The emergence of multiscale physical synchrony in audiences to Western classical music improvisation

Madalina Sas
ms6413@ic.ac.uk

Motivation

- **Physical synchronisation** marks a collective experience with benefits for rapport and learning.

- Performers synchronise when **improvising**, also showing higher brain signal **entropy**. Audiences also show higher entropy when listening to improvised music.

- In many types of popular music, concert audiences are known to synchronise with eachother. But in Western classical music tradition, audiences are seen as 'passive' or 'static'.

Dolan et al. (2013, 2018), Nozawa et al. (2019)

Goals

Exploring collective behaviour of audiences to classical music performance from the perspective of physical synchrony:

- Does the degree of improvisation affect physical synchrony?
- On what temporal scales does physical synchrony emerge?
- Does the audience's perception of the piece affect physical synchrony? Or the other way around?
- Does psychological absorption affect synchrony?

Modes of performance

Strict

controlling technical precision, timing coordination,
accuracy of the score's details, 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", deviate from
the written text in an unplanned coordination with
the other ensemble partners

Dolan et al. (2013)

Hypotheses

- There are differences in audience synchrony between the two modes of performance and between the two types of performance
- Audiences find improv > let-go > strict in improvisatory, innovative, emotionally engaging, musically convincing, and risk-taking
- Strong synchrony may emerge at different scales which depend on the nature of the piece
- More synchronous listeners perceive the music as more emotionally engaging
- There are differences in audience synchrony between blindfolded and non-blindfolded subjects

The Concert Experiment

Experiment Details

An interdisciplinary collaboration between

- Guildhall School of Music
- Tokyo Institute of Technology
- Imperial College London

When & where

- 16 October 2019
- Guildhall School of Music

Musicians

- **Portorius Quartet**:

 Sophia Prodanova, Nicole Petrus Barracks, Nathan Giorgetti, Diogo Ramos

Experiment Details

Audiences

- 60 participants with a wide range of experience with classical music
- data from only **42** subjects was evaluated (tech error or no data)
- **13** of the 42 subjects were **blindfolded** during the first 2 and last 2 pieces

Data from audiences

- Physical motion data from mobile **3D accelerometers**
- **Psychometric** questionnaires
- **Subjective reports** of listeners after each pair of performances
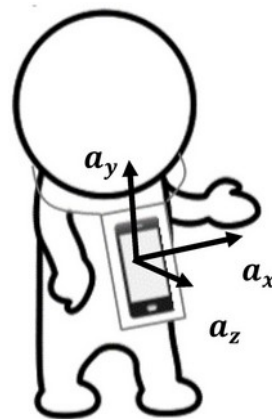
Programme

#	Performance Type	Composer	Leadership	Performance mode	Blindfold	Duration (s)
1	Repertoire	Mozart		let-go	1	137
2	Repertoire	Mozart		strict	1	120
3	Improvisation		single	strict	0	48
4	Improvisation		dynamic	strict	0	135
5	Improvisation		dynamic	let-go	0	183
6	Improvisation		single	let-go	0	110
7	Repertoire	Haydn		strict	1	136
8	Repertoire	Haydn		let-go	1	146

Repertoire performances

- **Mozart String Quartet KV. 421 no. 15**
  - Let-go first (piece 1)
  - Strict second (piece 2)
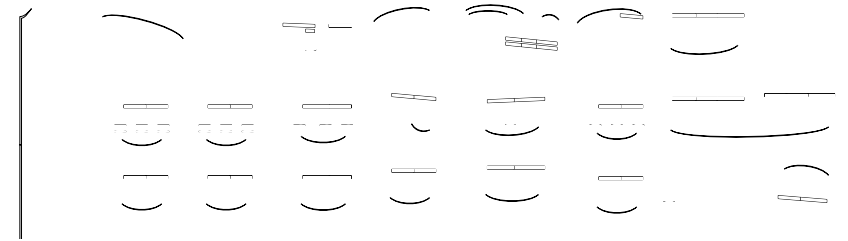
- **Haydn String Quartet Op. 76 no. 1, III**
  - Strict first (piece 7)
  - Let-go second (piece 8)
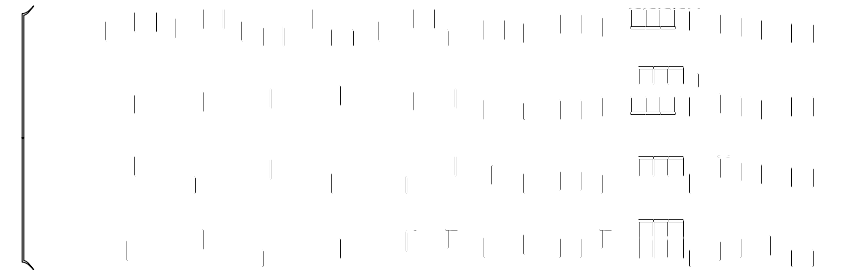
Methods of analysis

Synchrony analysis

- 3D accelerometer data normalised as $a_{norm} = \sqrt{x^2 + y^2 + z^2}$

- For each piece and pair of subjects compute wavelet coherence transform (WCT) coefficients for each scale s:

$$R_n^2(s) = \frac{\left| S\left(s^{-1} W_n^{XY}(s)\right)\right|^2}{S\left(s^{-1}\left|W_n^X(s)\right|^2\right) \cdot S\left(s^{-1}\left|W_n^Y(s)\right|^2\right)},$$

- where S is a smoothing operator, W^X is the wavelet transform of X, and $W^{XY} = W^X W^{Y*}$ is the cross-wavelet transform of X and Y

- WCT coefficients averaged across the time domain for each piece, then
  - for **global synchrony**, averaged across all pairs of subjects in each time scale s
  - for **subject synchrony**, averaged across pairs including that subject in each time scale s

Grinsted et al. (2004), Nozawa et al. (2020)

Accelerometer data (let-go vs strict) for Mozart
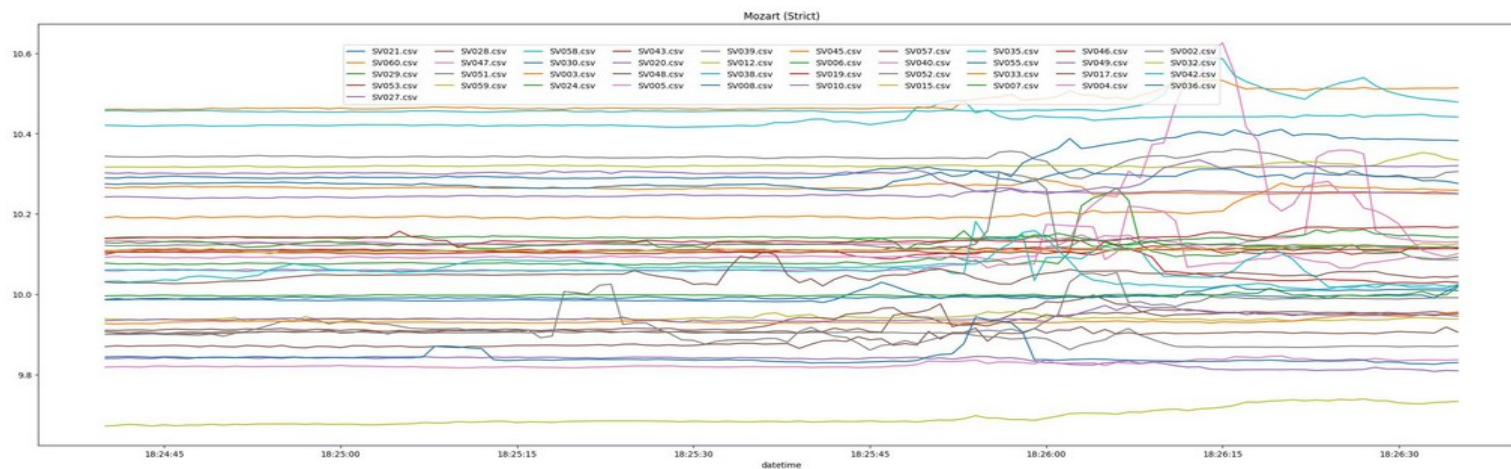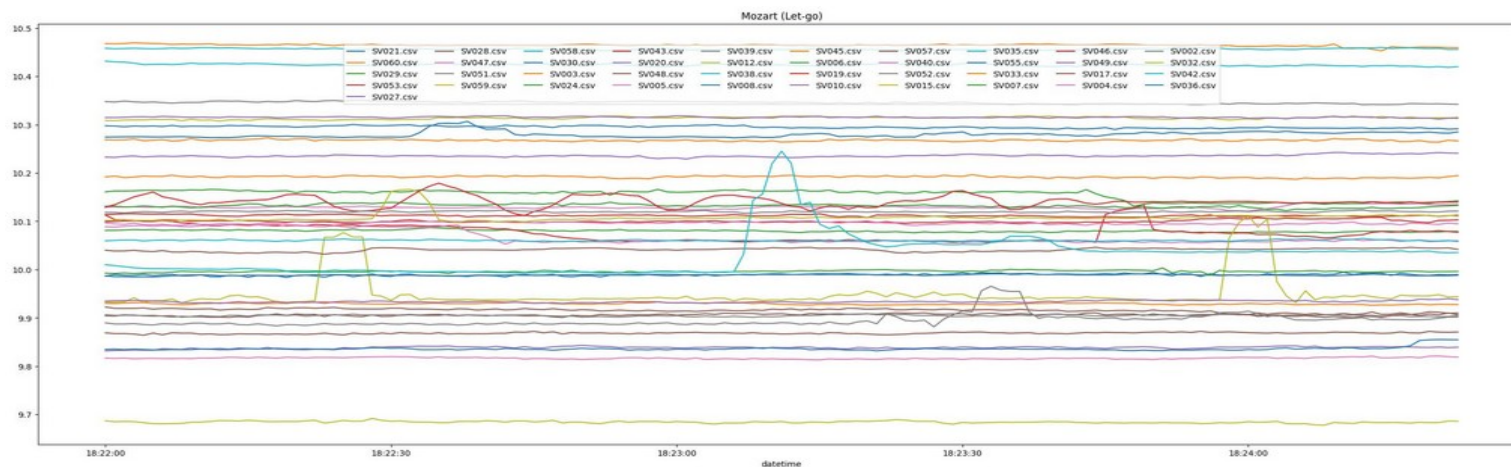
# Accelerometer data (strict vs let-go) for Haydn
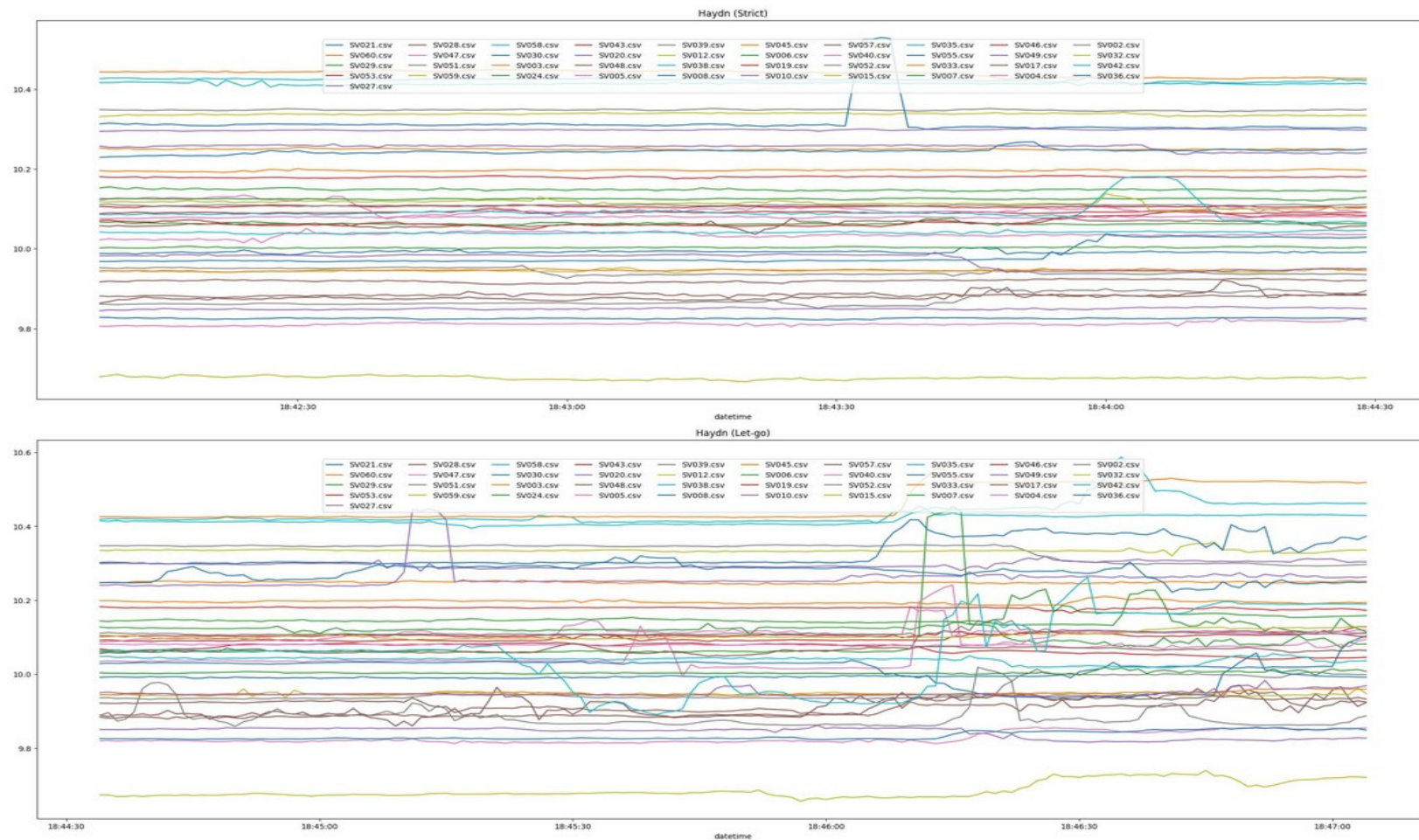
# Pairwise wavelet coherence transform (WCT)

- phase coherence between 2 signals
- a 2D array of wavelet coefficients, with time on the x-axis and periods (Fourier frequencies) on the y-axis
- cone of influence (COI) refers to area where boundary effects affect coherence
- we exclude cone of influence and average wavelet coefficients across the time axis for each classical piece, obtaining a value for each period, for each pair of subjects

Grinsted et al. (2004)
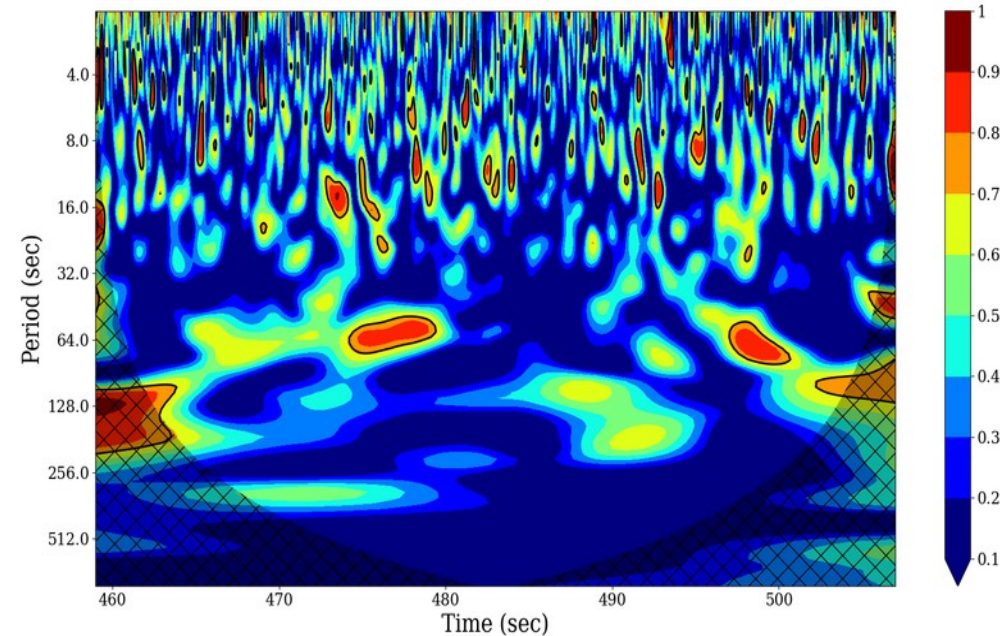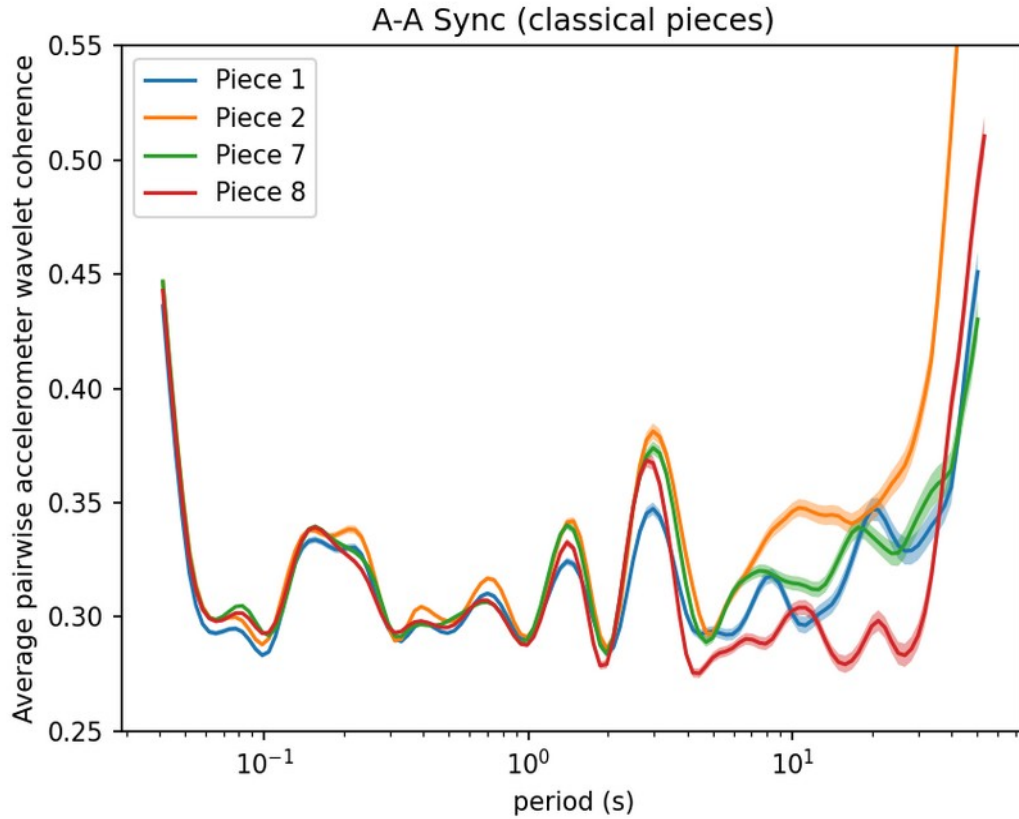
Cone of influence

Including cone of influence (COI)
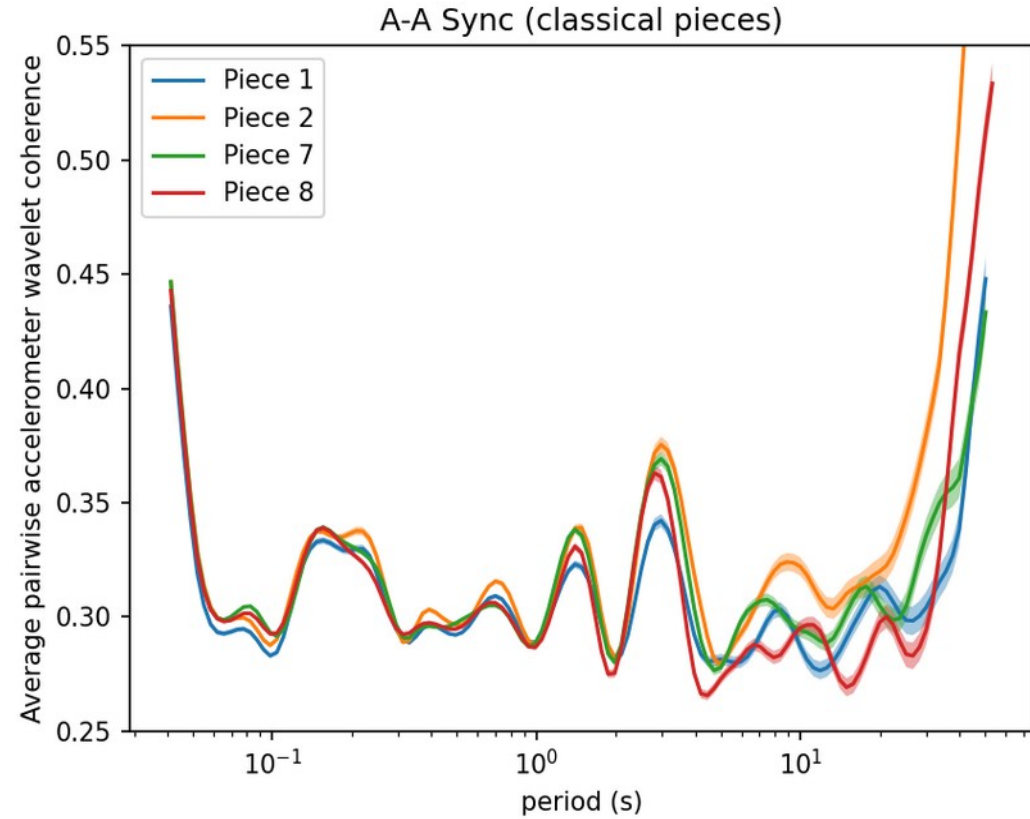
Excluding cone of influence (COI)

Audience ratings and questionnaires

- Responses to the Tellegen **absorption** scale (0-120) collected before experiment

- **Subjective ratings** using 6-point Likert scale (0-5) after each pair of performances:

  (1) improvisatory, (2) innovative, (3) emotionally engaging, (4) musically convincing, (5) risk-taking, (6) familiar, and (7) sleepiness inducing

- Results for the subjective ratings are averaged for all participants overall, and also for each mode of performance, composer, or type of performance

- Attempt to use ratings to explain individual degrees of sync

Tellegen & Atkinson (1974), *Dolan et al.* (2018)

Analysis ideas

Repertoire

- Compare synchrony by mode of performance and composer at different scales
- Match absorption and subjective ratings with synchrony at different scales

Performance type

- Compare audience ratings based on performance type (repertoire vs improv)
- Compare degrees of synchrony at different scales and overall

Blindfolding

- Effect of blindfolding on ratings and sync in different types and modes of performance, at different scales

Results

Audience ratings for performance mode

- Generally, the audiences do find let-go performances significantly more improvisatory, innovative, emotionally engaging and risk-taking
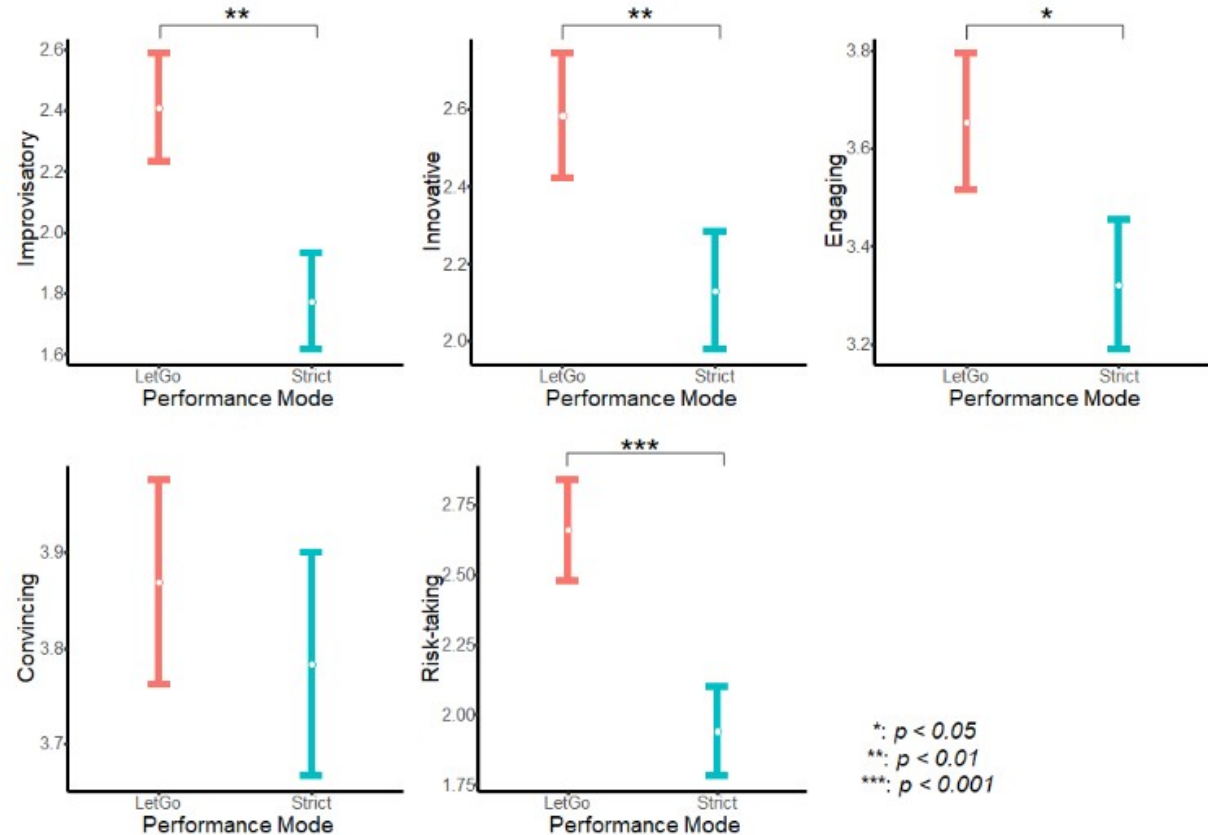
(analysis by T.Nozawa)

Audience ratings for composer

- Audiences find Haydn significantly more improvisatory (t(40)=-2.7,p=0.004) and more innovative (t(40)=-2.9,p=0.008) than Mozart on average
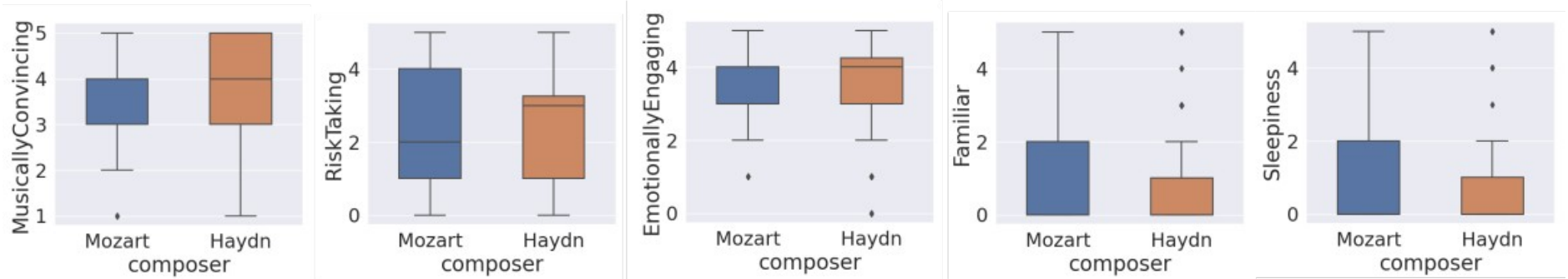
Improvisatory ratings

No	Item	Results
1	Improvisatory	Classic <<< Improvisation; Strict <<< Let-go
2	Innovative	Classic <<< Improvisation; Strict <<< Let-go
3	Emotionally engaging	Strict <~ Let-go
4	Musically convincing	Classic >> Improvisation
5	Risk-taking	Classic <<< Improvisation; Strict <<< Let-go
6	Familiarity	Classic >>> Improvisation
7	Sleepiness	No differences
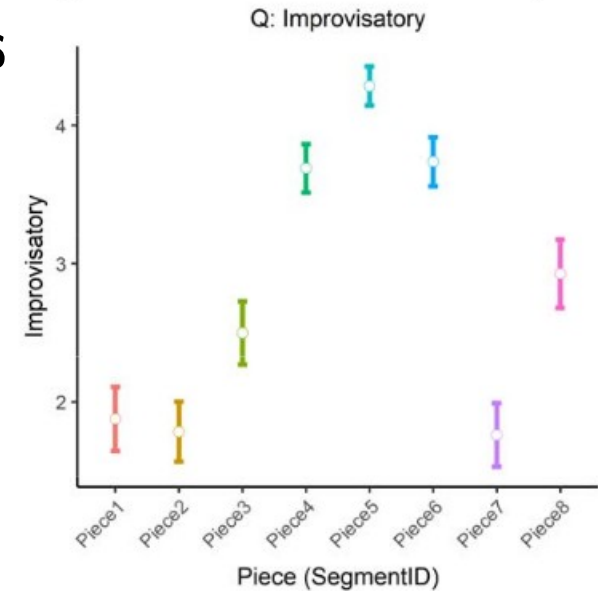
Q: Improvisatory

- analysis by Dr Takayuki Nozawa shows subjective ratings support the condition effects
- difference between Piece1 and Piece2 (Mozart) in improvisatory is smaller than difference between Piece7 and Piece8 (Haydn) which reflects subjective ratings of performers

- **Idea**: model using the improvisatory score instead of strict/let-go condition

# Audience absorption scores

- Absorption seems to be slightly positively correlated with improvisatory ratings on average
- These correlations are largely non-significant with the exception of the first piece (p=0.03)
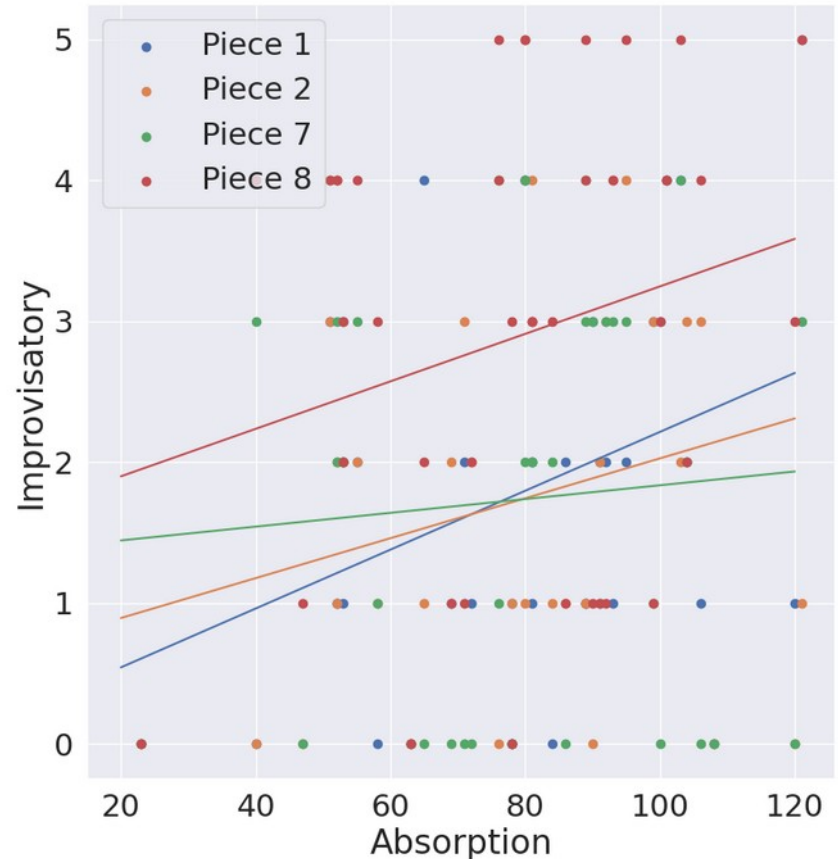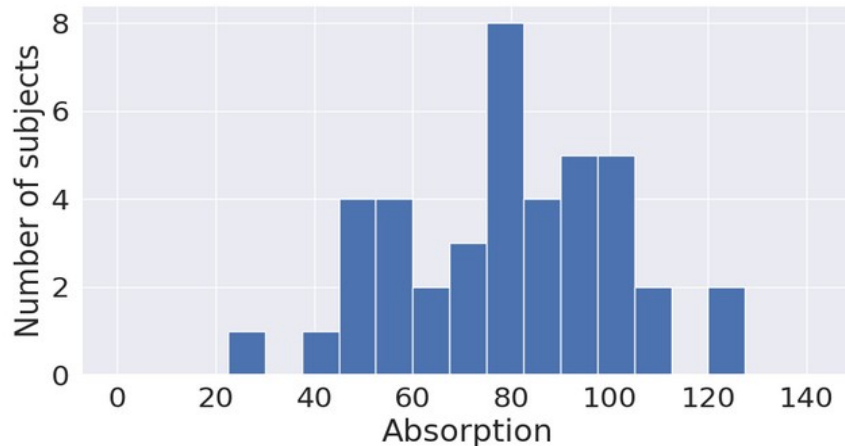
(no) Effect of absorption on audience synchrony

No significant correlations (Pearson)

Mozart Let-go	0.11873	0.46
Mozart Strict	0.03743	0.81
Haydn Strict	-0.11838	0.46
Haydn Let-go	-0.22151	0.16
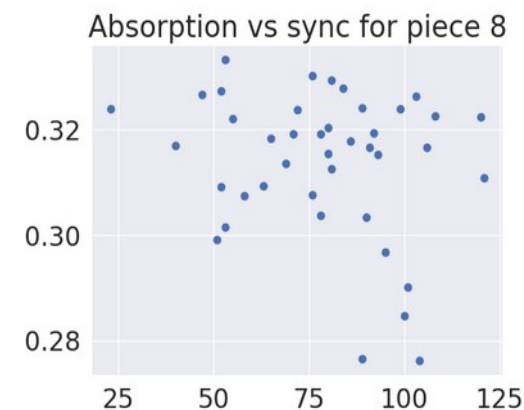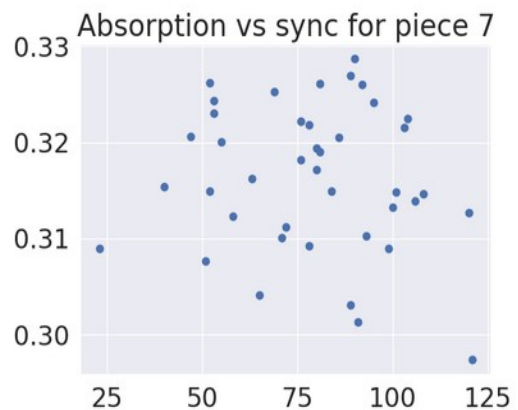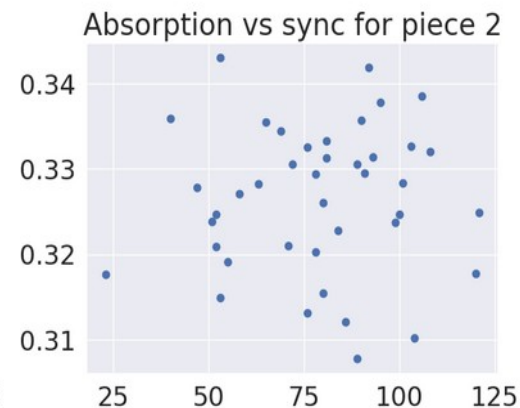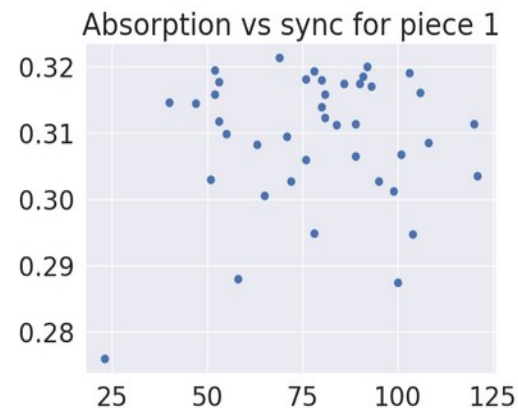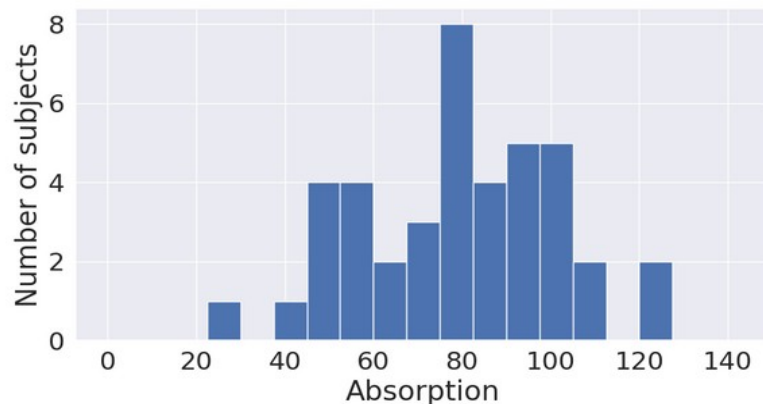
Results/discussion

- Audiences find let-go significantly more improvisatory, innovative, emotionally engaging and risk-taking
- Weak correlation between absorption and improvisatory rating
- Difference in improvisatory and innovative much more significant between strict and let-go in Haydn than Mozart

- Can this affect the audience's regime of synchrony?

# Effect of mode of performance and composer on audience sync in repertoire pieces

Effect of performance mode on audience sync

A-A Sync (let-go vs strict for repertoire pieces)
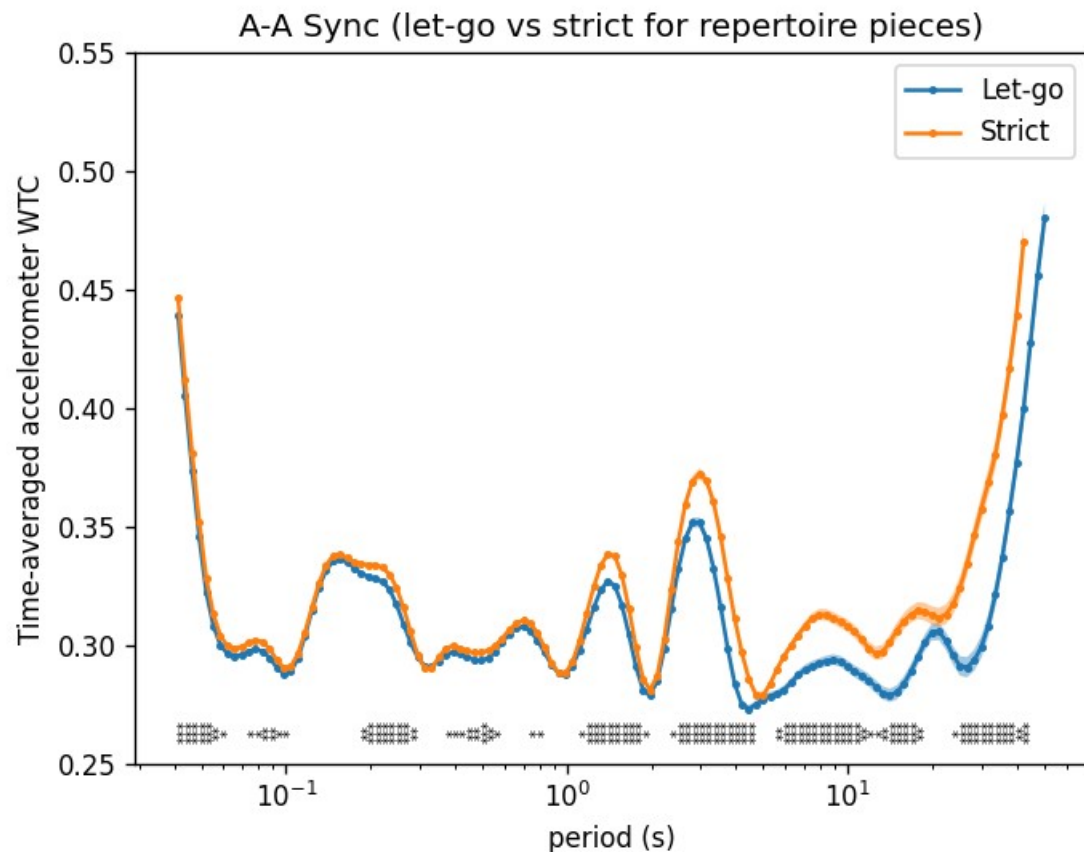
- Audience sync overall higher in strict, with significant differences across multiple bands
- Stronger effect in Mozart 2nd piece

A-A Sync (classical pieces)
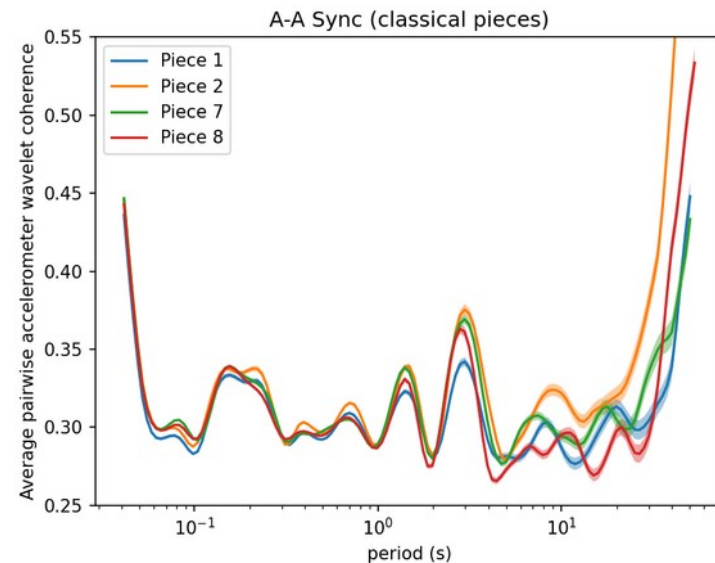
# Effect of composer on audience sync

A-A Sync (by composer)
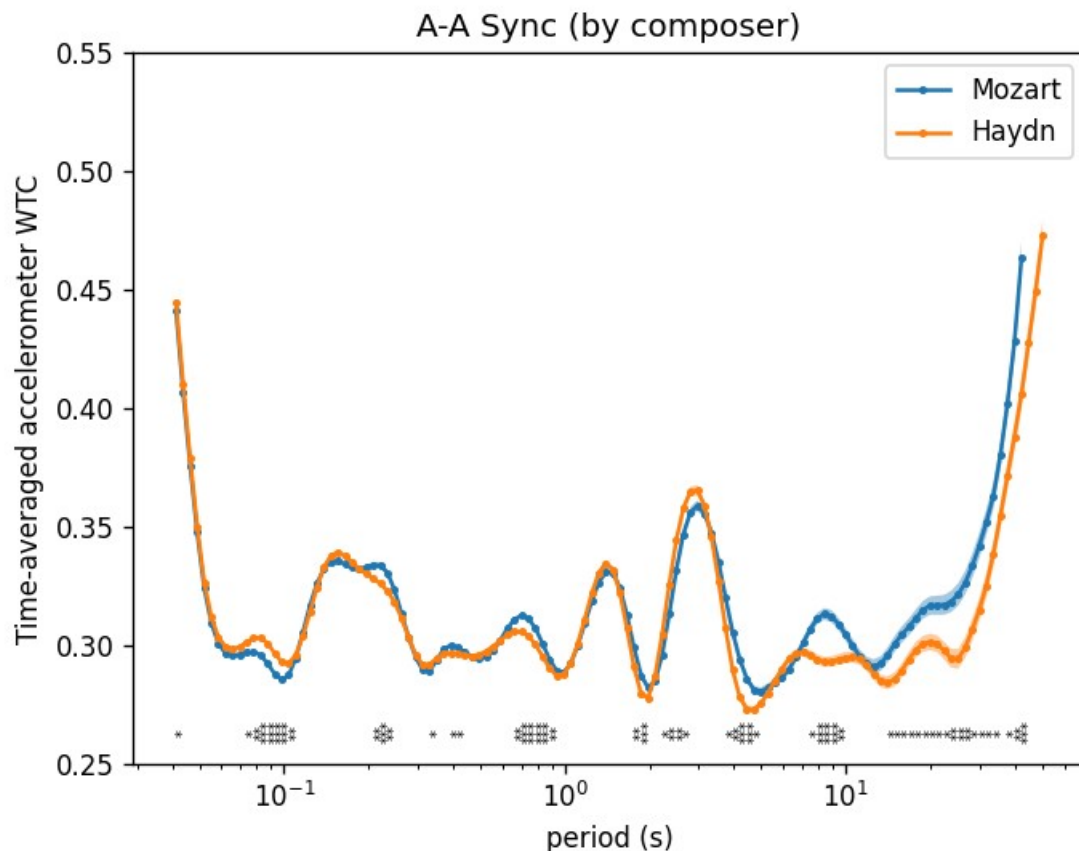
- A few bands of significant higher synchrony in Mozart in the longer scales (>8s) but also shorter scales (0.2-0.3s, 0.6-0.9s, 3-4s)
- significant higher synchrony in Haydn in two short bands: ~0.1s and 2-3s
- Difference not as strong between composers

- Do periods of synchrony reflect tempo characteristics of the piece?

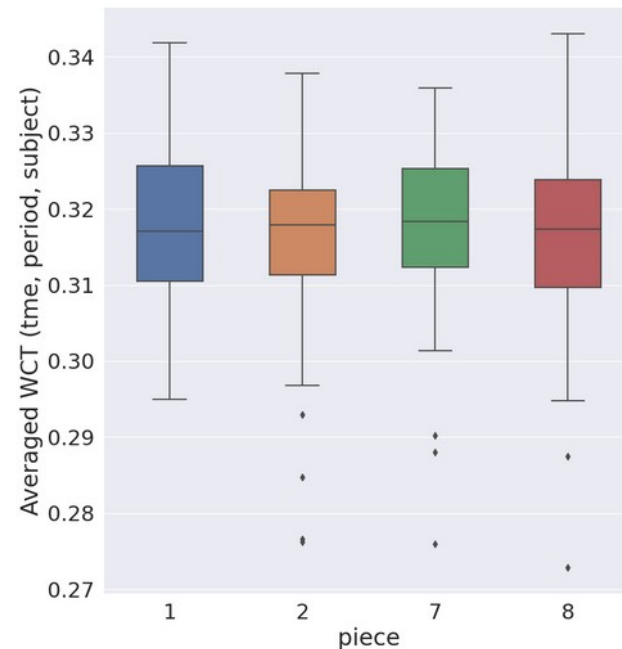**Audience sync by composer and performance mode**
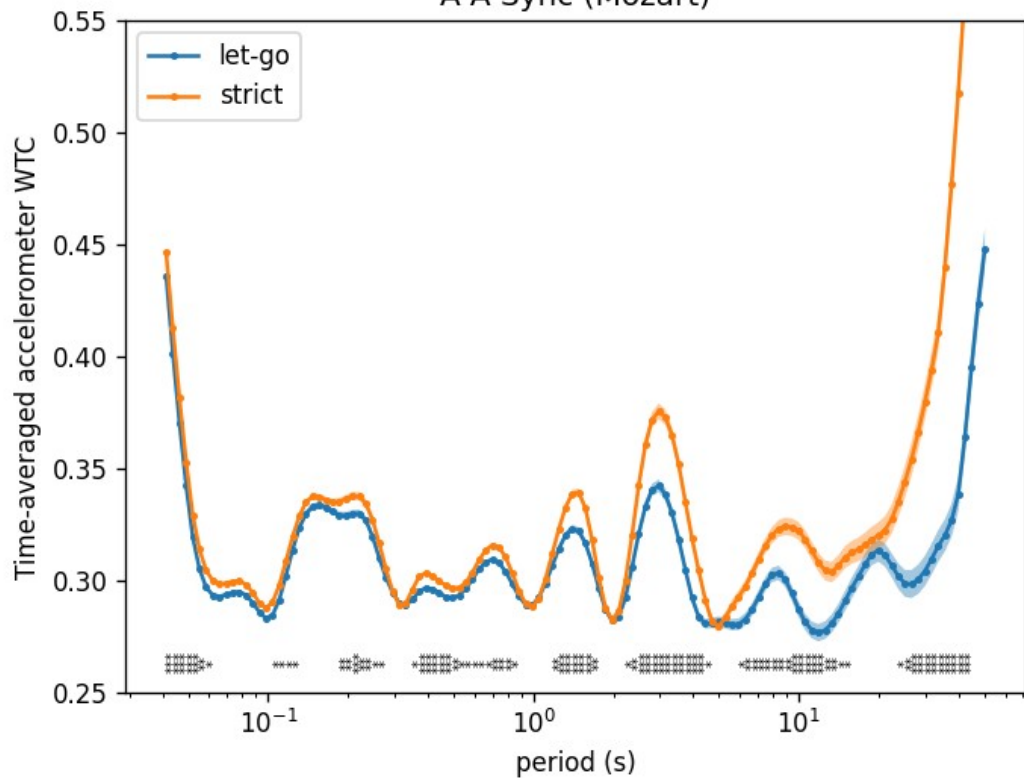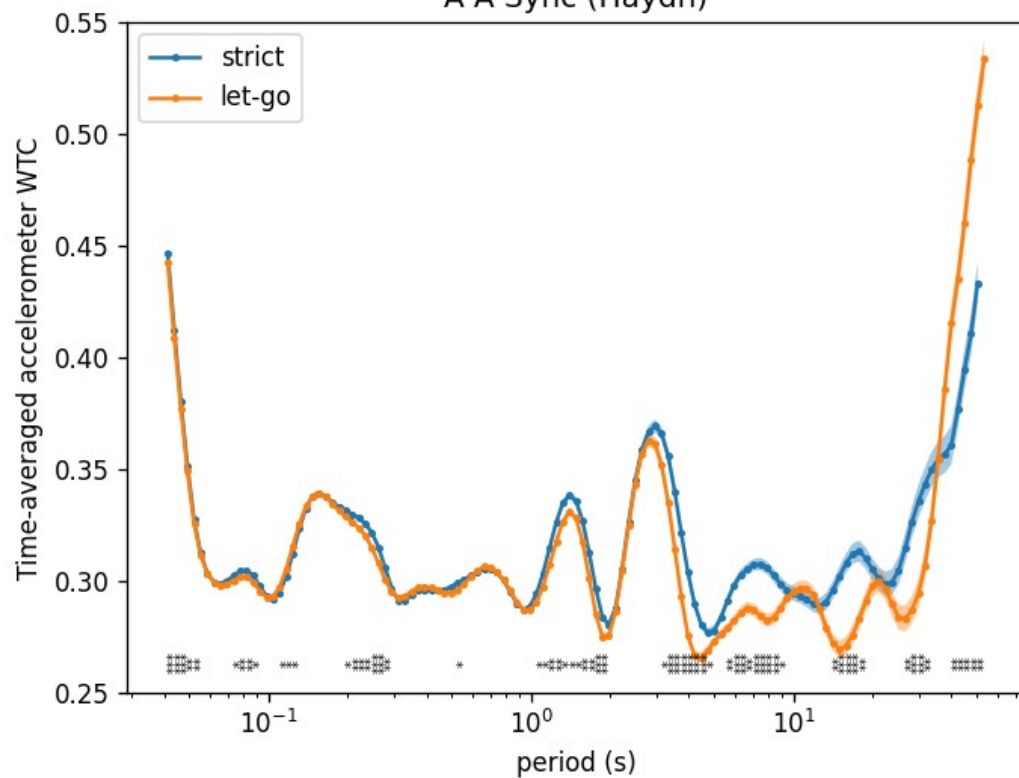
Audience sync by composer and performance mode

```
              Mixed Linear Model Regression Results
==================================================================
Model:                MixedLM    Dependent Variable:    WCT_Mean
No. Observations:     158        Method:                REML
No. Groups:           41         Scale:                 0.0001
Min. group size:      2          Log-Likelihood:        452.0412
Max. group size:      4          Converged:             Yes
Mean group size:      3.9
------------------------------------------------------------------
                          Coef.  Std.Err.    z     P>|z|  [0.025 0.975]
------------------------------------------------------------------
Intercept                 0.317   0.002  159.201 0.000  0.313  0.321
composer[T.Mozart]       -0.002   0.002   -0.983 0.325 -0.007  0.002
letgo                    -0.001   0.002   -0.477 0.633 -0.006  0.004
letgo:composer[T.Mozart]  0.005   0.004    1.320 0.187 -0.002  0.011
Group Var                 0.000   0.002
==================================================================
```
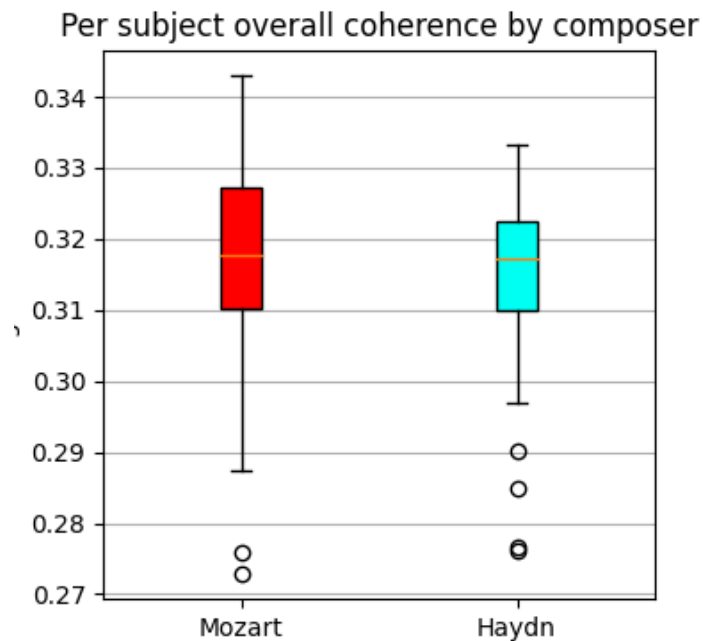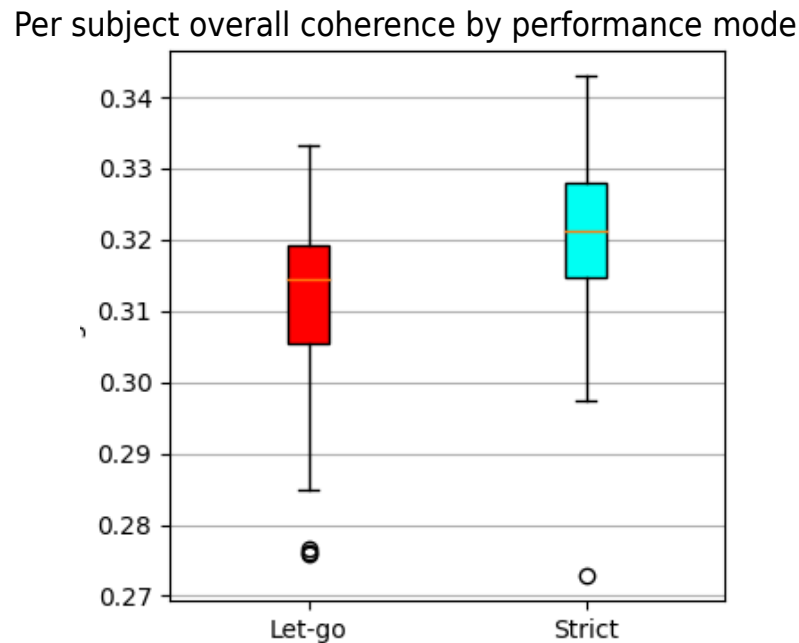
Average sync for all repertoire pieces

Per subject overall coherence by composer

Per subject overall coherence by performance mode

T(83) = 1.0932, p = 0.2774
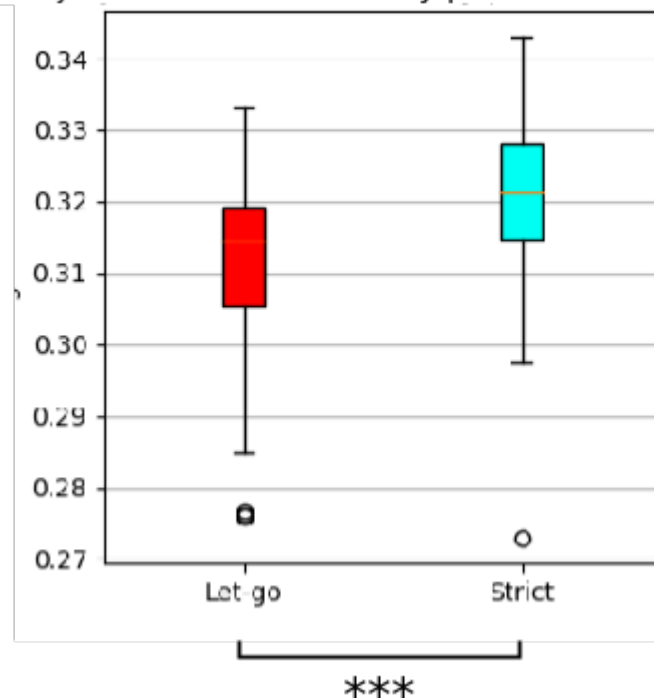No significant difference between composers.

T(83) = -5.3392, p = 8e-07
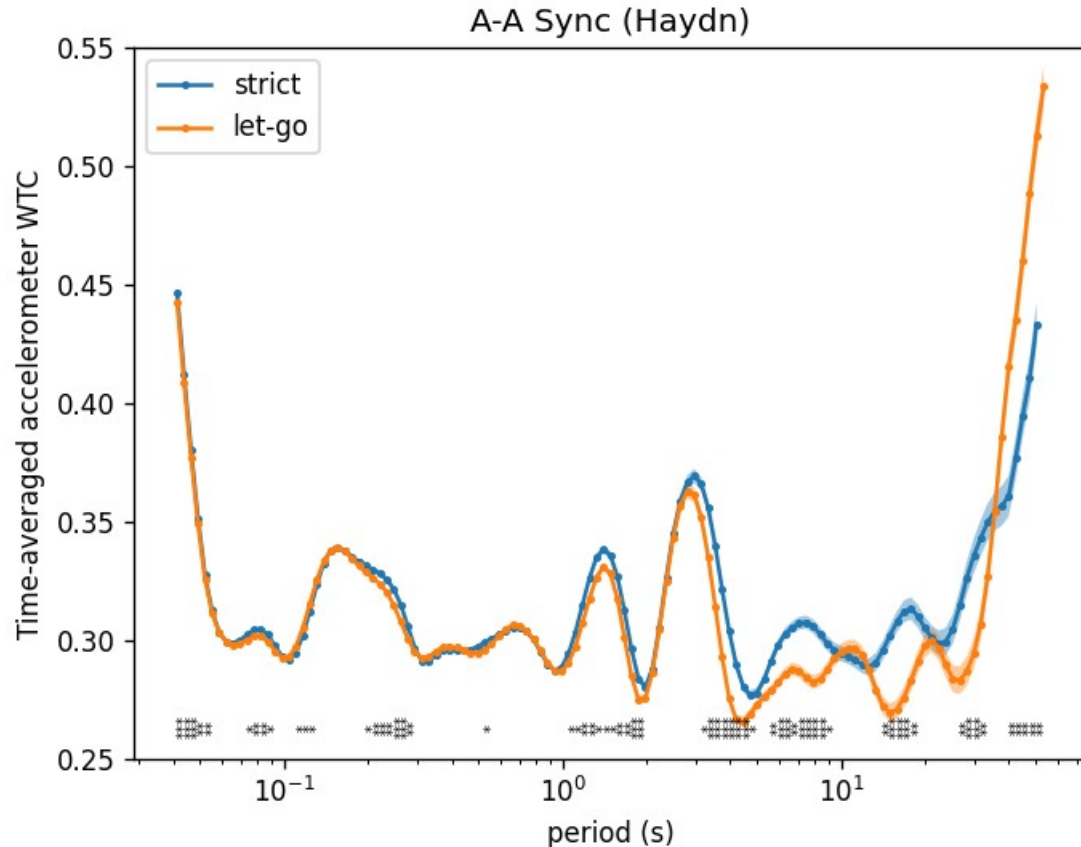Significant difference between modes.

Average sync for all repertoire pieces

- Average audience sync **consistently higher in strict than let-go**

- Interpretation idea: audiences follow the music, and strict performances are easier to predict

Per subject overall coherence by performance mode

Strict vs let-go: revisited (Haydn)

- Clearer qualitative distinction between modes of performance (according to musicians)
- Clear quantitative distinction between modes of performance (according to audience)
- Multiscale synchrony emerges: strict > letgo for period < 12s, and letgo > strict for period > 12s

Audience ratings for Haydn

- Audiences find let-go Haydn significantly more improvisatory, innovative, emotionally engaging and risk-taking
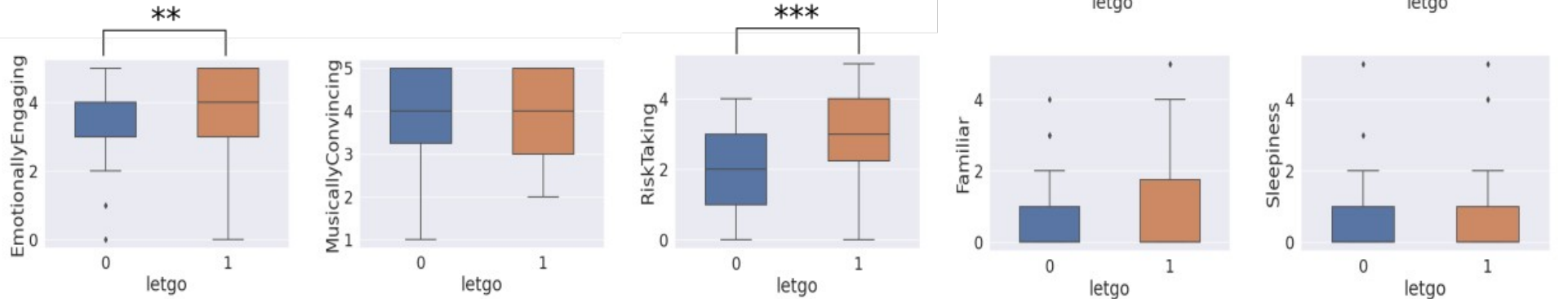
Results/discussion

- Results show more synchrony in strict than let-go on average, and no significant difference between composers
- In Haydn, multiscale synchrony emerges, with higher synchrony in let-go at longer (>12s) timescales and higher synchrony in strict at shorter (<12s) timescales

Analysis Questions:
- Is averaging values from different composers valid when not the same piece is being played? Different durations affect WCT coefficients
- Can the tempo of the piece affects the temporal scales of WCT?

Effect of type of performance (repertoire vs improvisation) on audience sync

Audience sync by type of performance
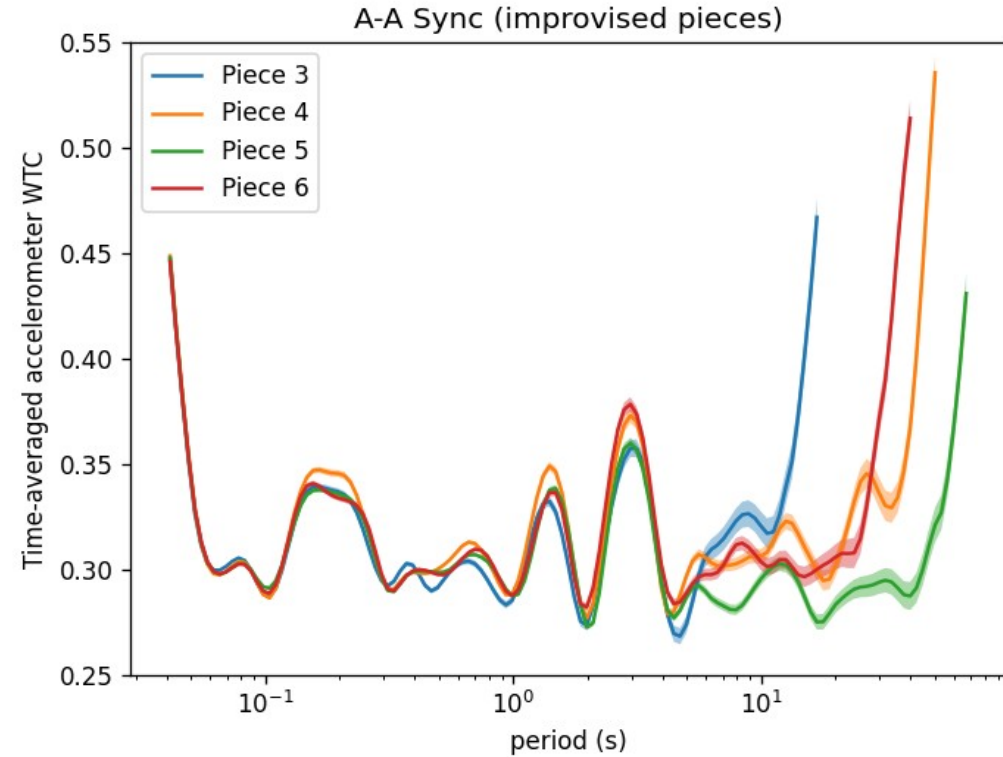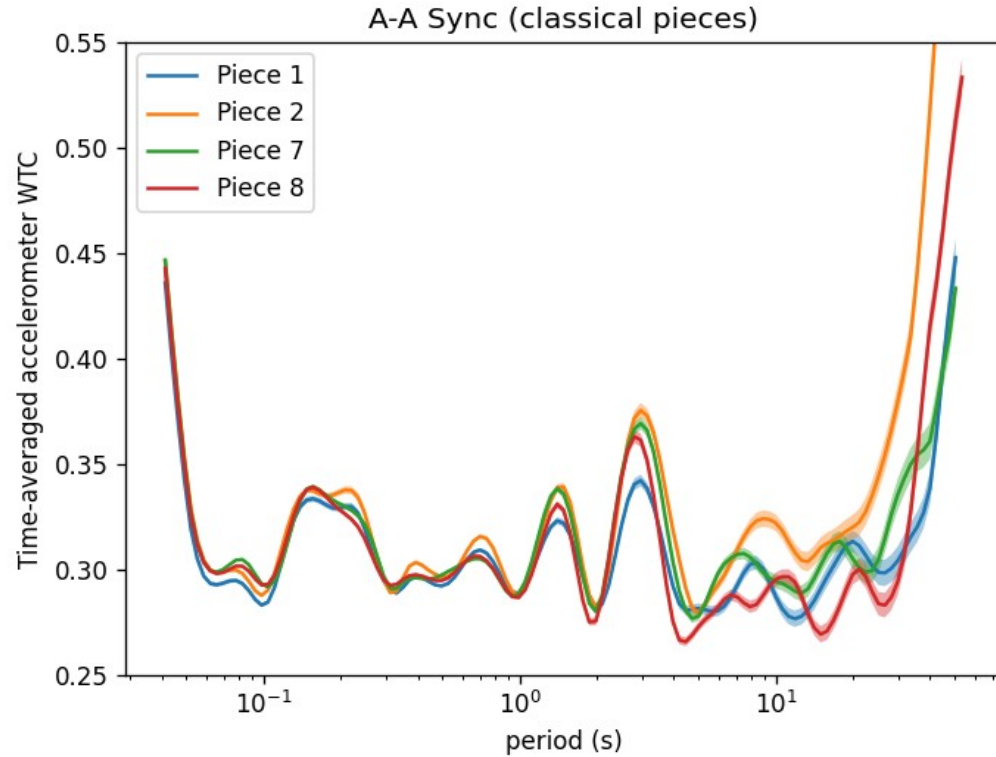
Excluding cone of influence (COI)

Audience sync by type of performance

Audience Sync (repertoire vs improvised pieces)
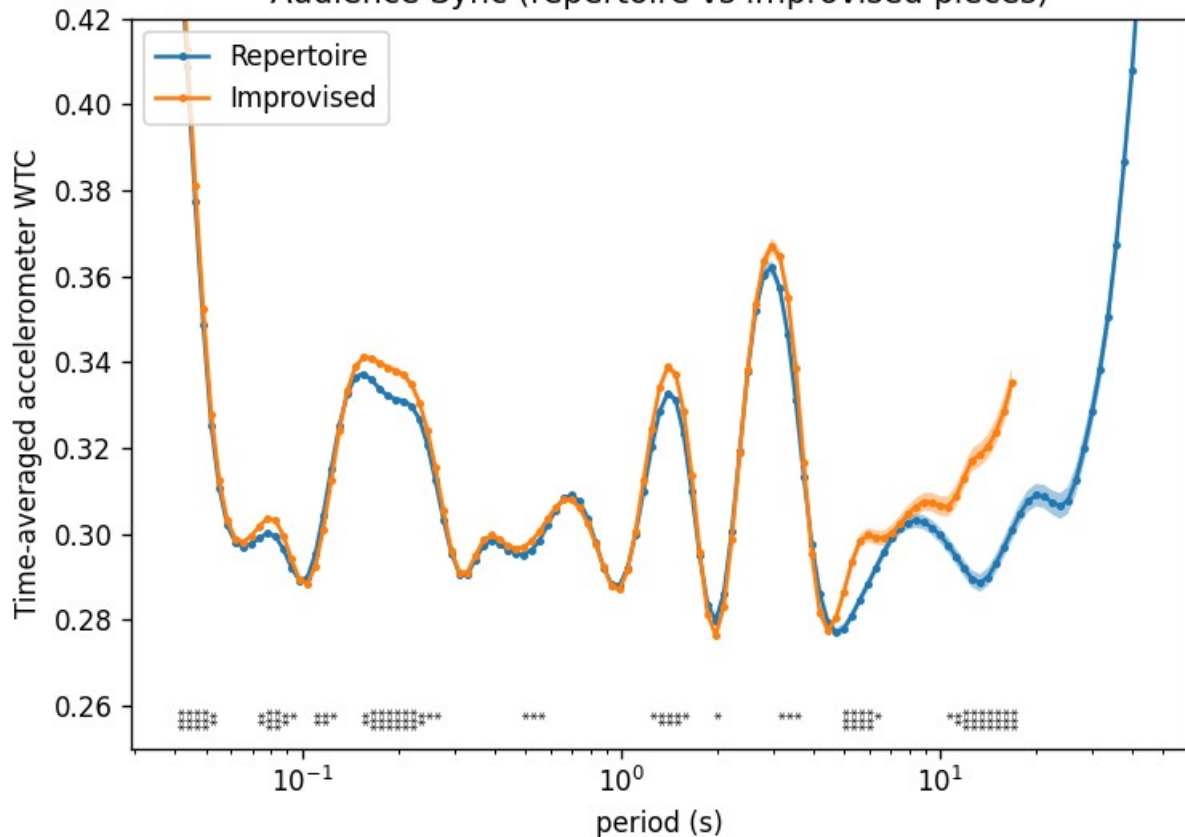
- Overall higher sync in improvisations than classical pieces, regardless of mode of performance
- Strongest effects happen in the longer frequency bands (5s-6s, corresponding to a measure, >10s, a 'musical gesture') but also at short, rhythmic periods (0.2s, 1.5s)

- One of the improvised pieces was very short – difficult to make a direct comparison

Effect of mode of performance in improvised pieces
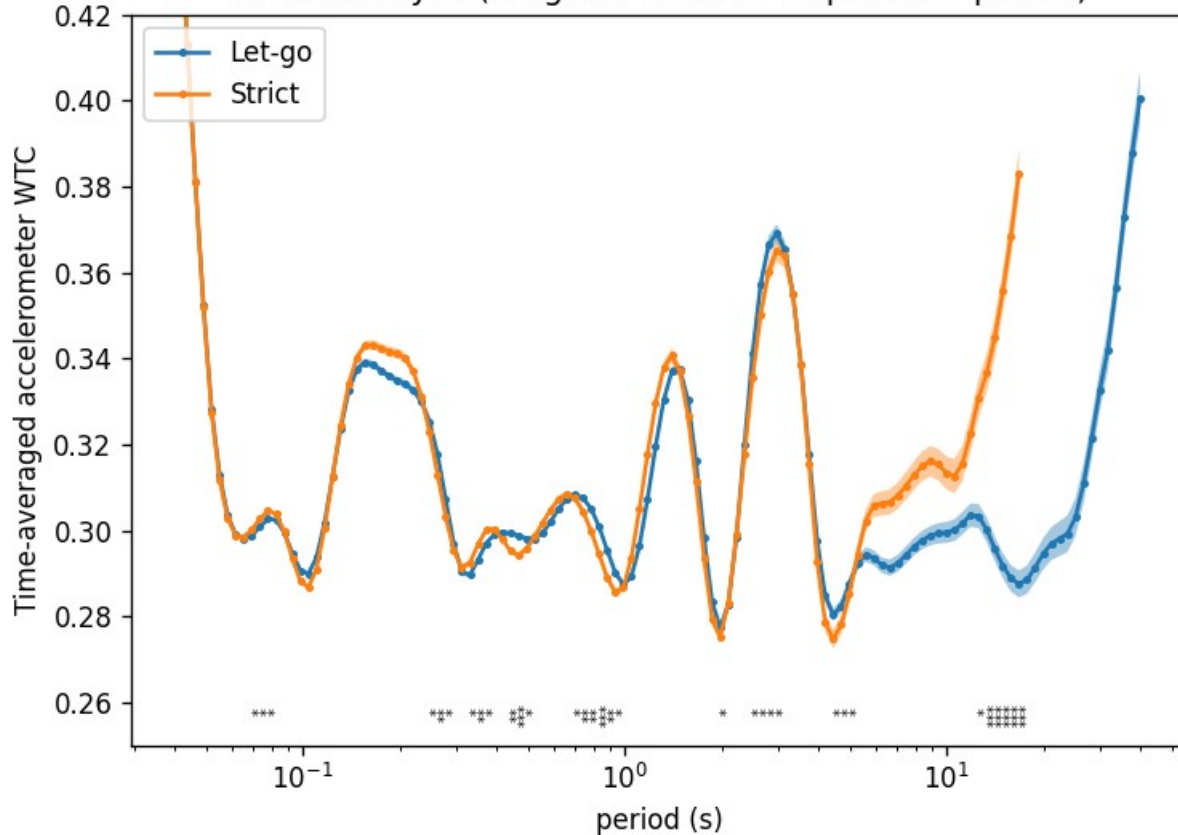
- Sync significantly lower for let-go at larger time scales: opposite effect from classical pieces

- Again this may be affected by the length of the pieces: time scales depend on the musical piece itself

Results/discussion

- Results show more synchrony in improvisations than repertoire performances, on average, especially at longer time scales
- Strict improvised performances show higher synchrony at longer time scales

Analysis Questions:
- should synchrony values be directly compared in repertoire vs improvisations?
- Is such an analysis valid when not the same piece is being played?
- Can the scales be matched?

Effect of blindfolding on audience body motion

Effect of blindfolding on audience sync

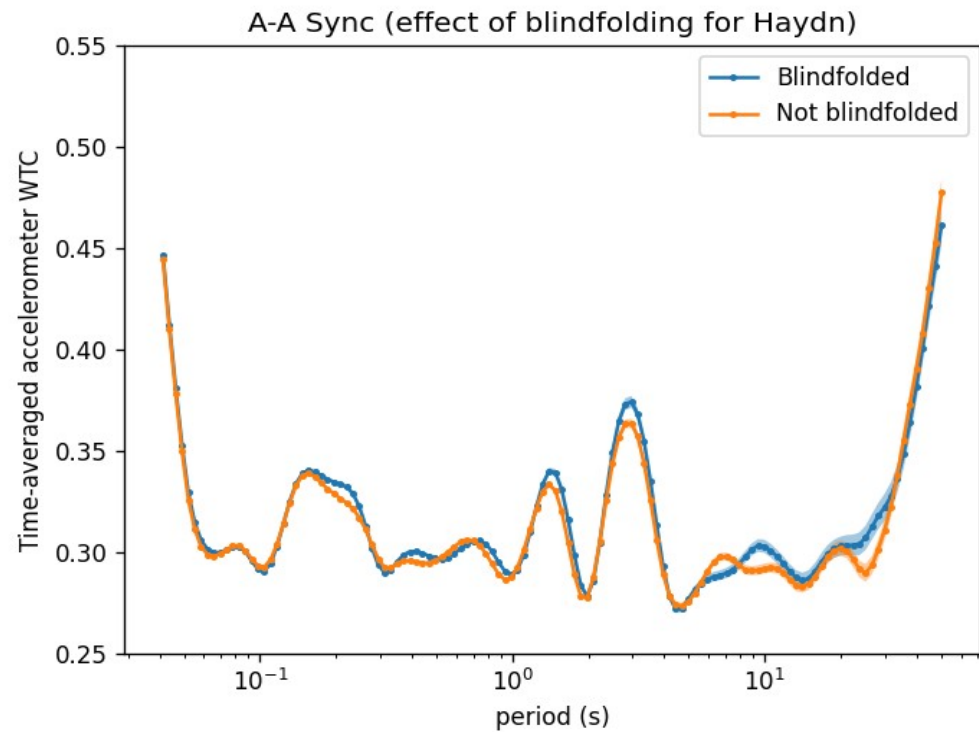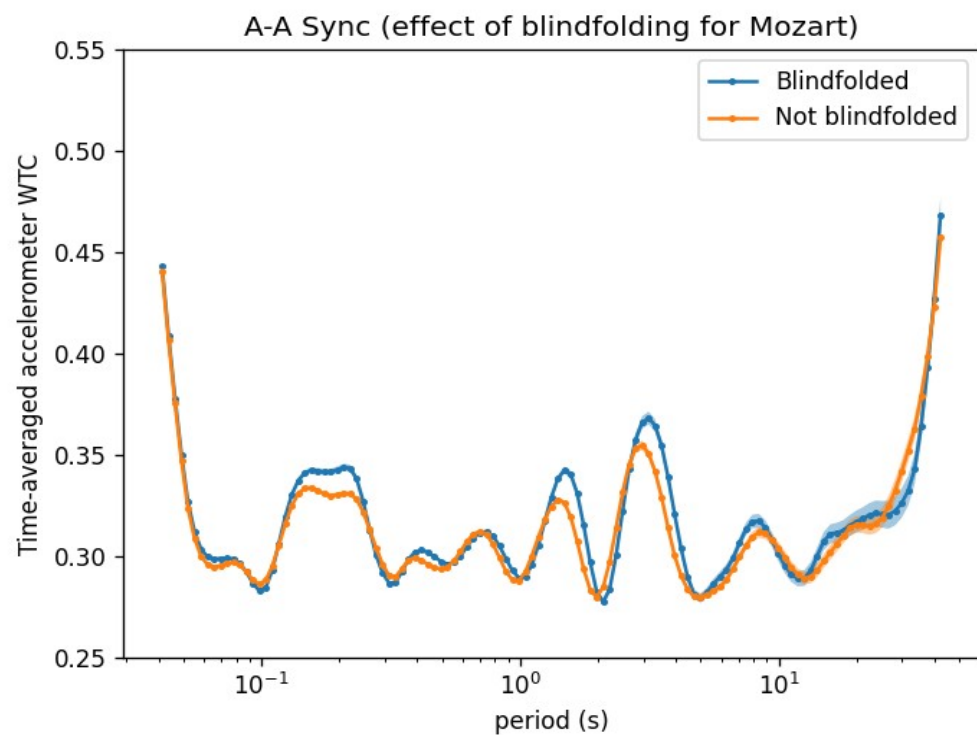A-A Sync (effect of blindfolding for repertoire pieces)
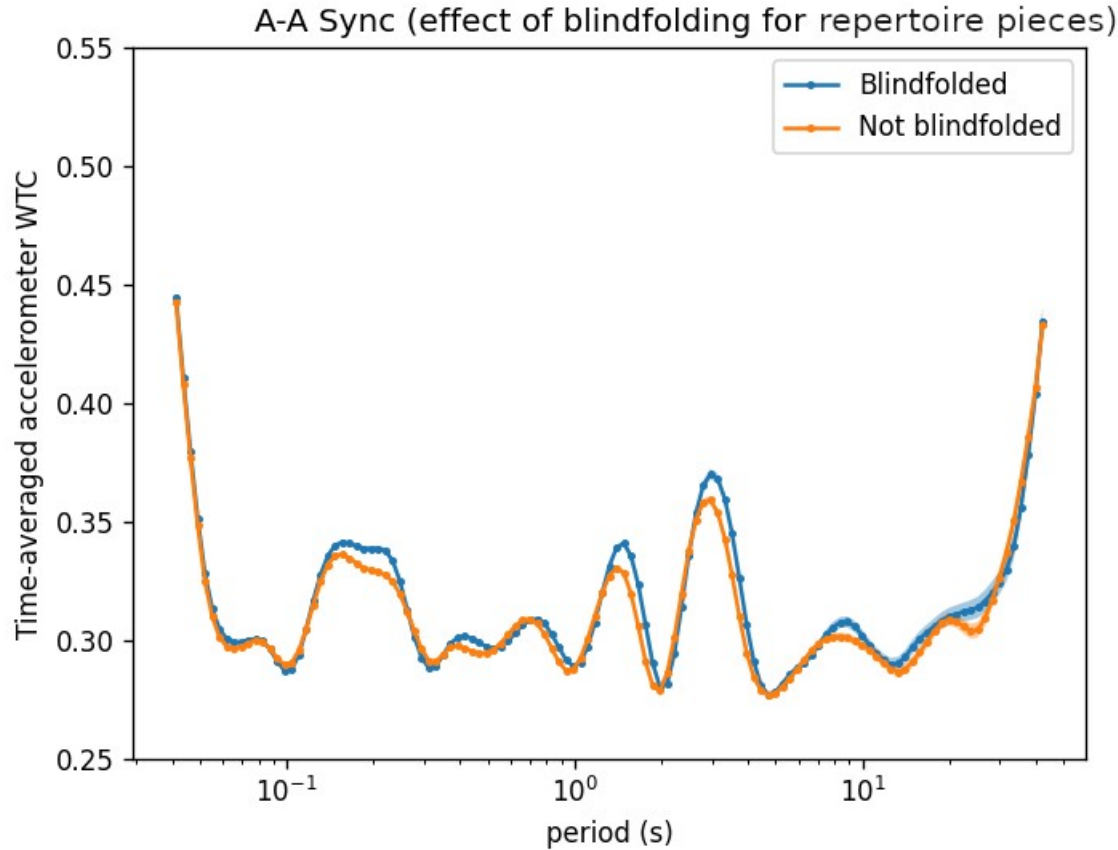
Overall, blindfolded subjects show slightly more synchrony than not blindfolded subjects, across all scales but especially in the 'peaks' of synchrony (0.1-03s, 1.5s, 3s)
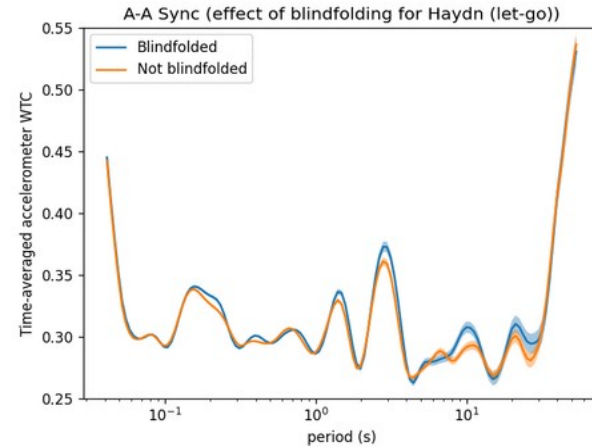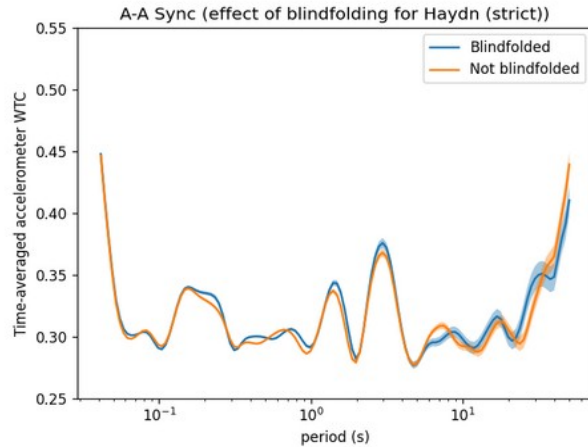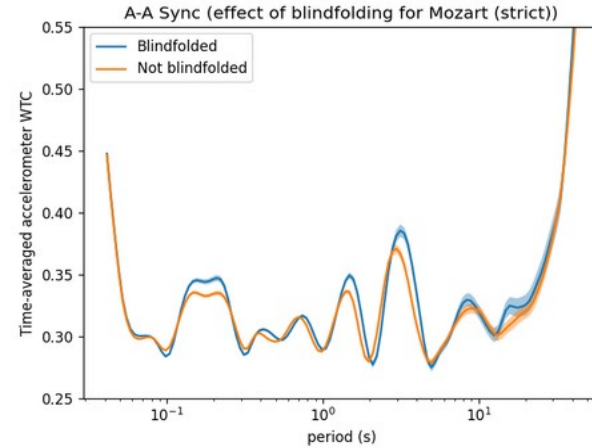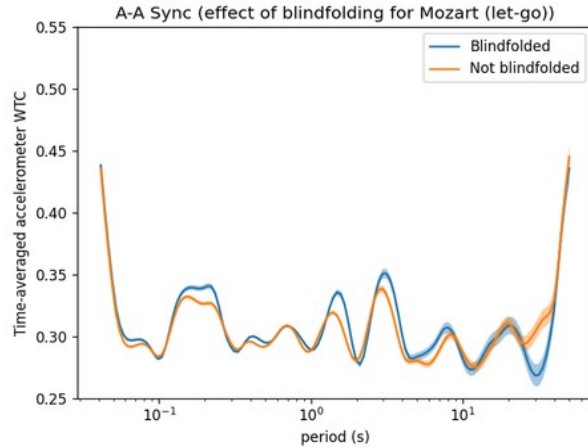
Effect of blindfolding by composer
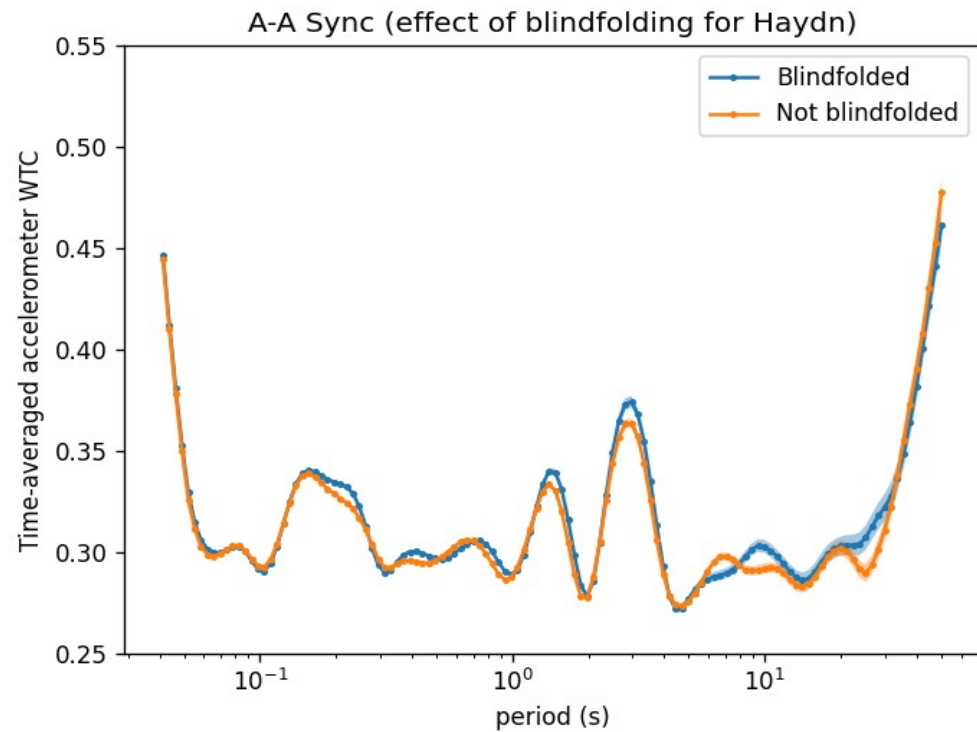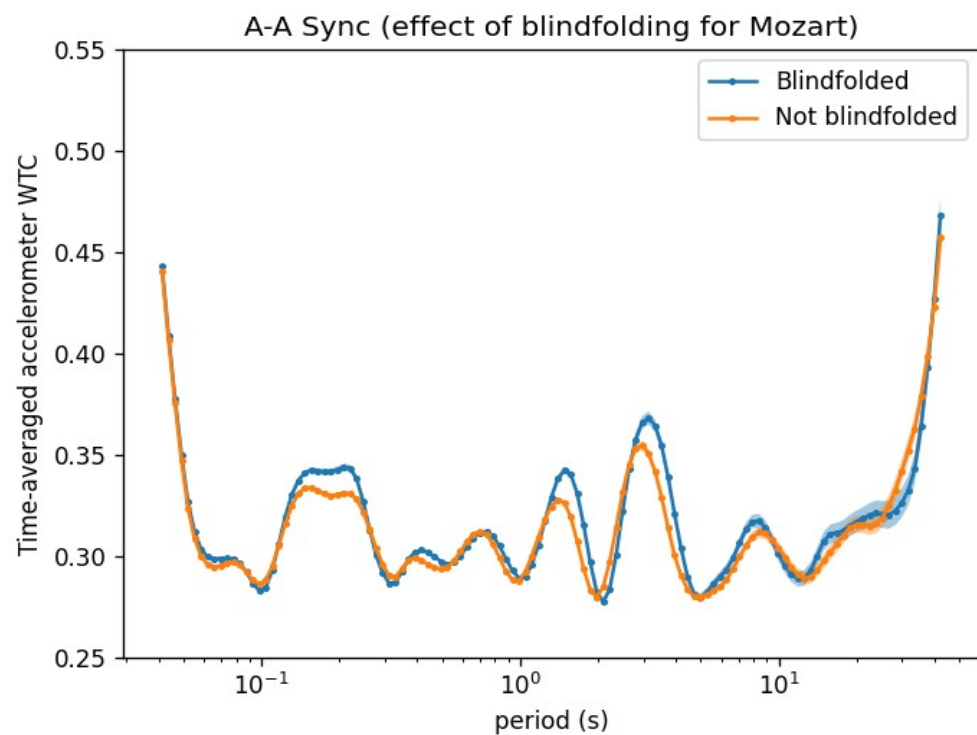
Effect of blindfolding by performance mode

Effect of blindfolding by composer and performance mode

Results/discussion

- A-A sync lower for the non-blinded audience members

- Effect of blindfolding on audience rating?