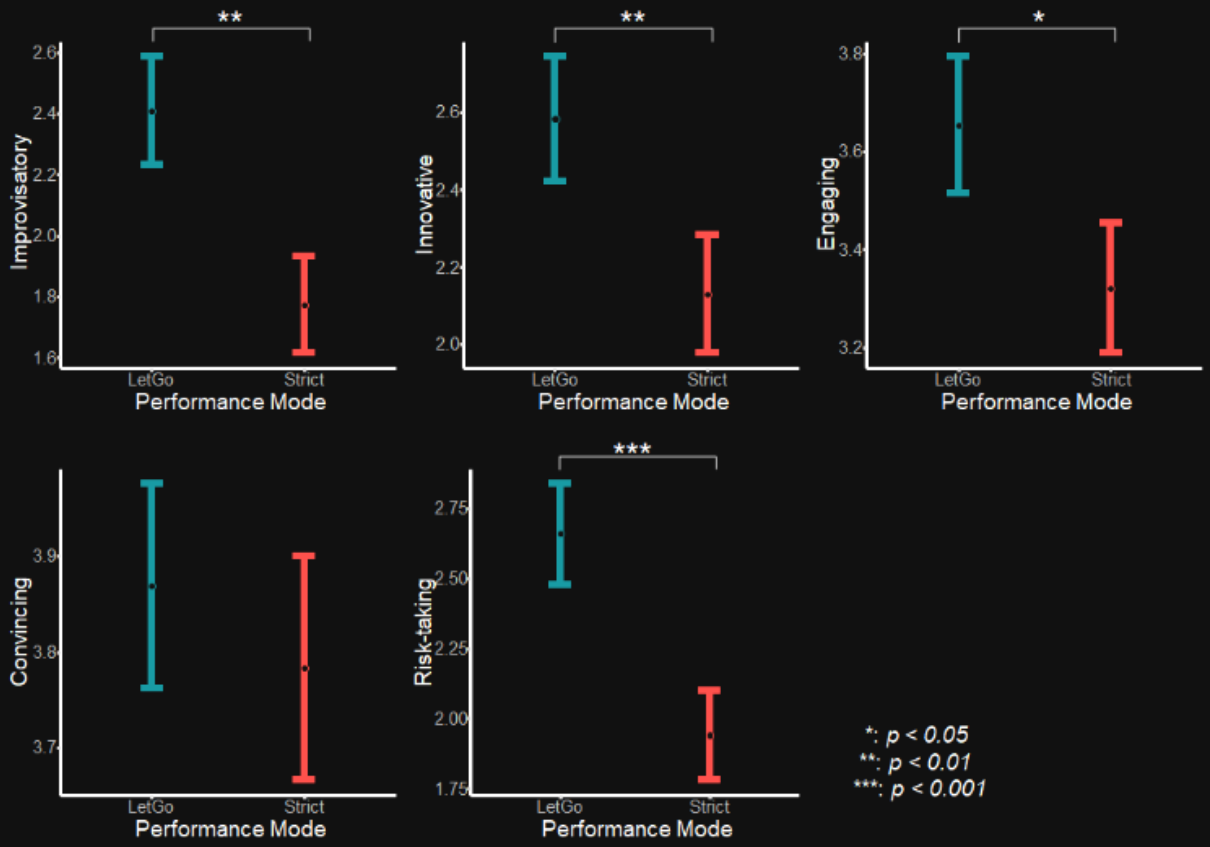
Group flow states encourage teamwork and cooperation.

Madsen et al (2022), Nozawa et al. (2019), Csíkszentmihályi (1990)

THE CONCERT EXPERIMENT

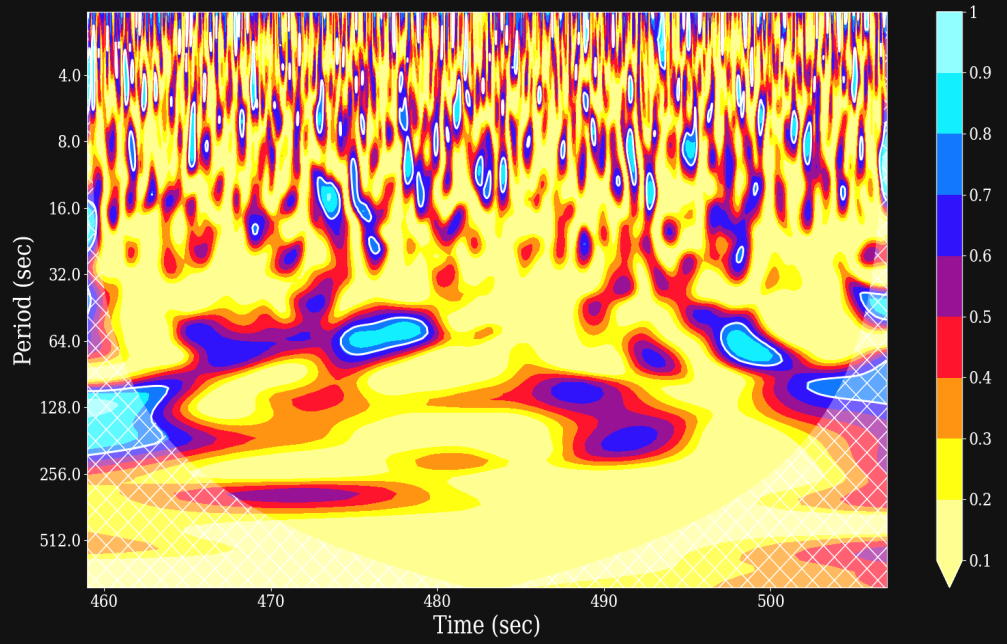
Nozawa*, Sas* et al (2023)

THE AUDIENCE'S PERSPECTIVE



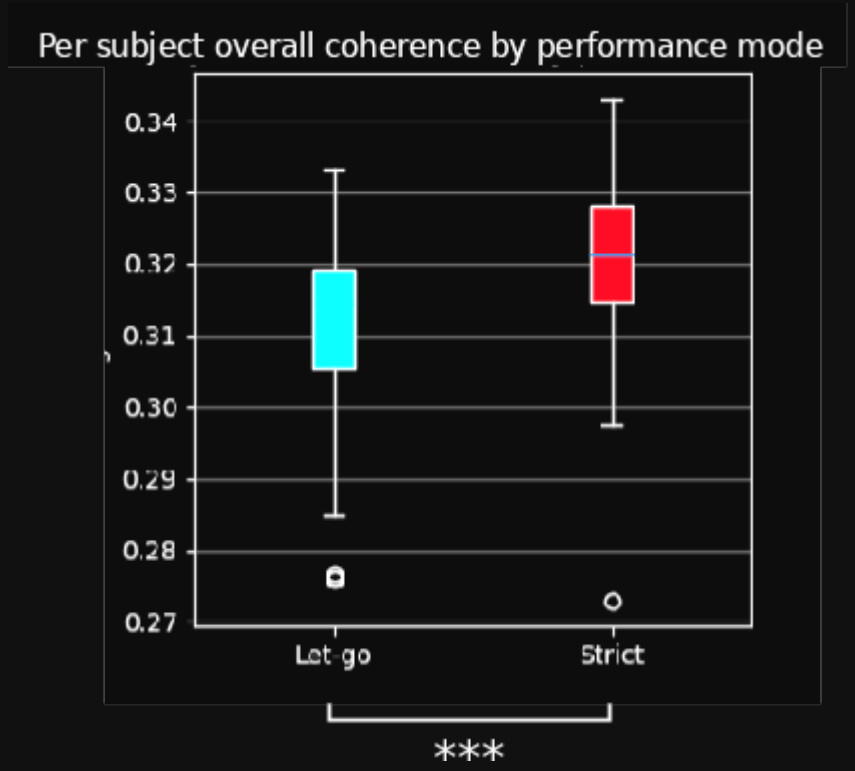
Nozawa, Sas et al (2023)

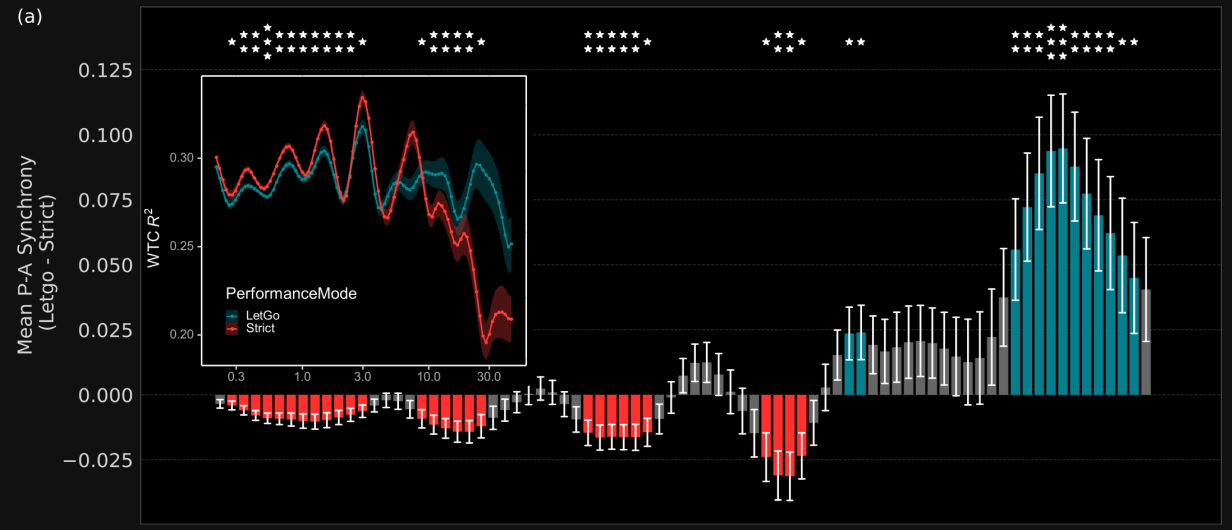
COLLECTIVE MOVEMENT

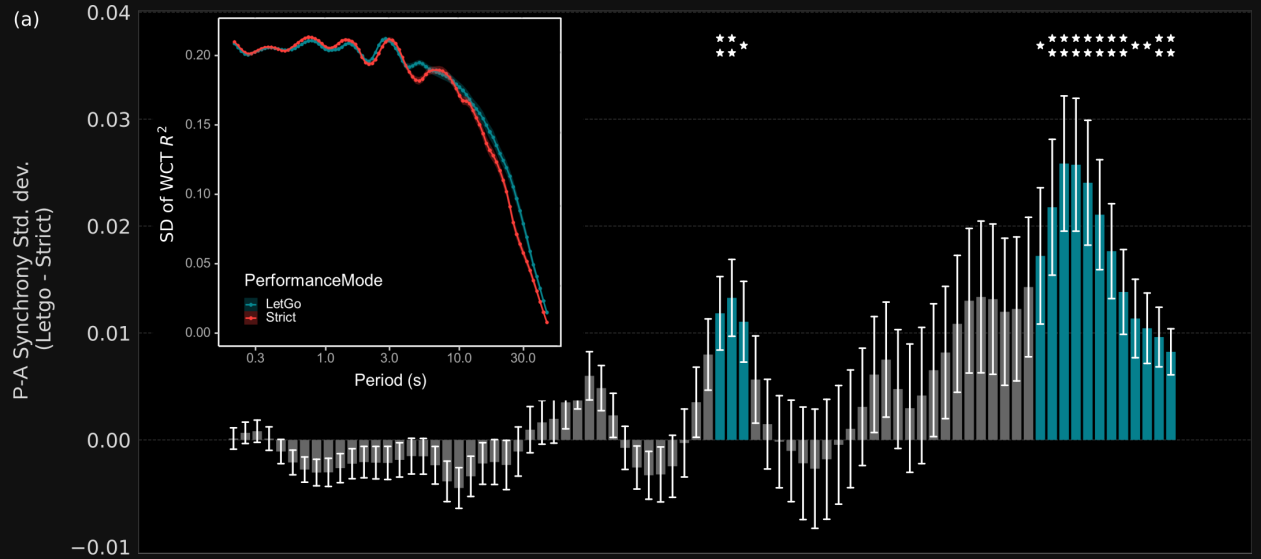


Grinsted et al (2006), Nozawa et al (2019)

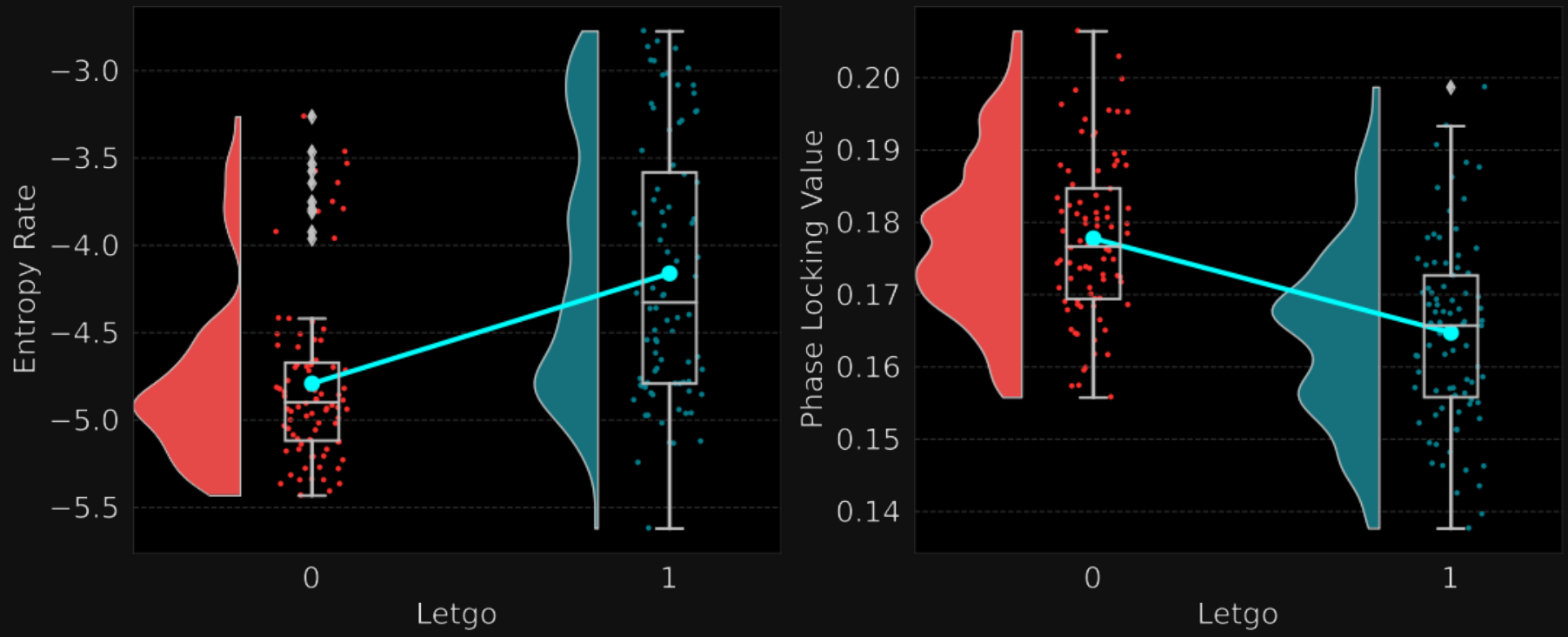
COLLECTIVE MOVEMENT



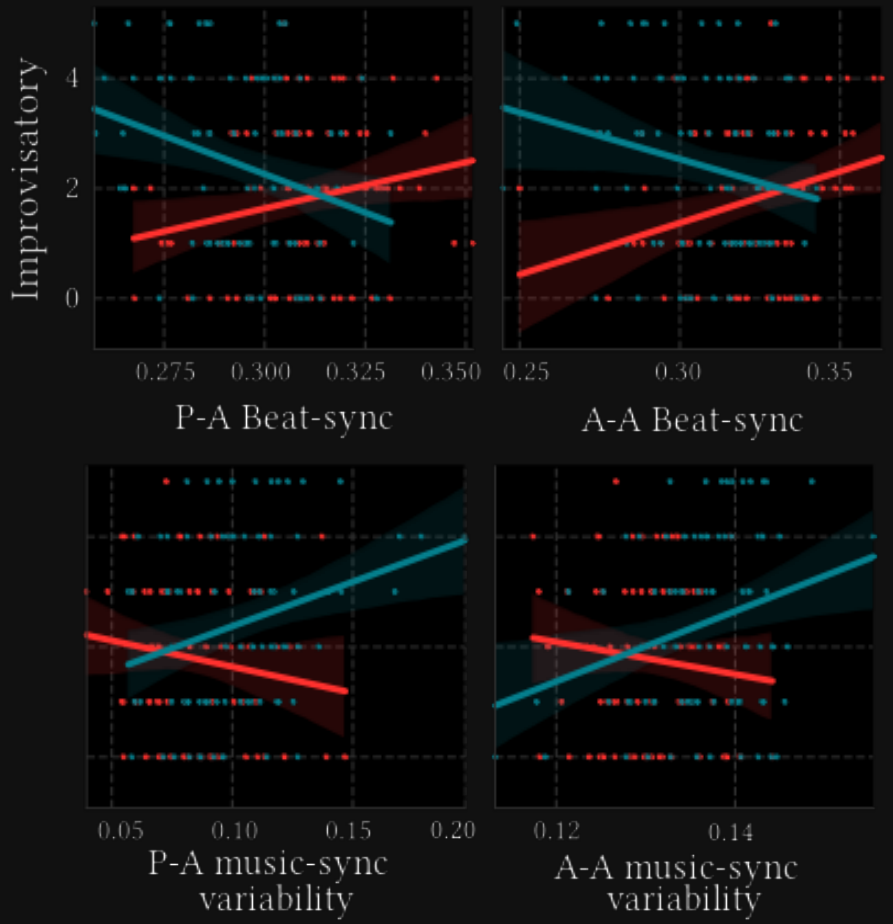

(a)
Mean P-A Synchrony (Letgo - Strict)
0.125
0.100
0.075
0.050
0.025
0.000
−0.025
WTC R^2
0.30
0.25
0.20
PerformanceMode
LetGo
Strict
0.3
1.0
3.0
10.0
30.0


(a)
P-A Synchrony Std. dev. (Letgo - Strict)
0.04
0.03
0.02
0.01
0.00
−0.01
SD of WCT R^2
0.20
0.15
0.10
0.05
0.00
PerformanceMode
LetGo
Strict
0.3
1.0
3.0
10.0
30.0
Period (s)

COLLECTIVE BREATHING



COLLECTIVE EXPERIENCE



Higher sync in breathing and short-term movements (**beat-sync**).

Enjoyment is associated with the long-term (**music-sync**) high synchrony.

The perception of risk-taking is related to higher temporal variability in long-term synchrony.

Multi-scale sync seen in other performer-audience collective motion.

CLOSING THOUGHTS

Complexity can help us study phenomena while avoiding reductionism.

The creative improvisatory state of mind is an altered high-entropy state.

High entropy (but not too high!) pervades creative acts, in the music, the movement, and the brains of performers and audiences.

Self-similarity ubiquitous in beauty.

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