

Music from the heart

Music engineering & cardiovascular science

Elaine Chew

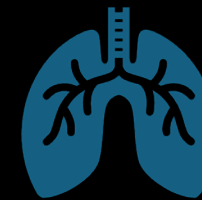


European Research Council
Established by the European Commission

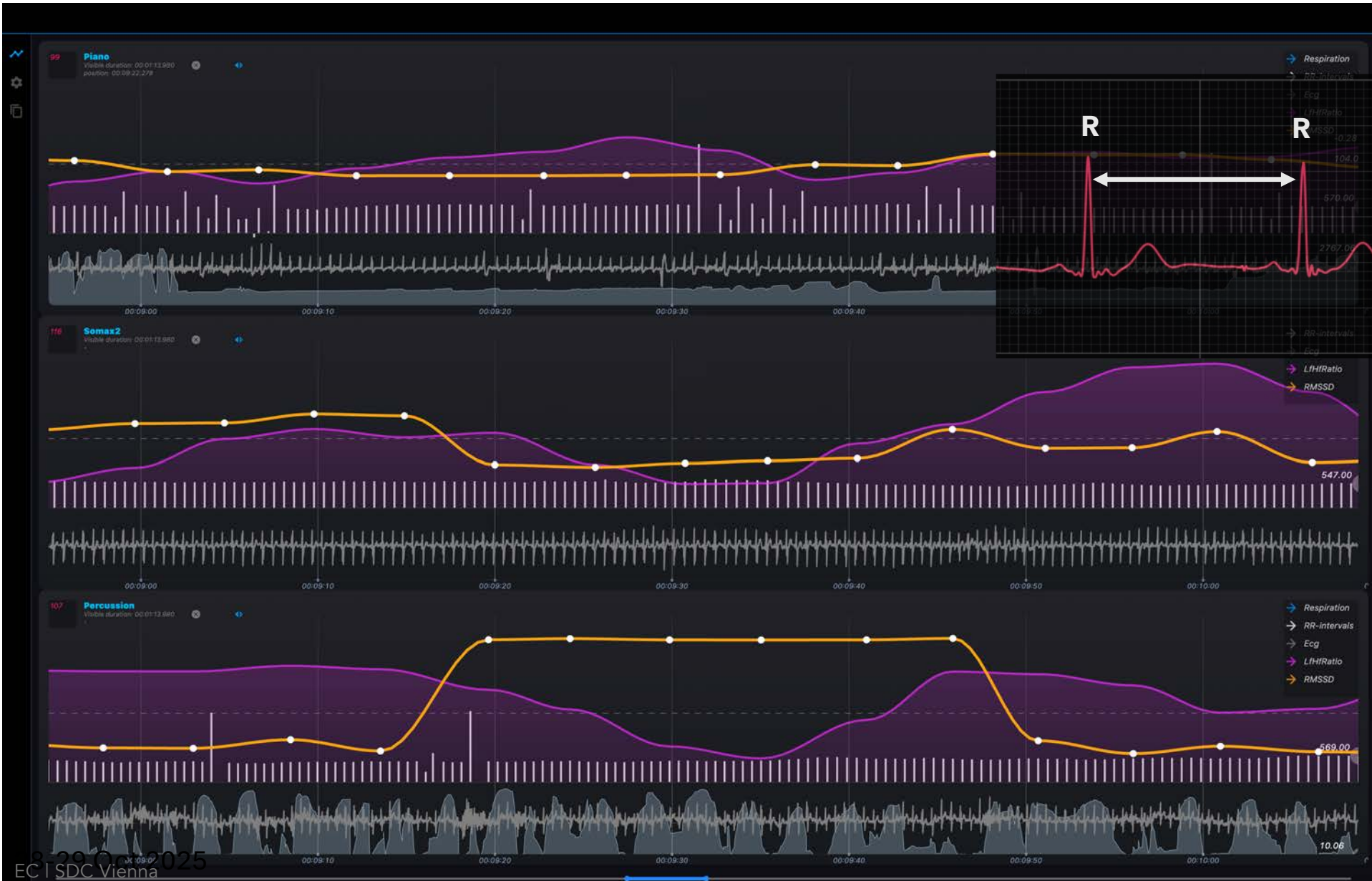
Cosmos



Physiological Monitoring



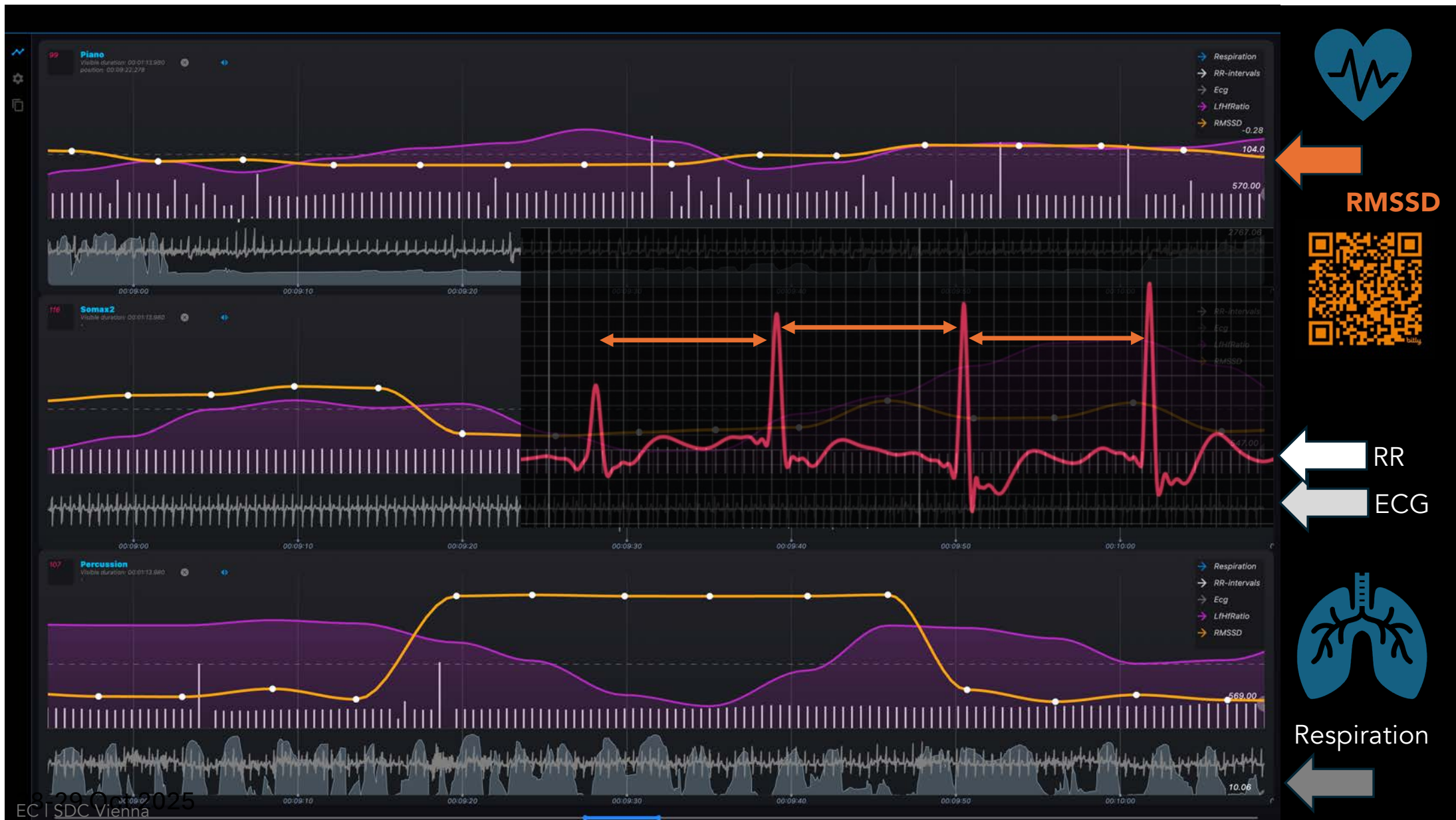
fitgadgetreviews



RR
ECG



Respiration



RMSSD



RR

ECG



Respiration



Pictures Courtesy of Yamaha Music Europe



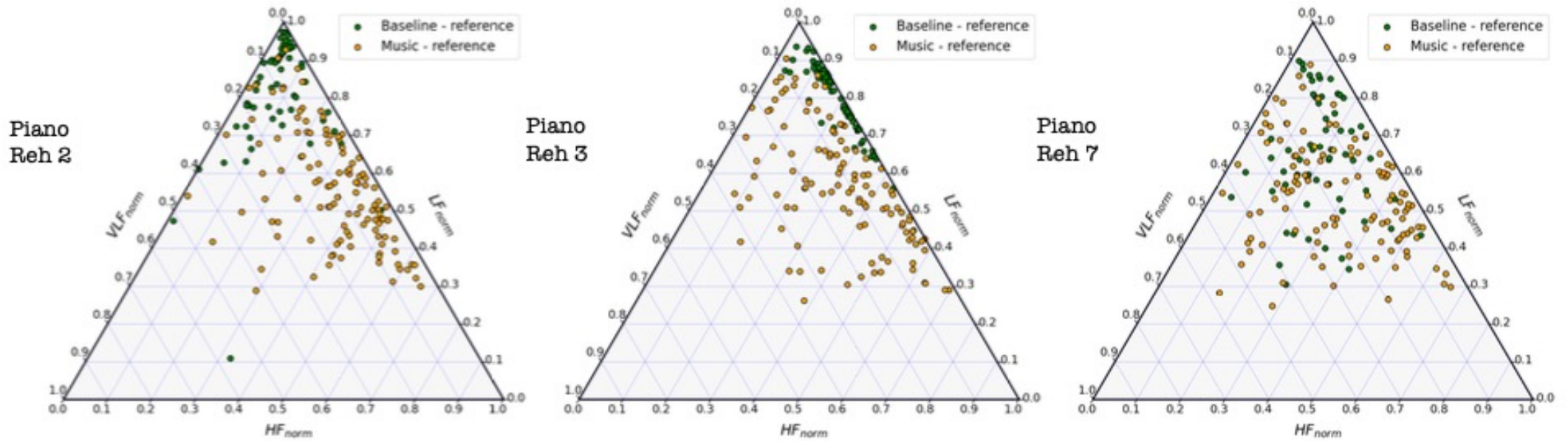
Elaine Chew

Ian Pressland

Hilary Sturt

Rehearsal Heartbeats

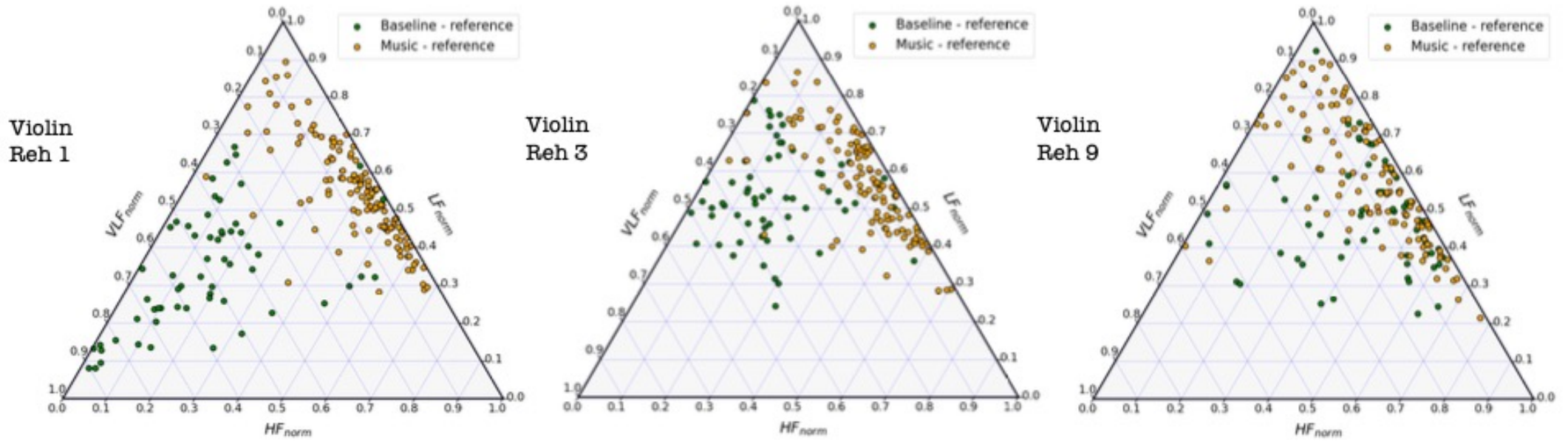
Example II: Pianist, rehearsals 2, 3, 7



Baseline
Music

Rehearsal Heartbeats

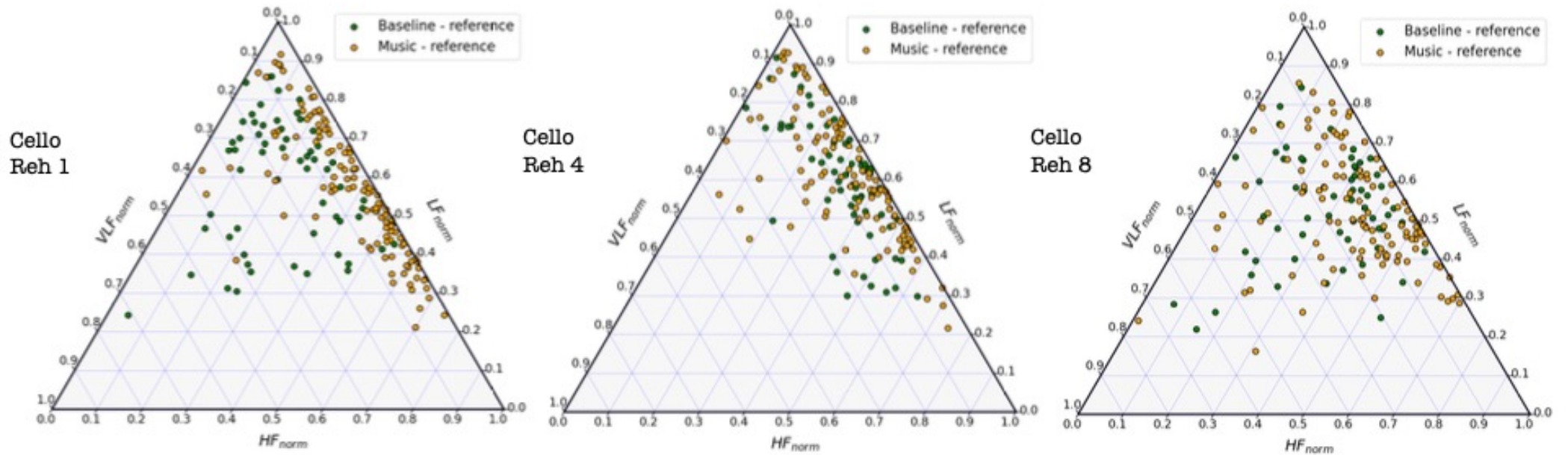
Example III: Violinist, rehearsals 1, 3, 9



Baseline
Music

Rehearsal Heartbeats

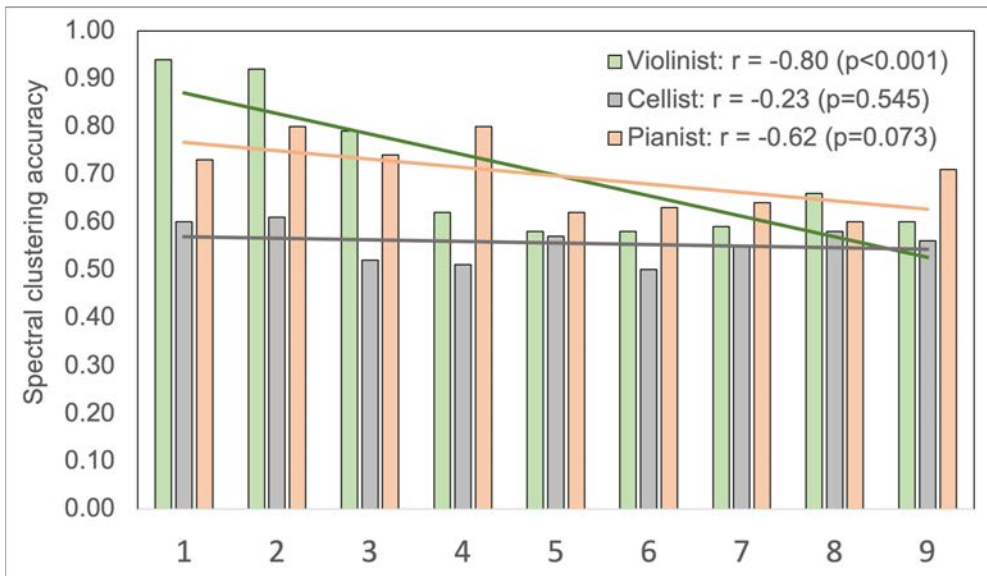
Example IV: Cellist, rehearsals 1, 4, 8



Baseline
Music

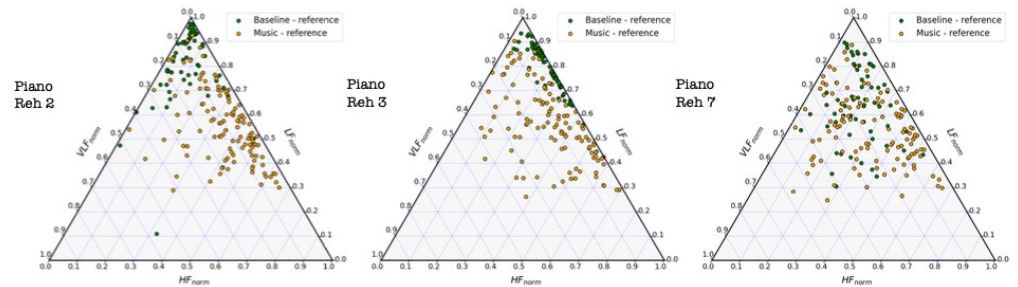
Rehearsal Heartbeats

Before vs. during playing
 VLF–LF–HF balance
became more similar
 over rehearsals

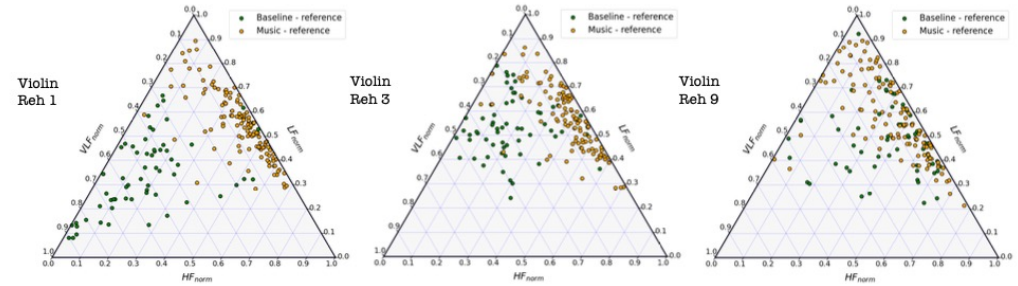


Soliński, Reed, Chew CinC 2023b

Example II: Pianist, rehearsals 2, 3, 7

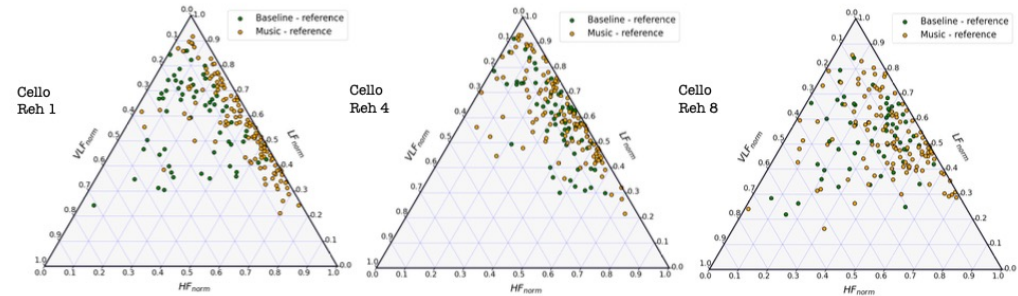


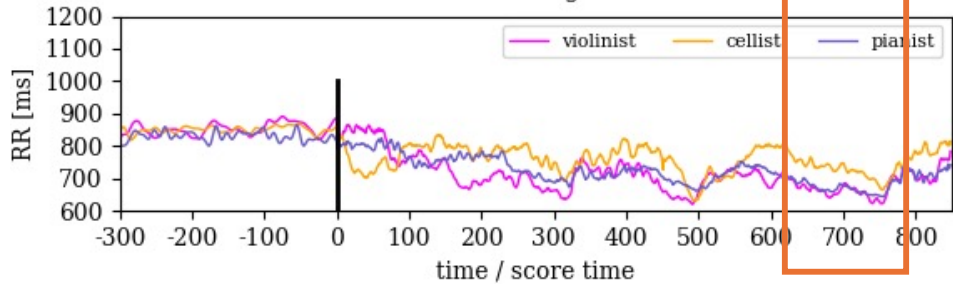
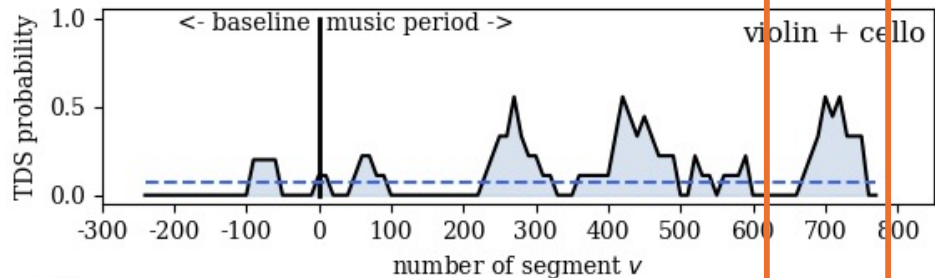
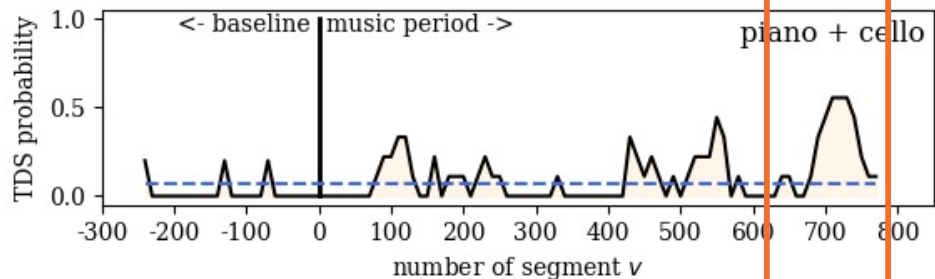
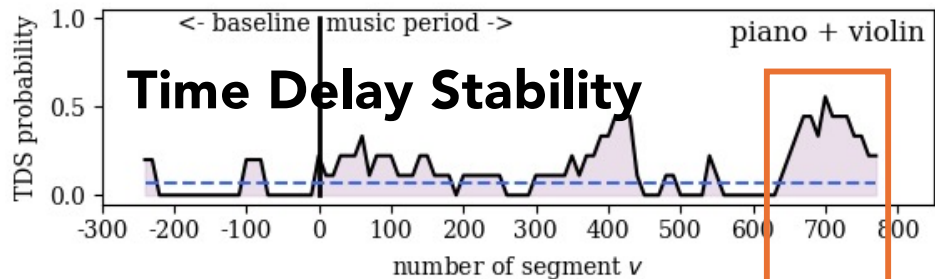
Example III: Violinist, rehearsals 1, 3, 9



the baseline and performance become less distinguishable over rehearsals, which may indicate a learning effect or adaptation to the task over repeated performances, significant for violin, weakly for piano, and less so for cello.

Example IV: Cellist, rehearsals 1, 4, 8





(75) 31

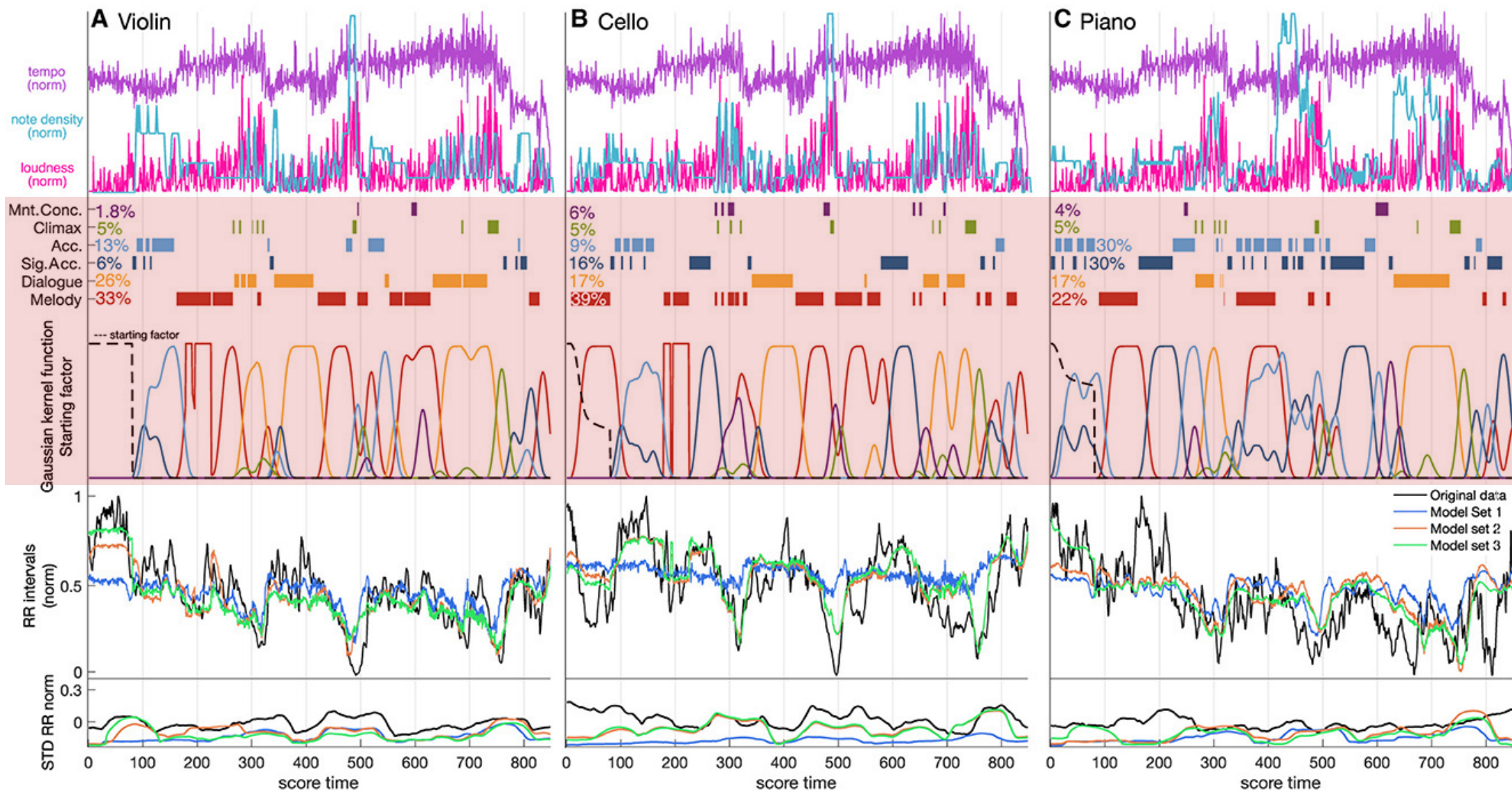
Un poco più lento.

Un poco più lento.

F.S. 31.



Soliński, Reed, Chew Cinc 2023a



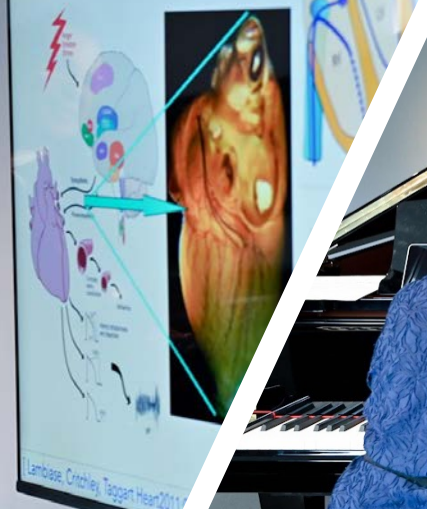
Heart, Brain, Music, Data Event Science Gallery London

March 2023

Denis Noble

Pier Lambiase

Heart-brain Interactions



EC | SDC Vienna

Hilary Sturt (violin)
Ian Pressland (cello)



Franz Schubert performed by Hilary Sturt, Ian Pressland, Elaine Chew

Piano Trio No. 2 @ SGL: II. Andante con moto

Denis Noble



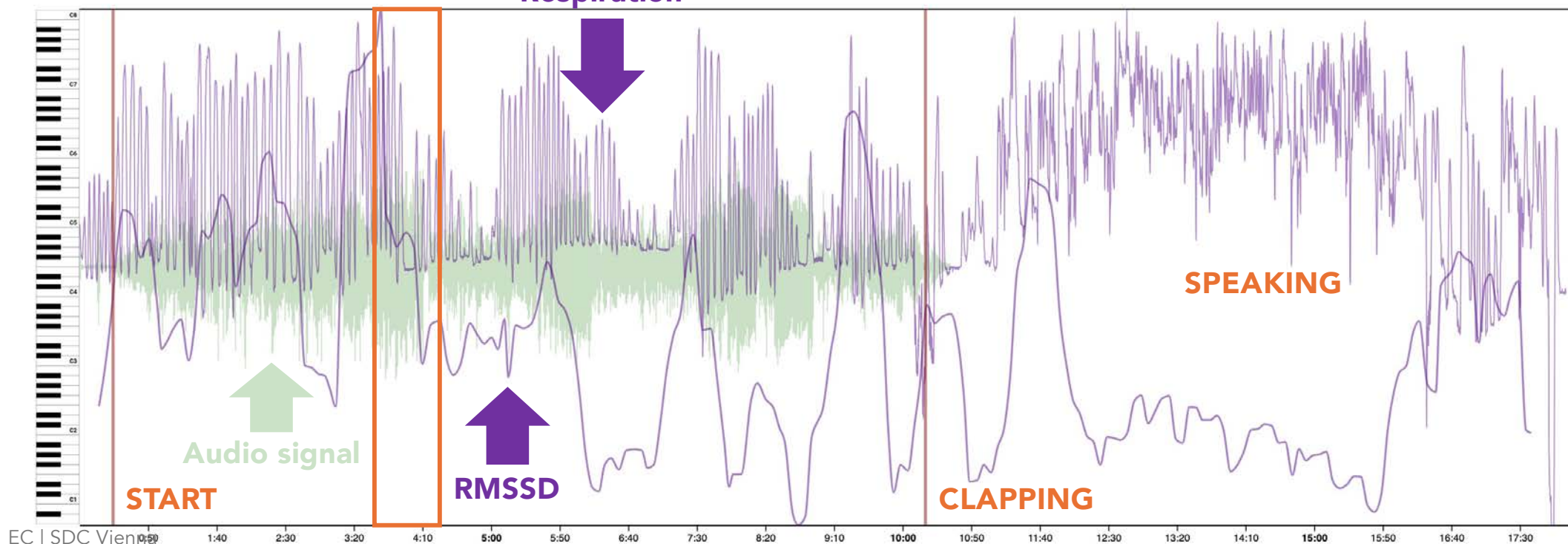
L1:	ECG	RR	HR	RESP	RMSSD	SDNN	CVNN	pNN50	pNN20	MeanRR	VLF	LF	HF	LFnu	HFnu	LFHF	TotalPower	ShannonEnt
-----	-----	----	----	------	-------	------	------	-------	-------	--------	-----	----	----	------	------	------	------------	------------

P2:	ECG	RR	HR	RESP	RMSSD	SDNN	CVNN	pNN50	pNN20	MeanRR	VLF	LF	HF	LFnu	HFnu	LFHF	TotalPower	ShannonEnt
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P3:	ECG	RR	HR	RESP	RMSSD	SDNN	CVNN	pNN50	pNN20	MeanRR	VLF	LF	HF	LFnu	HFnu	LFHF	TotalPower	ShannonEnt
-----	-----	----	----	------	-------	------	------	-------	-------	--------	-----	----	----	------	------	------	------------	------------



Respiration



Art is not what you see but what you make others see ~ Degas

Salut d'Amour cosmonote.isd.kcl.ac.uk

Elgar performed by Elaine Chew
Salut d'Amour

Username:	guestUser2
Password:	CSedit2021

The interface displays a piano roll with a keyboard on the left and a time axis from 0:00 to 1:15. Multiple colored lines (green, blue, purple, red) represent different musical features. Below the piano roll is a spectrogram and a waveform. A control bar at the top includes play, stop, and volume buttons, along with various analysis tools like a waveform icon, a musical note icon, a power icon, a speaker icon, a magnifying glass icon, a left arrow icon, a right arrow icon, a speech bubble icon, a list icon, a plus icon, a minus icon, a close icon, a refresh icon, and a checkmark icon.

EC | SDC Vienna

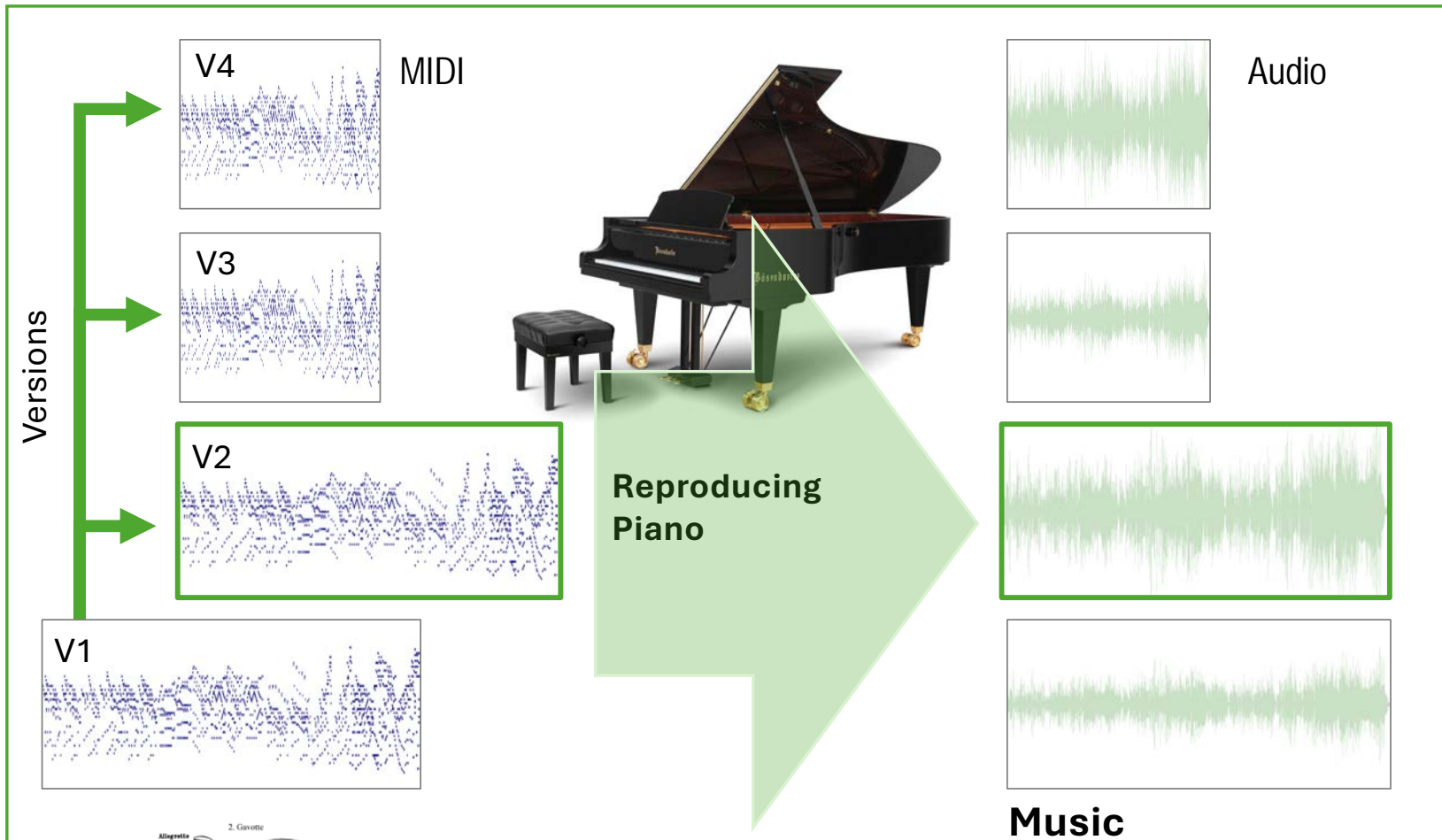


Lawrence Fyfe
Daniel Bedoya






Bedoya, Fyfe, Chew Front. Psychol. 2022
Bedoya, Fyfe, Chew Music & Sci 2025

HeartFM Study

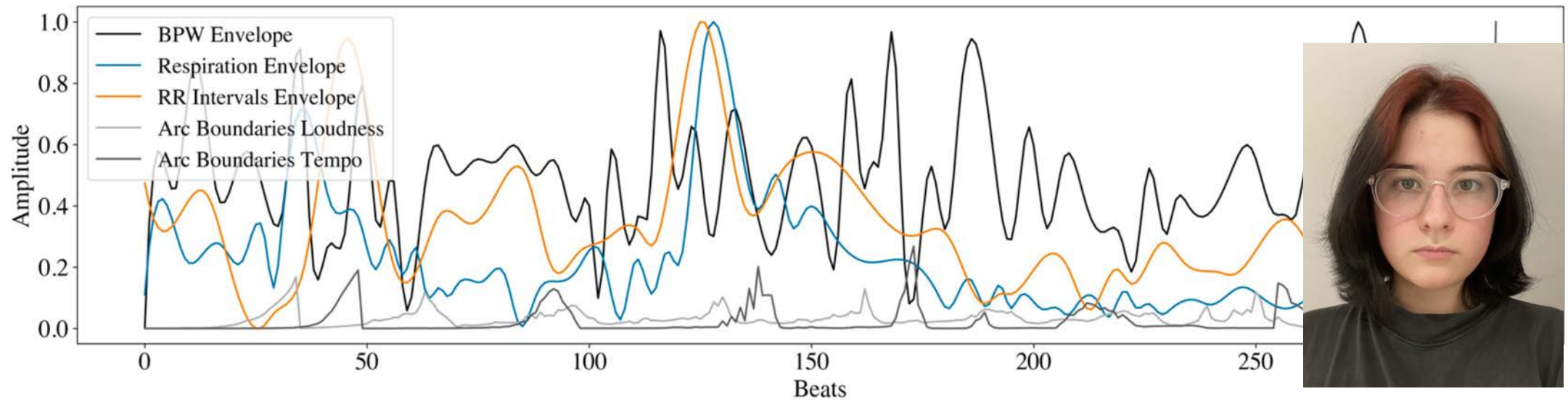
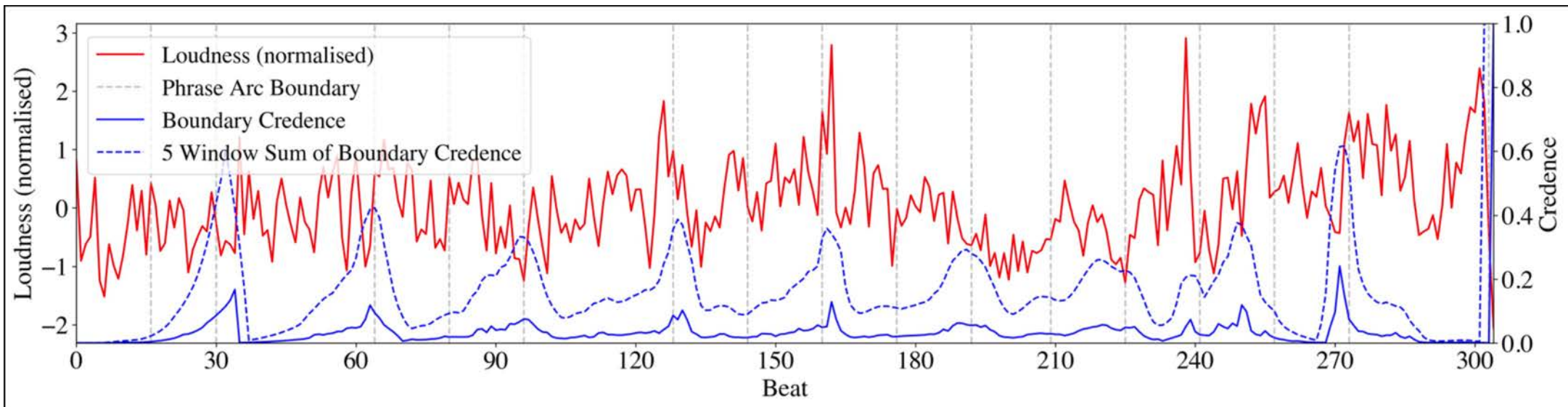


Features

-  Loudness
-  Tempo
-  Tension (harmonic)
+
Annotations
Spectral features



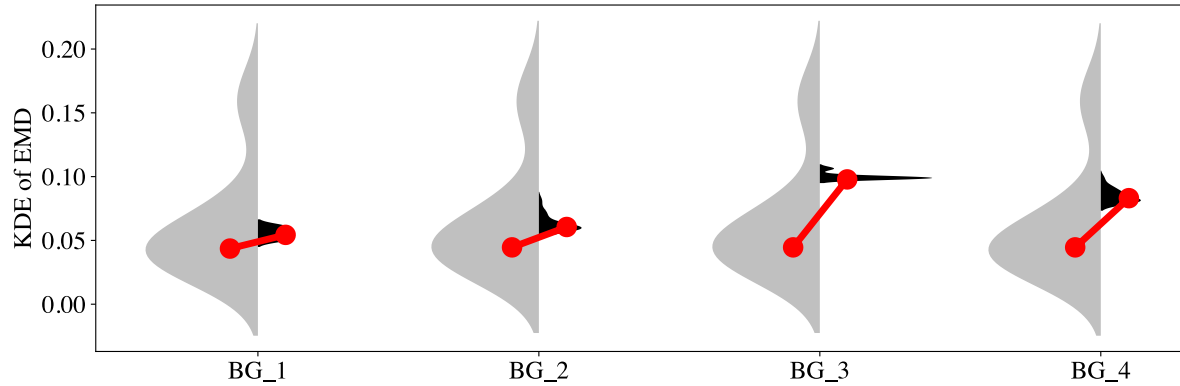
Player



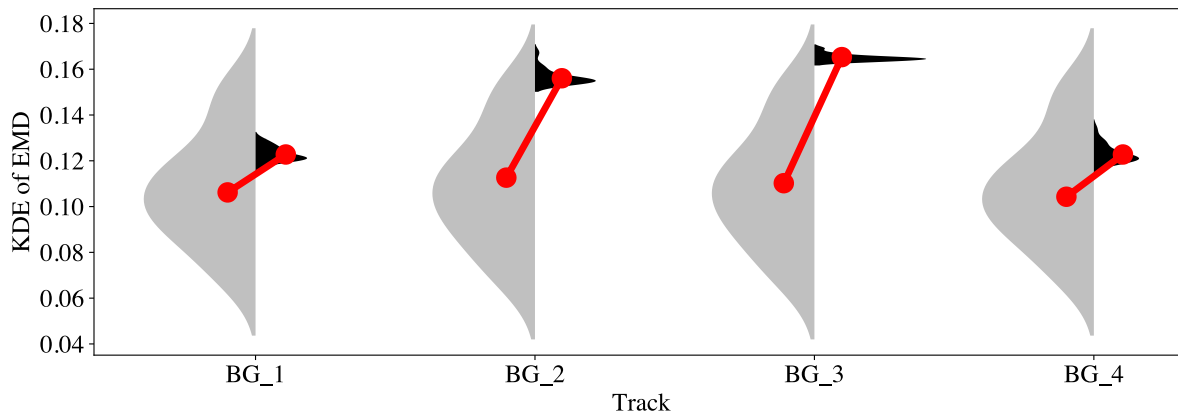
Natalia Cotic

Entrainment

Original Surrogate Median



Loudness–Blood Pressure Waveform Similarity



Tempo–Blood Pressure Waveform Similarity

More Distance
(Less Similar)



Less Distance
(More Similar)

Higher difference (less similarity) for surrogate



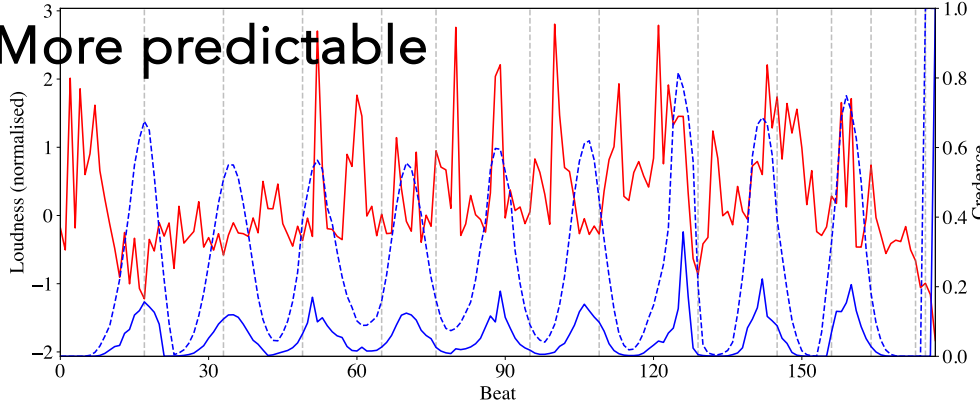
Greater synchronisation during music listening

Cotic, Pope, Soliński,
Lambiase, Chew ESC 2025



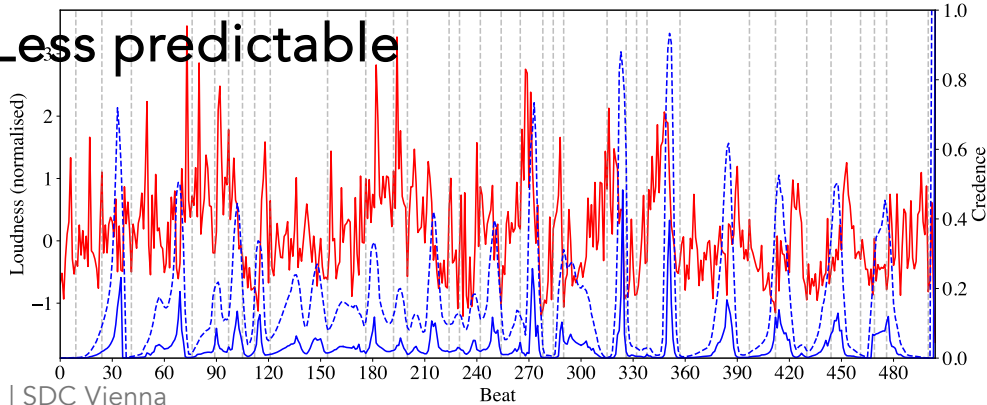
— Loudness (normalised) - - - Phrase Arc Boundary — Boundary Credence - - - 5 Window Sum of Boundary Credence

More predictable



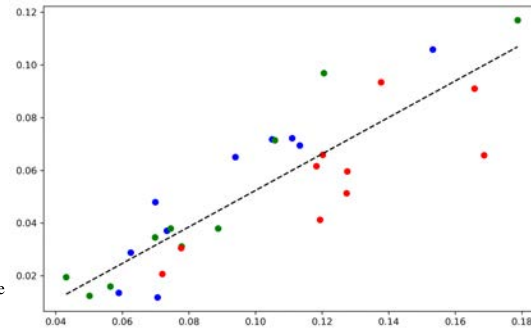
— Loudness (normalised) - - - Phrase Arc Boundary — Boundary Credence - - - 5 Window Sum of Boundary Credence

Less predictable



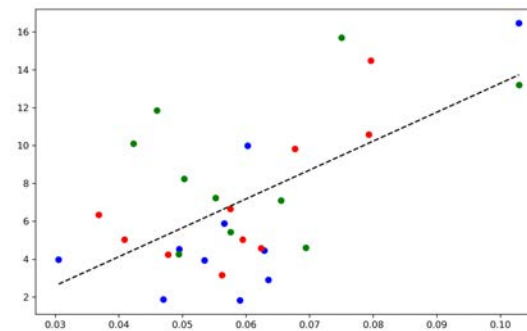
EC | SDC Vienna

Loudness-Tempo vs. Tempo-BP



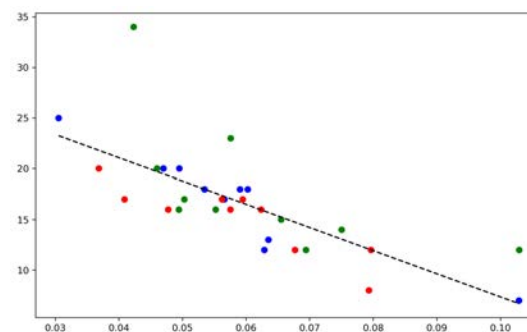
Concurrence between music features increases tempo-BP entrainment

Arc Length Stdev vs. Loudness-BP



Lower arc length standard deviation → more arc regularity

Arcs vs. Loudness-BP



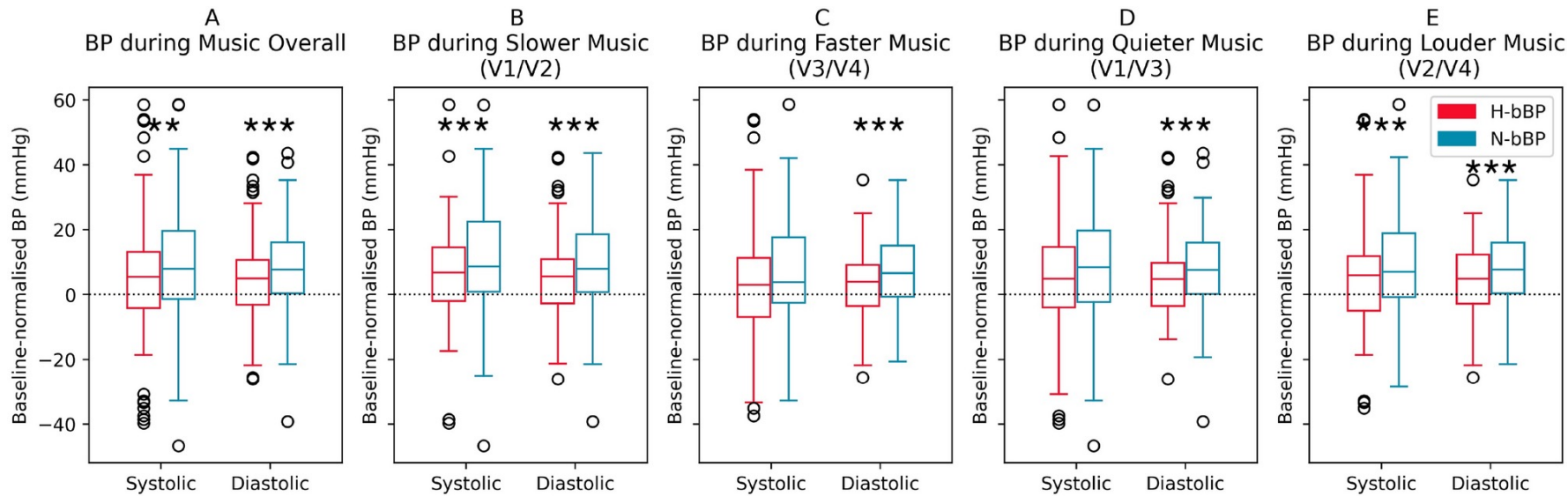
High number of arcs within a track

Cotic, Pope, Soliński, Lambiase, Chew ESC 2025

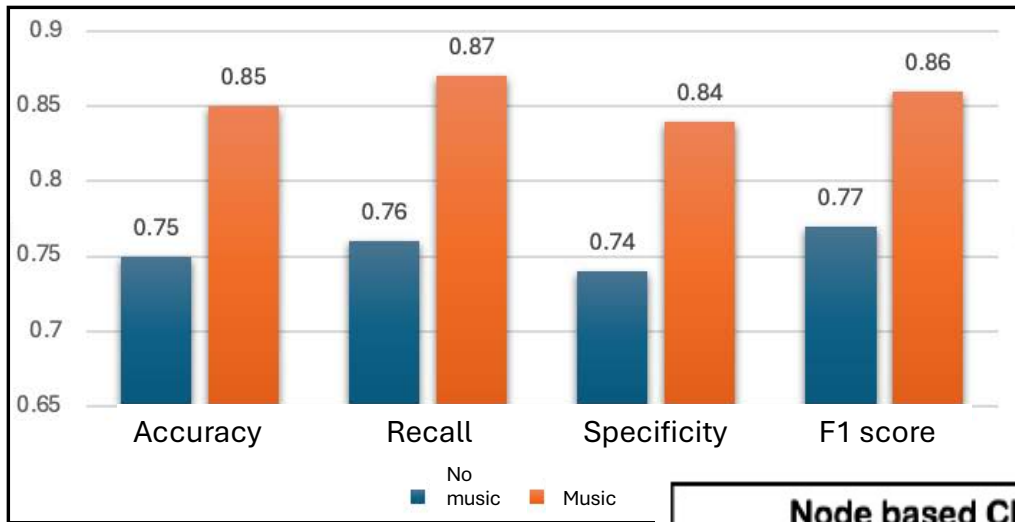
High blood pressure inhibits cardiovascular responsiveness to expressive classical music



Vanessa Pope



Mean normalised SBP and DBP during baseline and music. Both significantly higher for N-bBP participants overall, during slower music, and louder music. During faster and quieter music, only N-bBP's diastolic BP averages are significantly higher than H-bBP's. P-values below 0.0083 are indicated with ***.

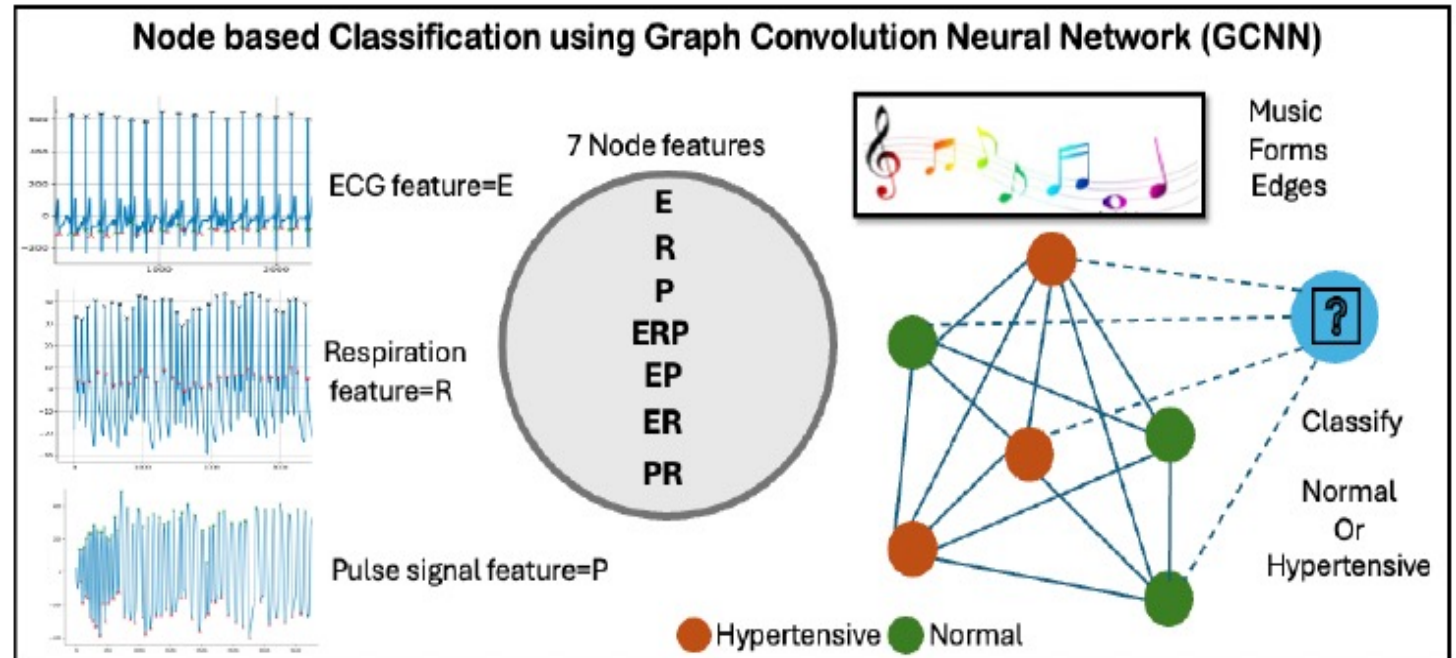


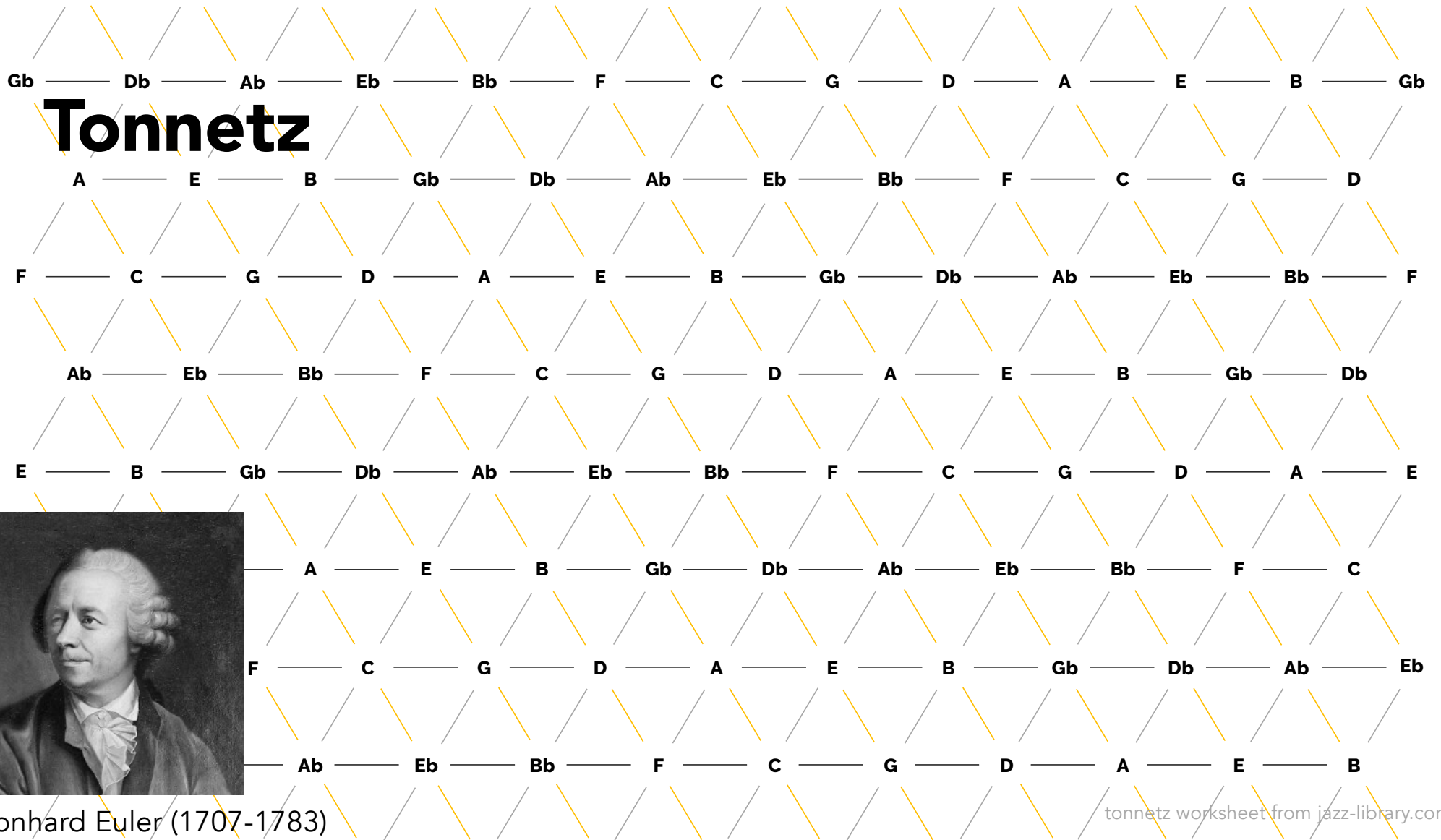
Music-based GCNN Diagnosis of Hypertension

Pal, Cotic, Soliński, Pope, Lambiase, Chew ESGCO 2024

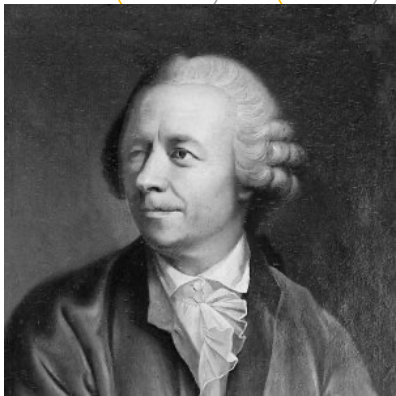


Poulomi Pal





Tonnetz



Leonhard Euler (1707-1783)

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E	B	F#	C#	G#	D#	A#	E#	B#
C	G	D	A	E	B	F#	C#	G#
Ab	Eb	Bb	F	C	G	D	A	E
Fb	Cb	Gb	Db	Ab	Eb	Bb	F	C
Dbb	Abb	Ebb	Bbb	Fb	Cb	Gb	Db	Ab

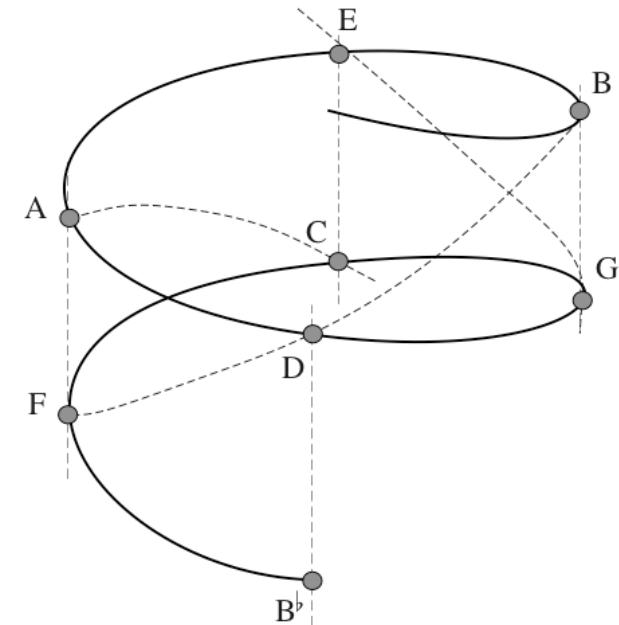
The image shows a 5x9 grid of musical notes. The notes are arranged in a specific order. Two notes, 'D' in the second row, third column and 'D' in the third row, seventh column, are circled in red. Two large red arrows are drawn over the grid. The first arrow starts at the circled 'D' in the second row, third column, curves left and down to point at 'Cb' in the fourth row, second column. The second arrow starts at the circled 'D' in the third row, seventh column, curves right and down to point at 'Db' in the fifth row, eighth column. There are also shaded red areas: one under 'G' and 'D' in the second row, and another under 'D', 'A', and 'E' in the third row.

Spiral Array Model

Chew (2000) MIT dissertation
Chew (2014) Springer monograph

E	B	F#	C#	G#	D#	A#	E#	B#
C	G	D	A	E	B	F#	C#	G#
Ab	Eb	Bb	F	C	G	D	A	E
Fb	Cb	Gb	Db	Ab	Eb	Bb	F	C
Dbb	Abb	Ebb	Bbb	Fb	Cb	Gb	Db	Ab

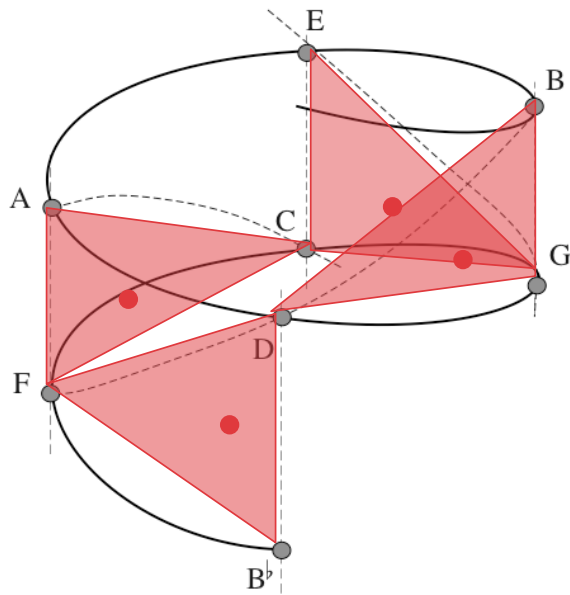
the harmonic network



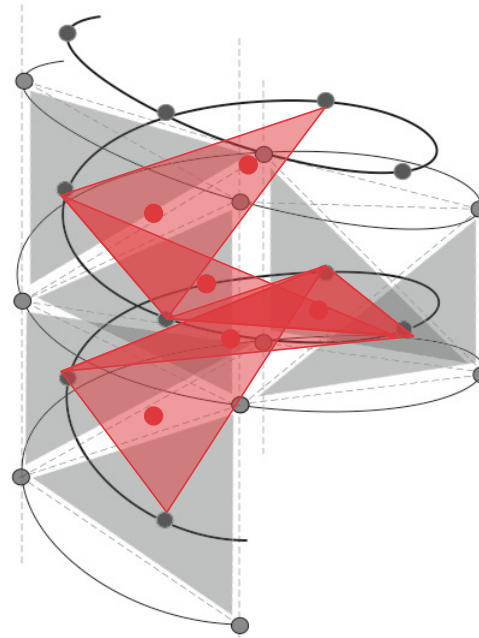
pitch class
representations

Spiral Array Model

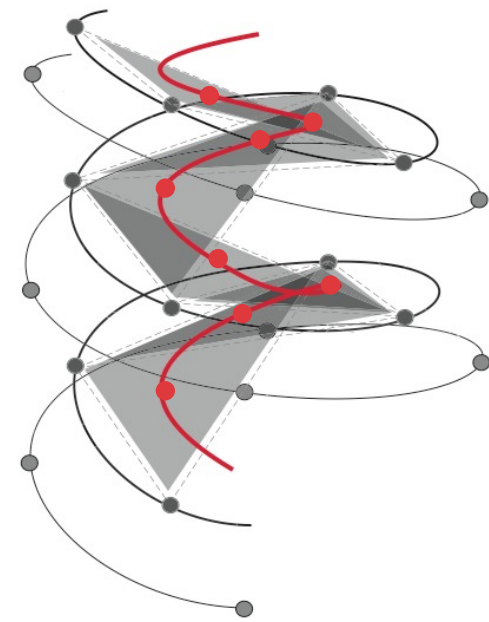
Chew (2000) MIT dissertation
Chew (2014) Springer monograph



from pitch classes
to chords



from chords
to keys



nested
helices

Spiral Array Model

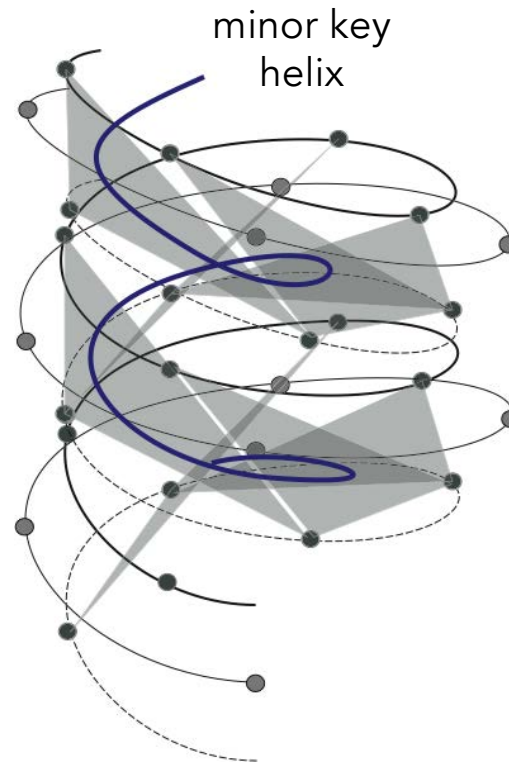
Supervisors



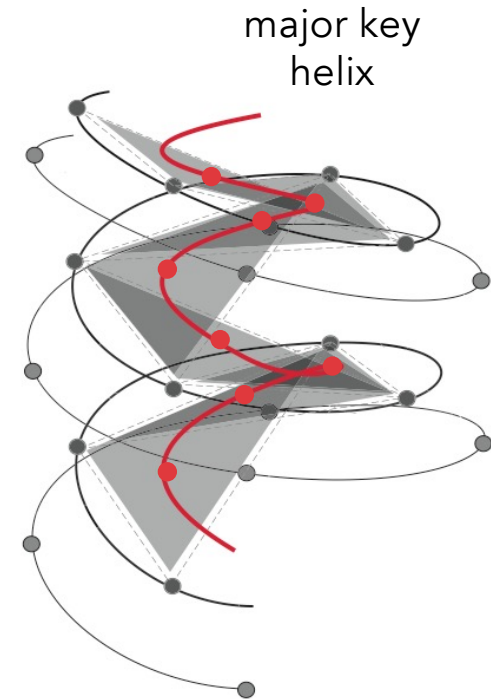
Jeanne
Bamberger



Georgia
Perakis



Chew (2000) MIT dissertation
Chew (2014) Springer monograph



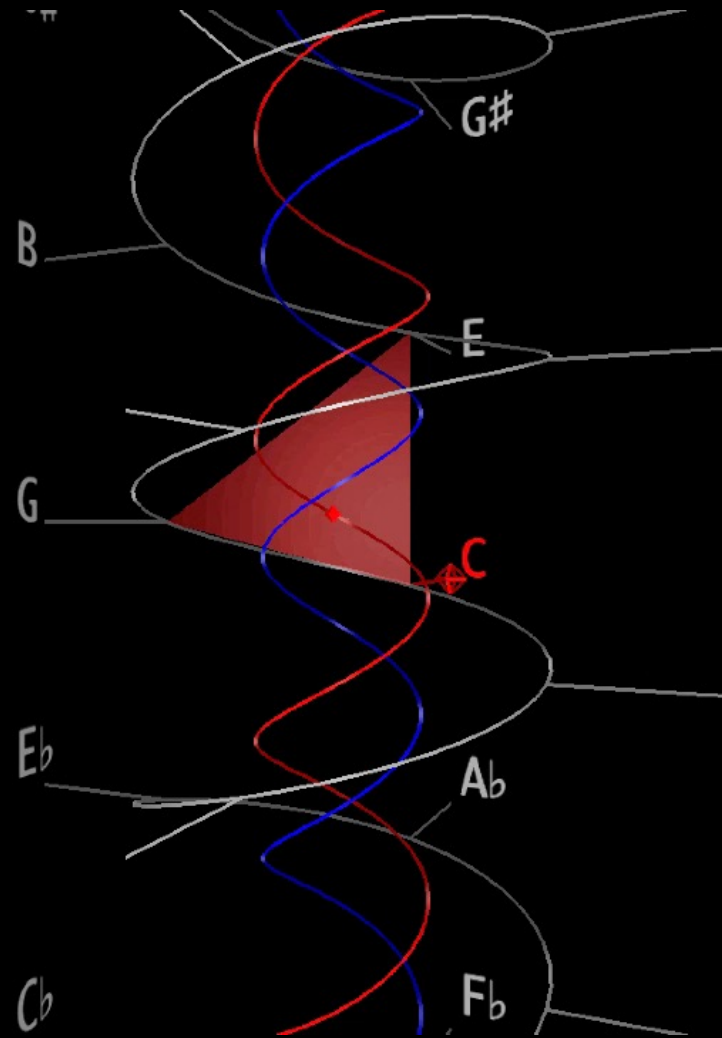
MuSA.RT

Chew & François
ACM MM 2003



Music on the spiral array, real-time
Software engineer: Alexandre R J François

EC | SDC Vienna



 [bit.ly/musa rt-videos](https://bit.ly/musa_rt-videos)

The Philadelphia Inquirer

MIT Technology Review

LA Phil



youtu.be/vsuFtEoqync

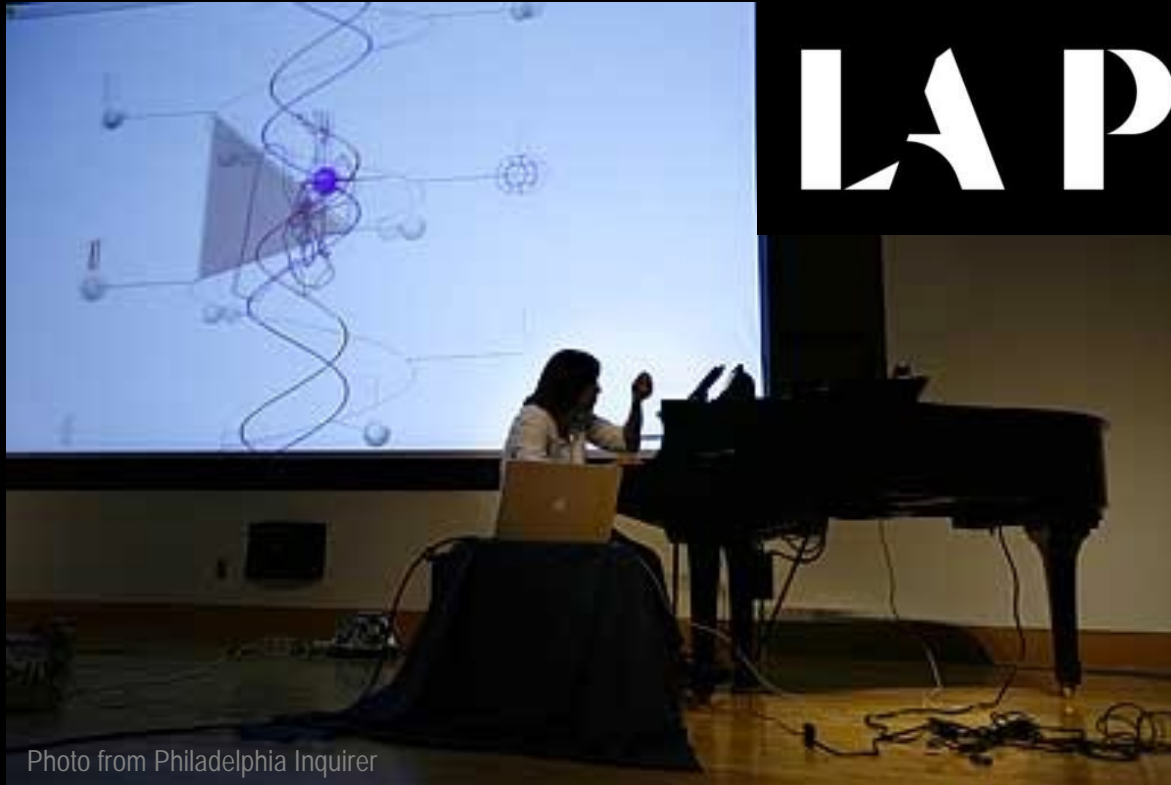
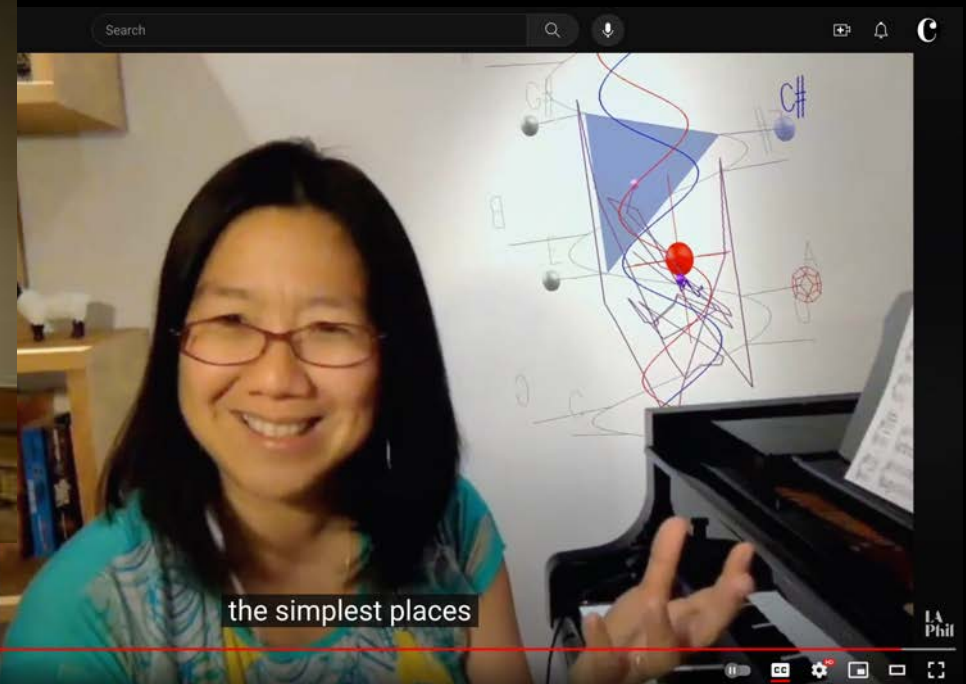


Photo from Philadelphia Inquirer



the simplest places



Mimi international debut in Berlin 2007



Mimi at the Berlin
Musical Instrument
Museum

Mimi and the Seiler piano –
the first MIDI grand piano,
built in the 1983 for tv
production – Berlin Musical
Instrument Museum,
inaugural MCM conference,
May 2007

Francois, Thurmond, Chew NIME 2007

Mimi in Pasadena 2010



Isaac Schankler



Mimi at People Inside Electronics
Mimi & Isaac Schankler, People Inside
Electronics, Boston Court Performing Arts
Center, Pasadena, CA, June 5, 2010

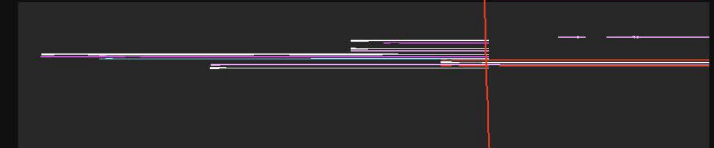
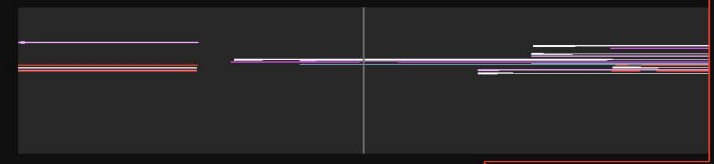
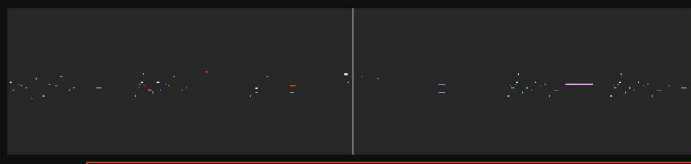
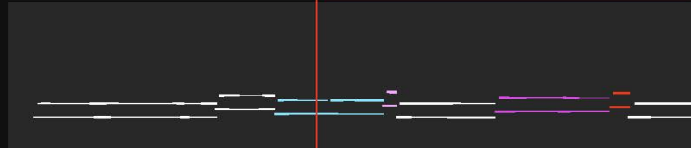
Schankler, Chew, Francois Digital Da Vinci 2014

 bit.ly/mimi-human-machine-improv

Mimi4x



Isaac Schankler



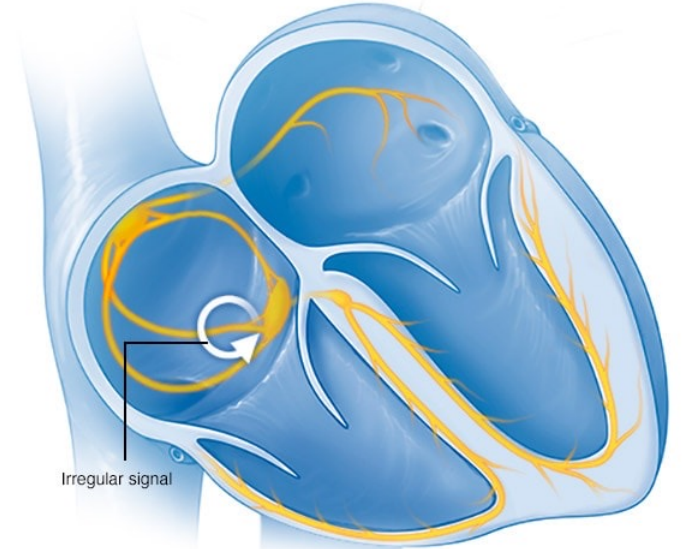
 bit.ly/mimi-human-machine-improv
#8 on playlist

Francois, Schankler, Chew IMIDA 2013



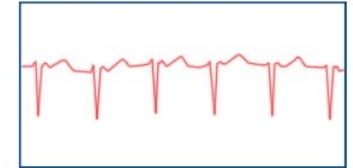
- ▶) 60 bpm
- ▶) 120 bpm
- ▶) 240 bpm

© MAYO FOUNDATION FOR MEDICAL EDUCATION AND RESEARCH

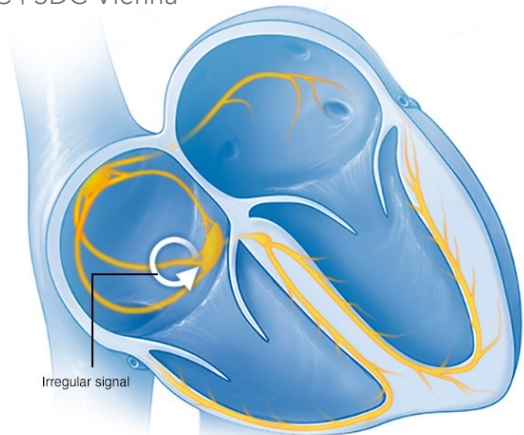


Typical heartbeat

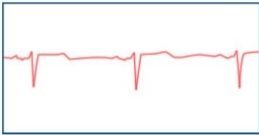
SVT



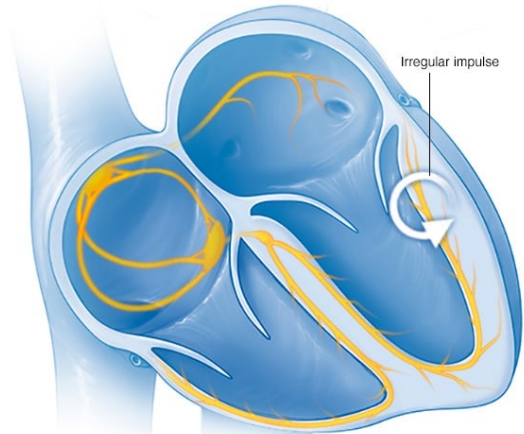
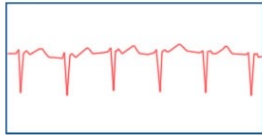
Supraventricular Tachycardia



Typical heartbeat



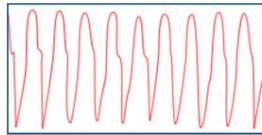
SVT



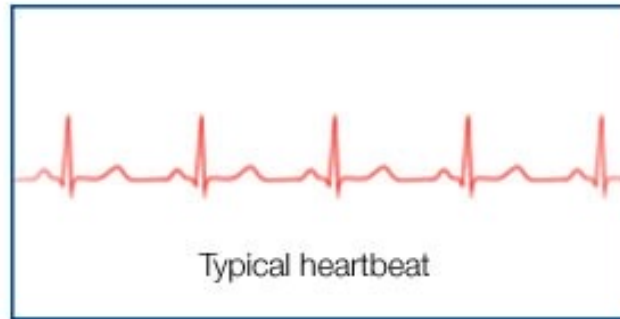
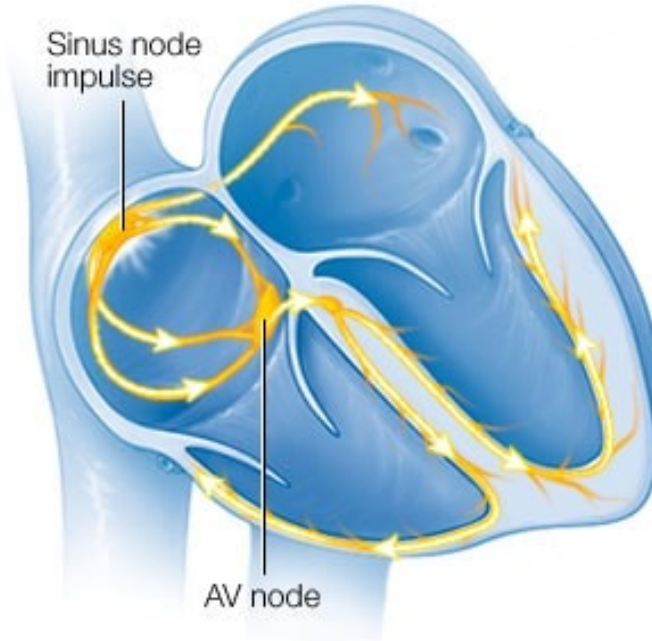
Typical heartbeat



Ventricular tachycardia



Typical heart rhythm



s/Follow-up:

Discharge Contents has been verbally discussed

Comments:

4 wire study-spontaneous SVT. Long response. No evidence of accessory His synch PVC's and para-Hisian p Mapped earliest atrial electrogram resulted in clinical AVNRT terminated by slow JT and SR. Completed research restitution protocol. No inducible tachycardia at end of study. echo pre-AVNERP

Conclusion: Successful ablation

Plan;
Stop anti-arrhythmic medication and
Dr Lambiase

Comments:



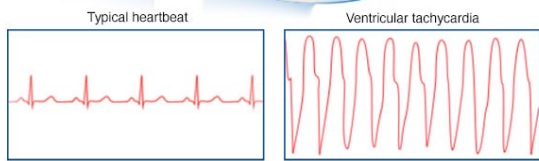
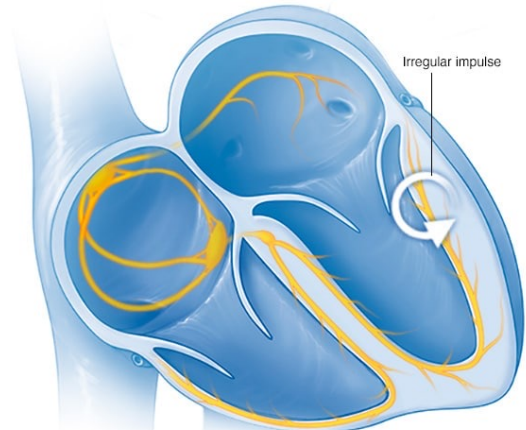
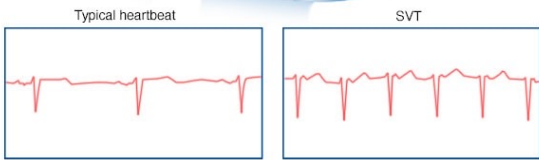
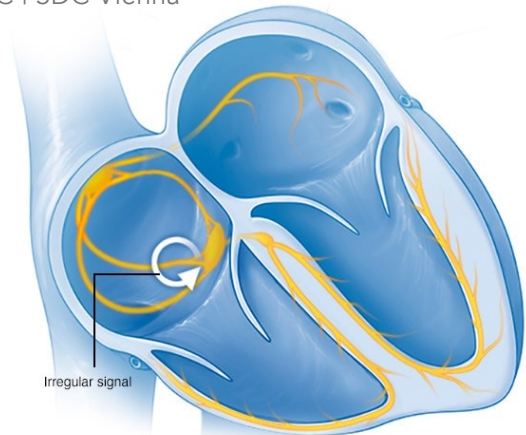
Comments:

Barts Health
NHS Trust

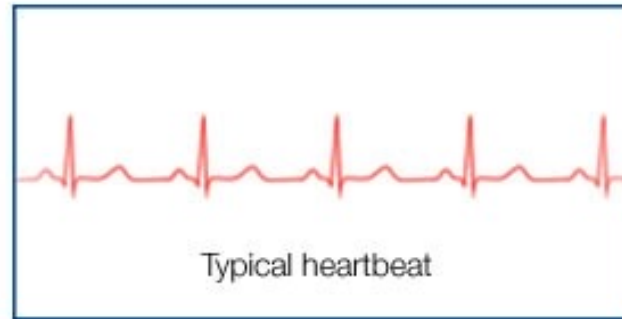
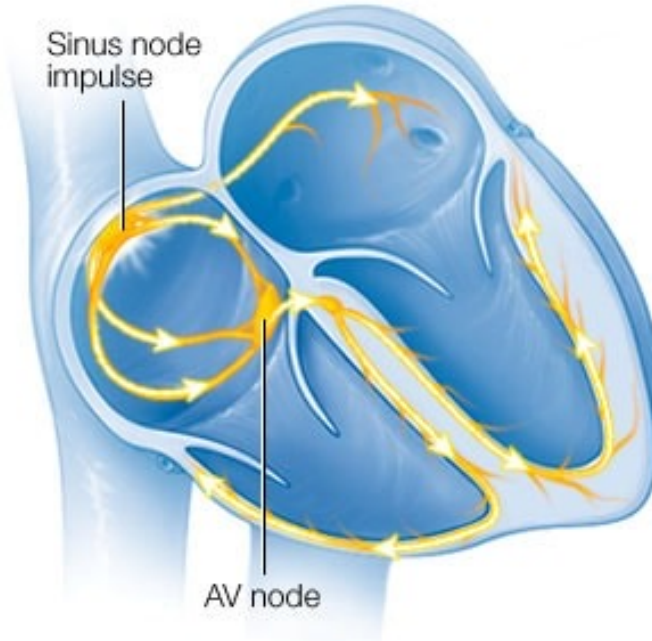
To:

EC | SDC Vienna

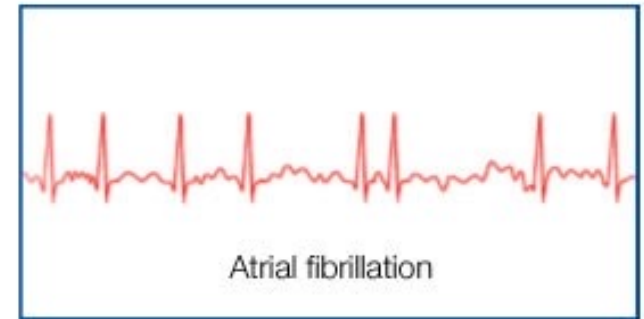
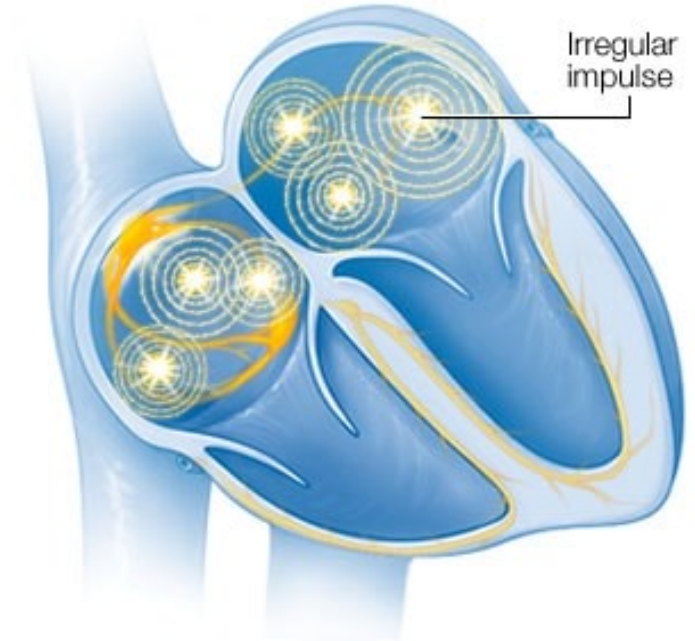


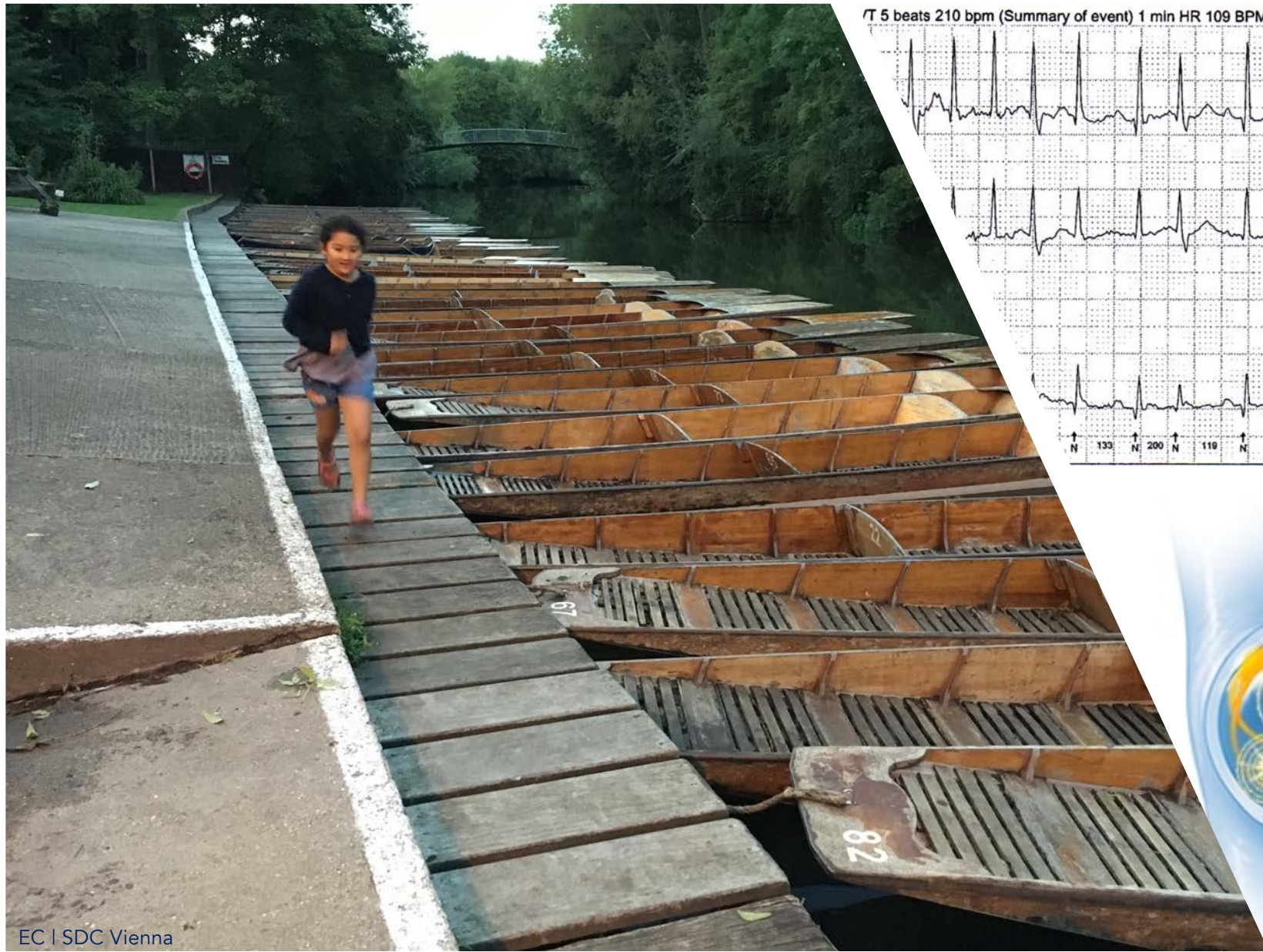


Typical heart rhythm

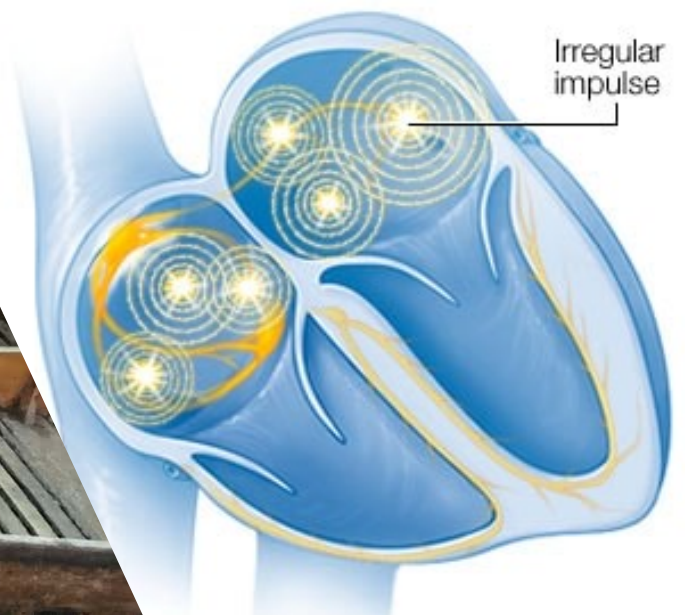
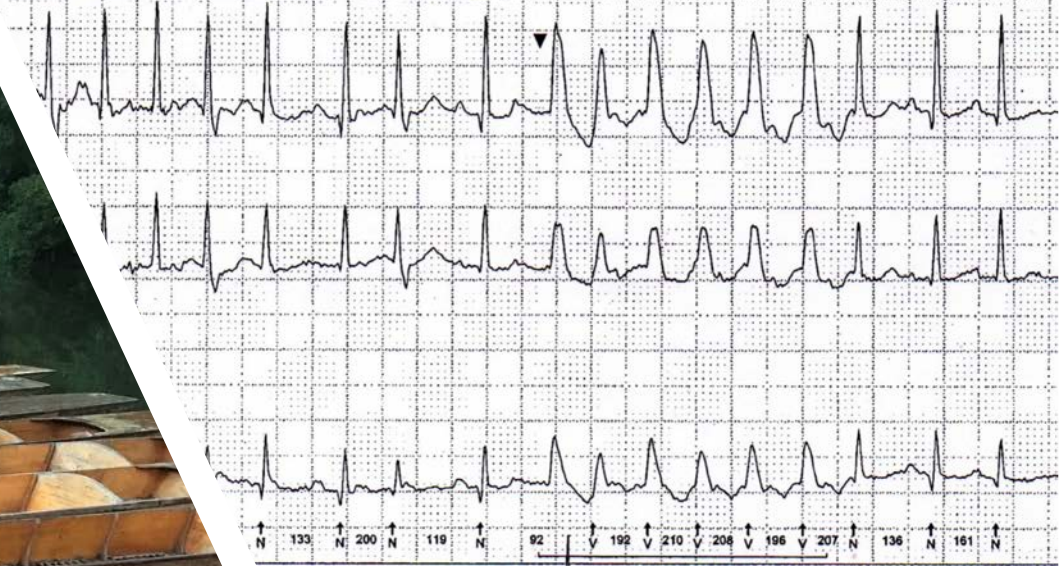


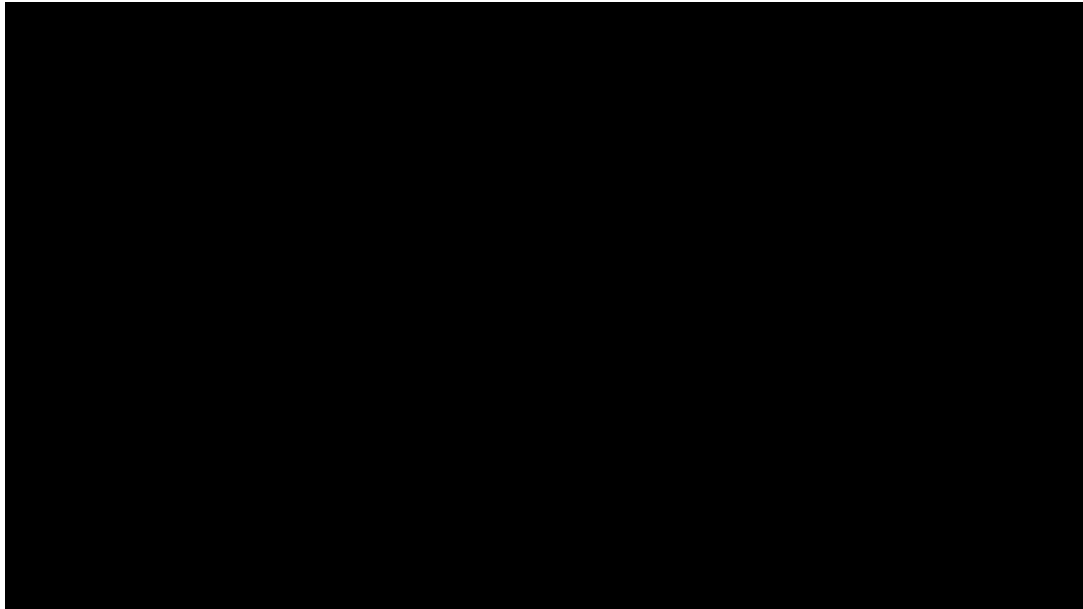
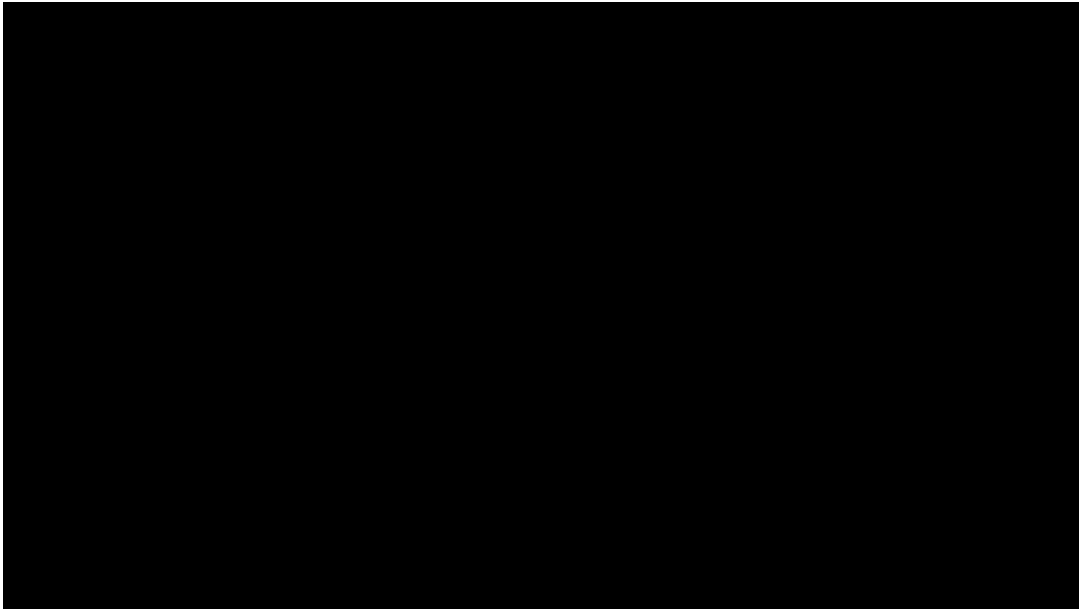
Atrial fibrillation (AFib)





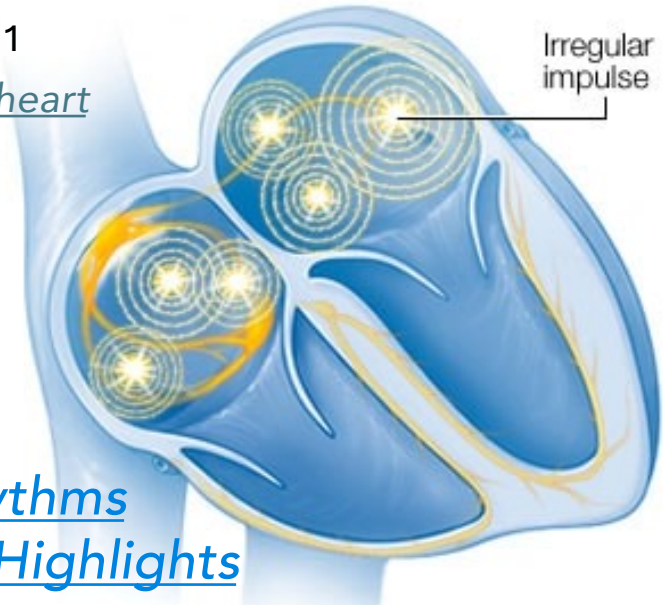
7 5 beats 210 bpm (Summary of event) 1 min HR 109 BPM





Chew et al. Sci Am 2021

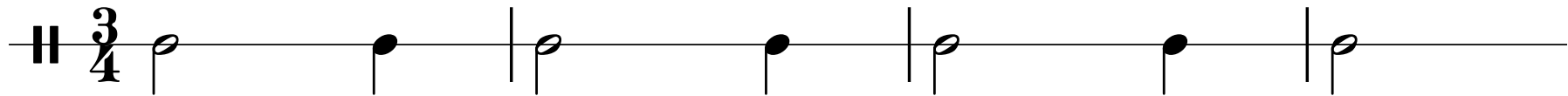
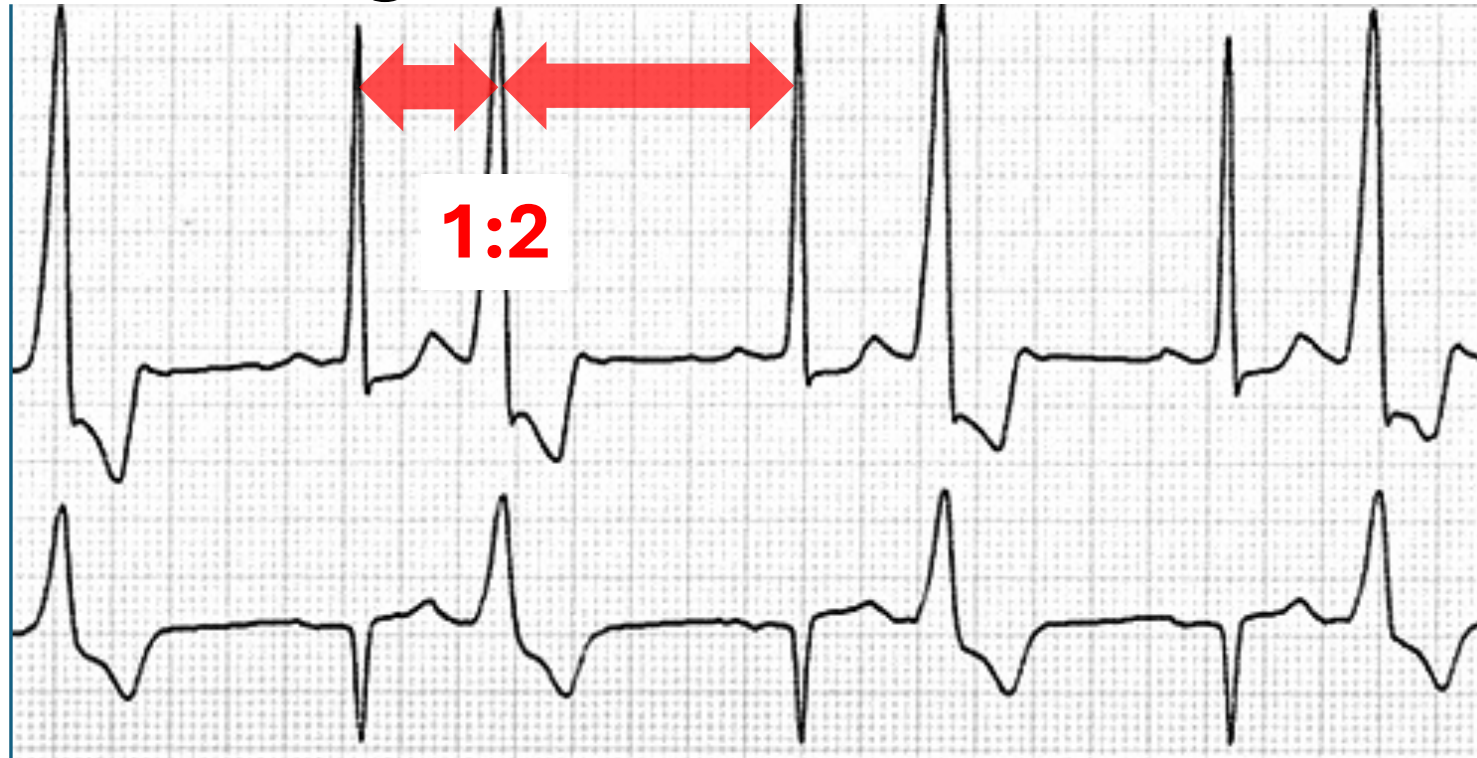
 bit.ly/sciam-musicheart



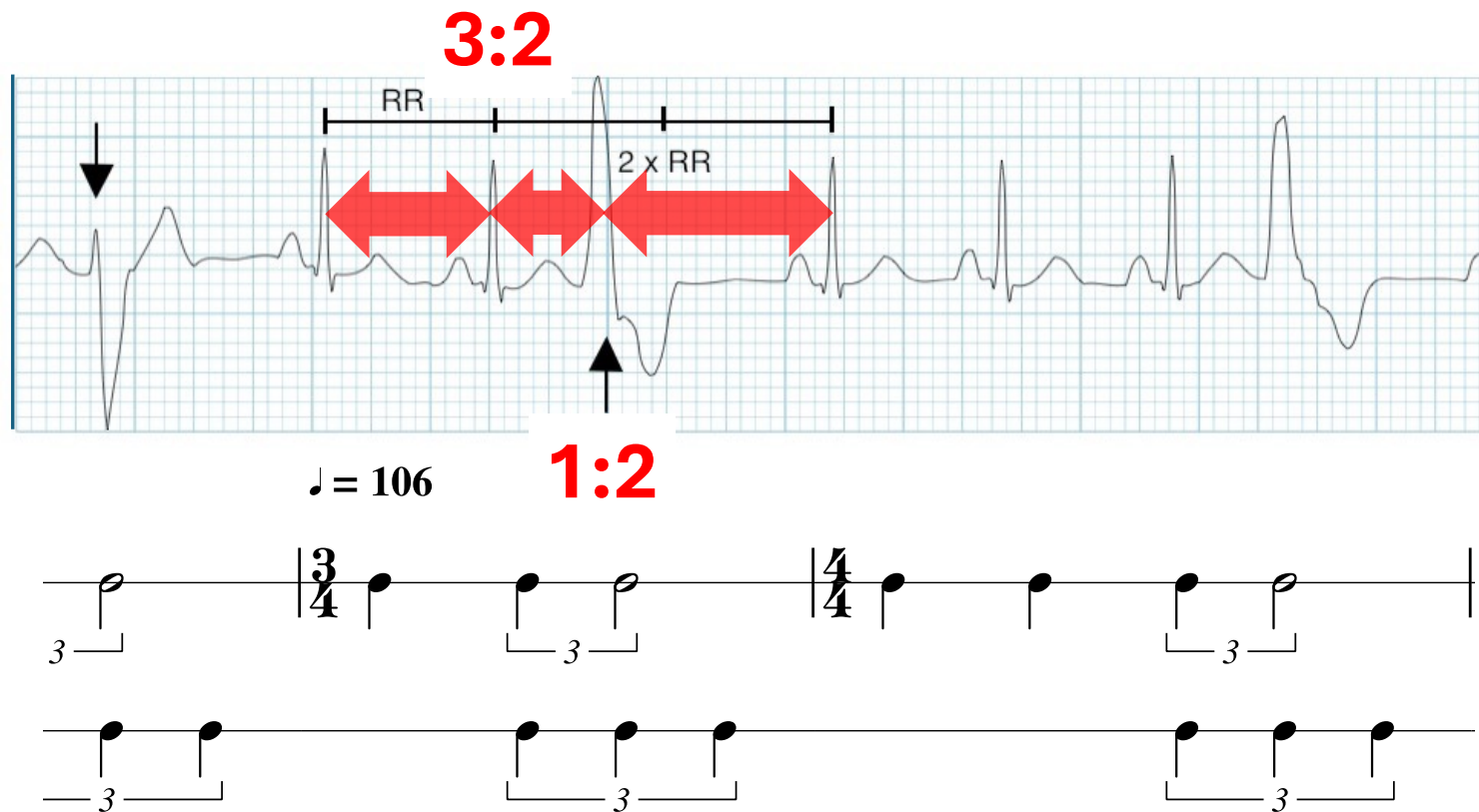
bit.ly/StolenRhythms
bit.ly/ec-HolterHighlights

Premature ventricular complexes
(Bigeminy)

Representing heart RHYTHMS



Representing heart RHYTHMS



Premature ventricular complexes
(Multifocal)

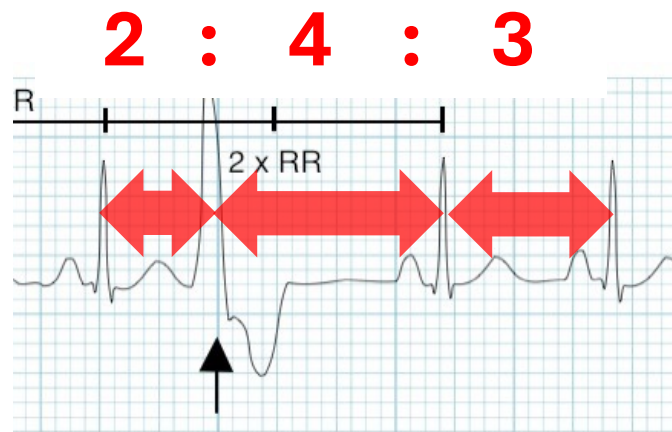
Representing heart RHYTHMS

Little Etudes for Piano

Chew 2020

Based on aberrations of
cardiac electrophysiology

VI. A La Bru Rondo Turk
(Ventricular Ectopics)



Dave Brubeck / adapted by Elaine Chew
5 April 2020

$\text{♩} = 80-120$

N - VE - N - N - VE - N

2 : 4 : 3 : 2 : 4 : 3

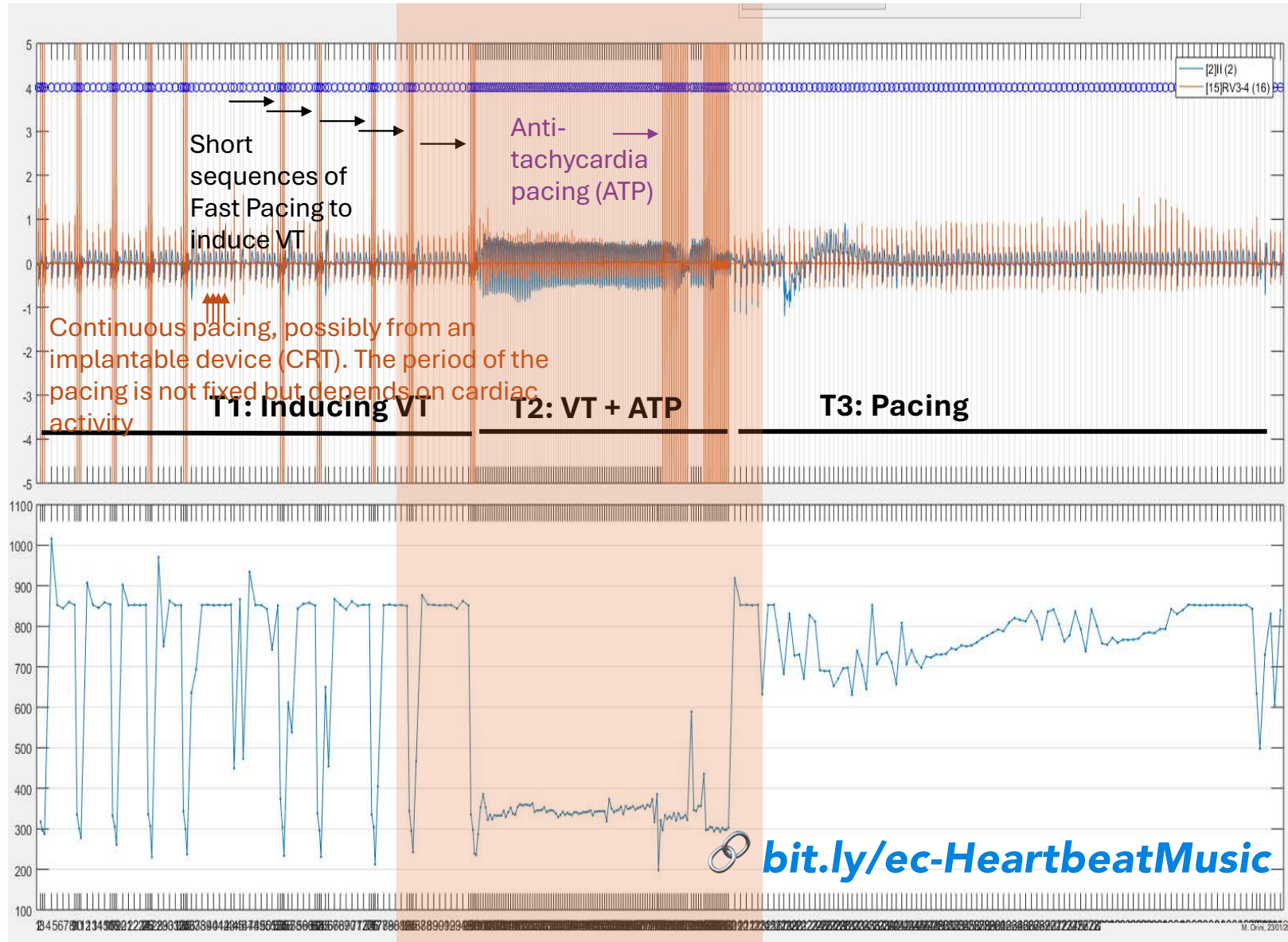


Chew, Orini, Lambiase EHJ 2021

 bit.ly/LittleEtudes



Annotations by Michele Orini



Chew, E. (2021). On Making Music with Heartbeats. In E. R. Miranda (ed.): *Handbook of Artificial Intelligence for Music*, Chapter 9, pp. 237-261. Springer: Cham, Switzerland

Autonomic Nervous System

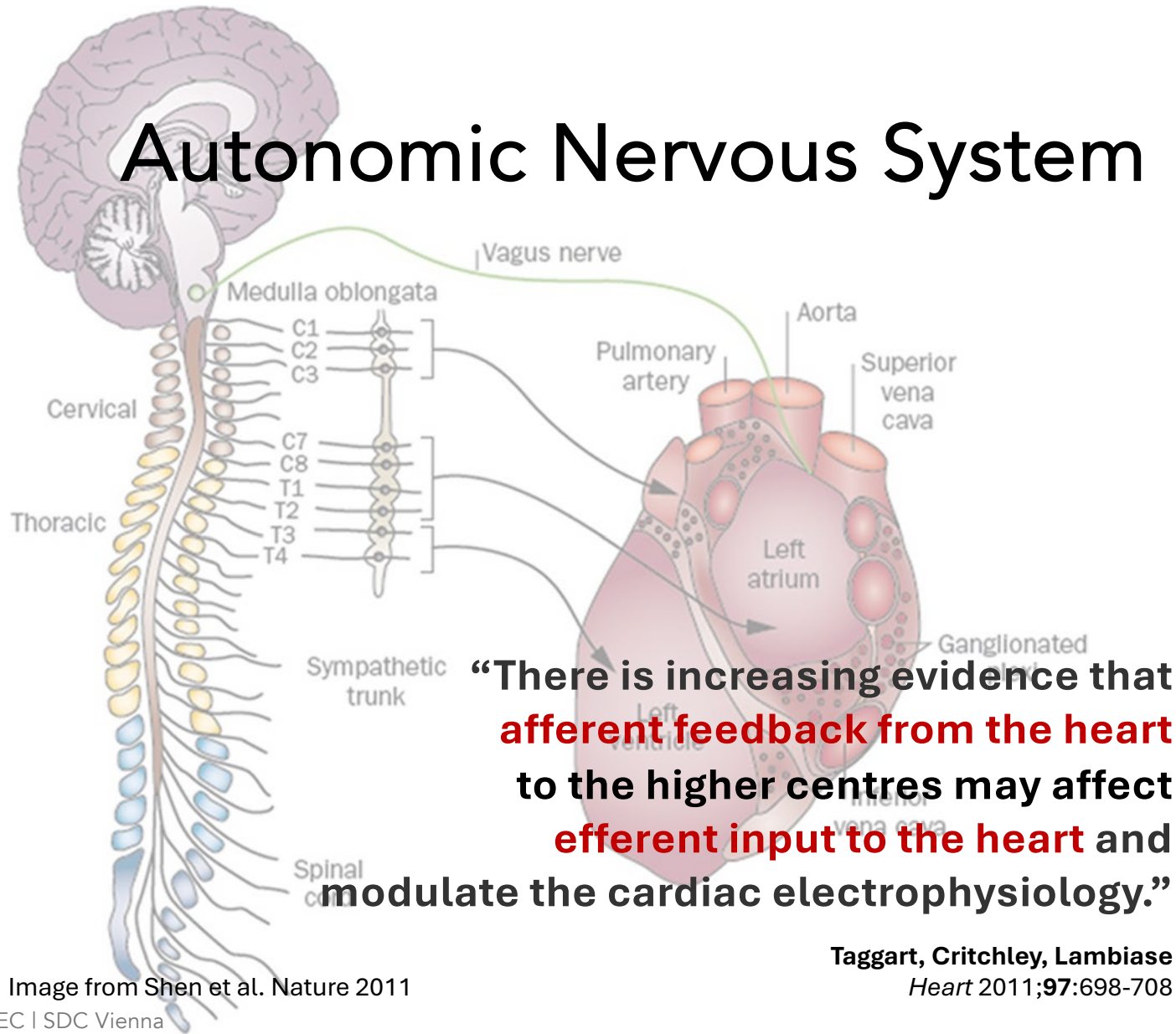


Image from Shen et al. Nature 2011
EC I SDC Vienna

Taggart, Critchley, Lambiase
Heart 2011;97:698-708

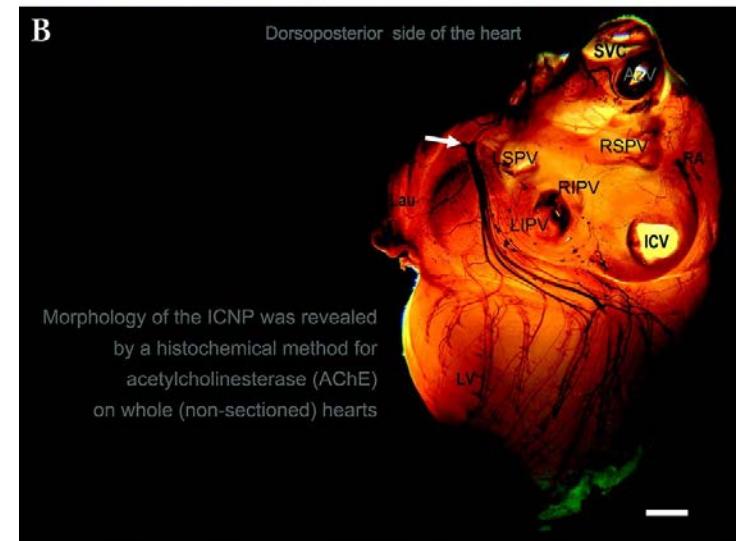
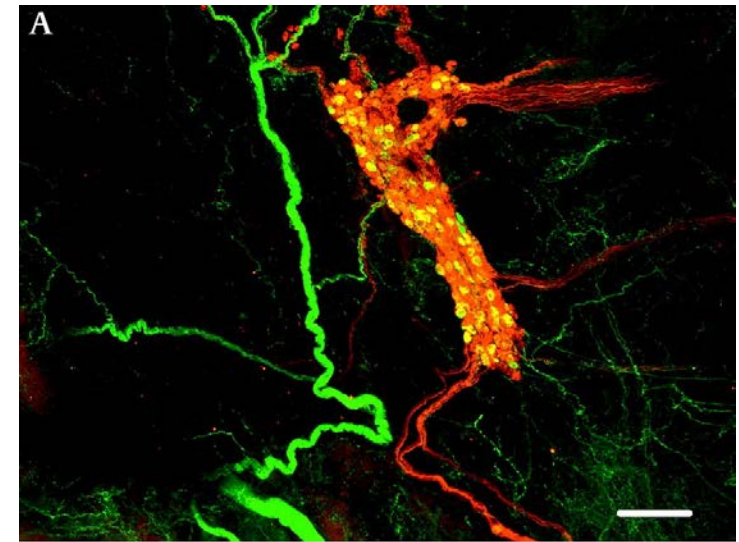
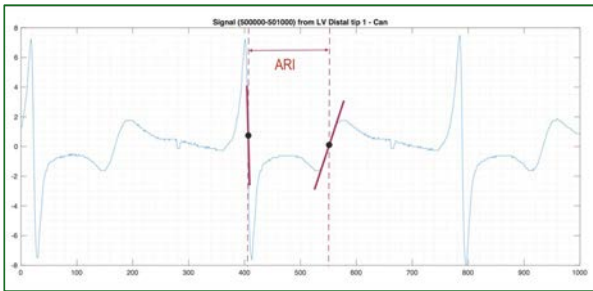
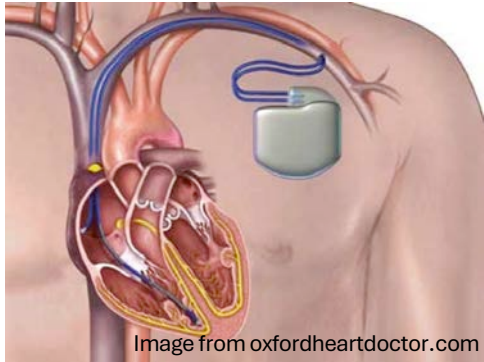


Image from Taggart, Critchley, Lambiase 2011

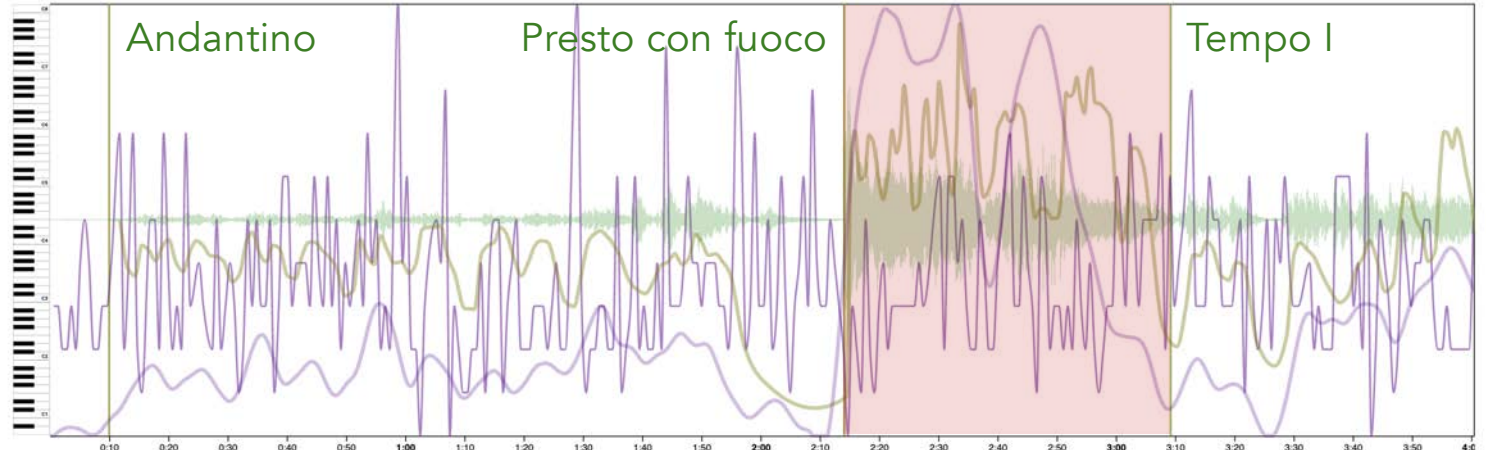


**Intracardiac
Electrogram**

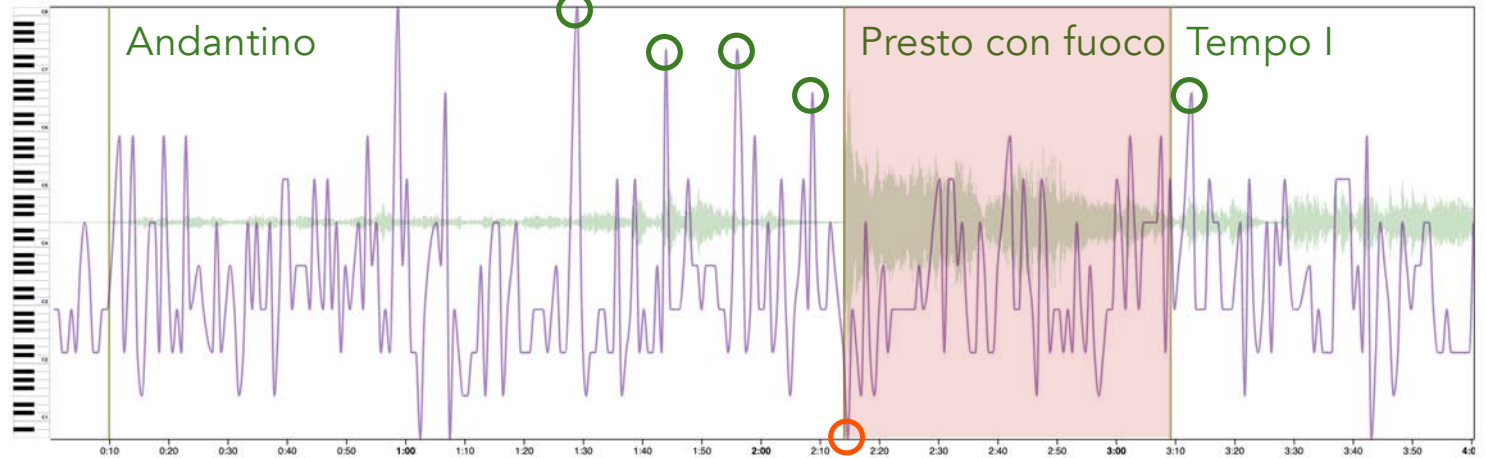
→ **Activation
Recovery
Interval**

Chopin performed by Elaine Chew
Ballade n°2 - Take 2 – Day 3

Chew, Fyfe, Picasso, Lambiase EHJ 2024



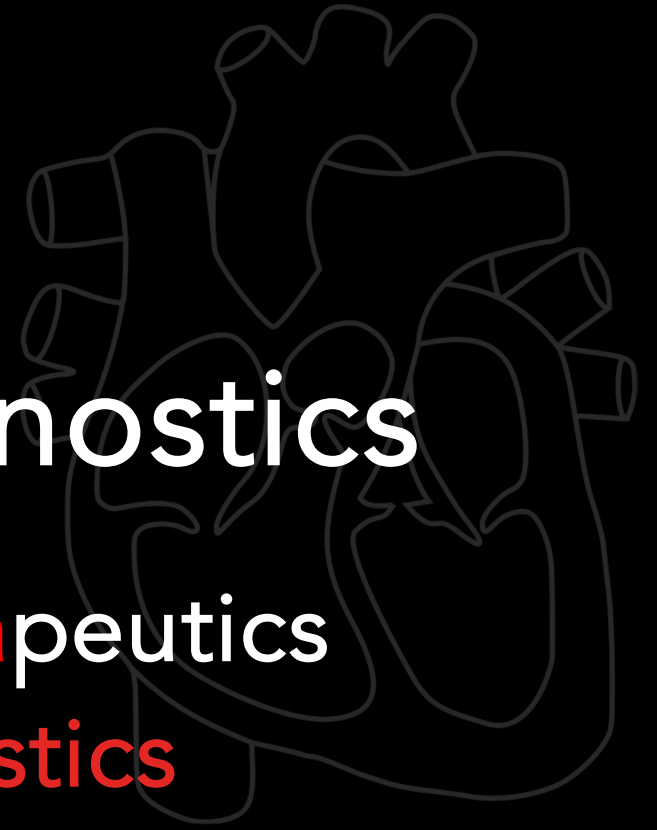
Chopin performed by Elaine Chew
Ballade n°2 - Take 2 – Day 3



**Loudness
Tempo**

Music **Heart** Theranostics

music-based digital **therapeutics**
and precision **diagnostics**





Performance

**Boulez
Fragment
d'une ébauche**



bit.ly/3xboulez-fragment

BOULEZ



Francesco Guerri

Voice



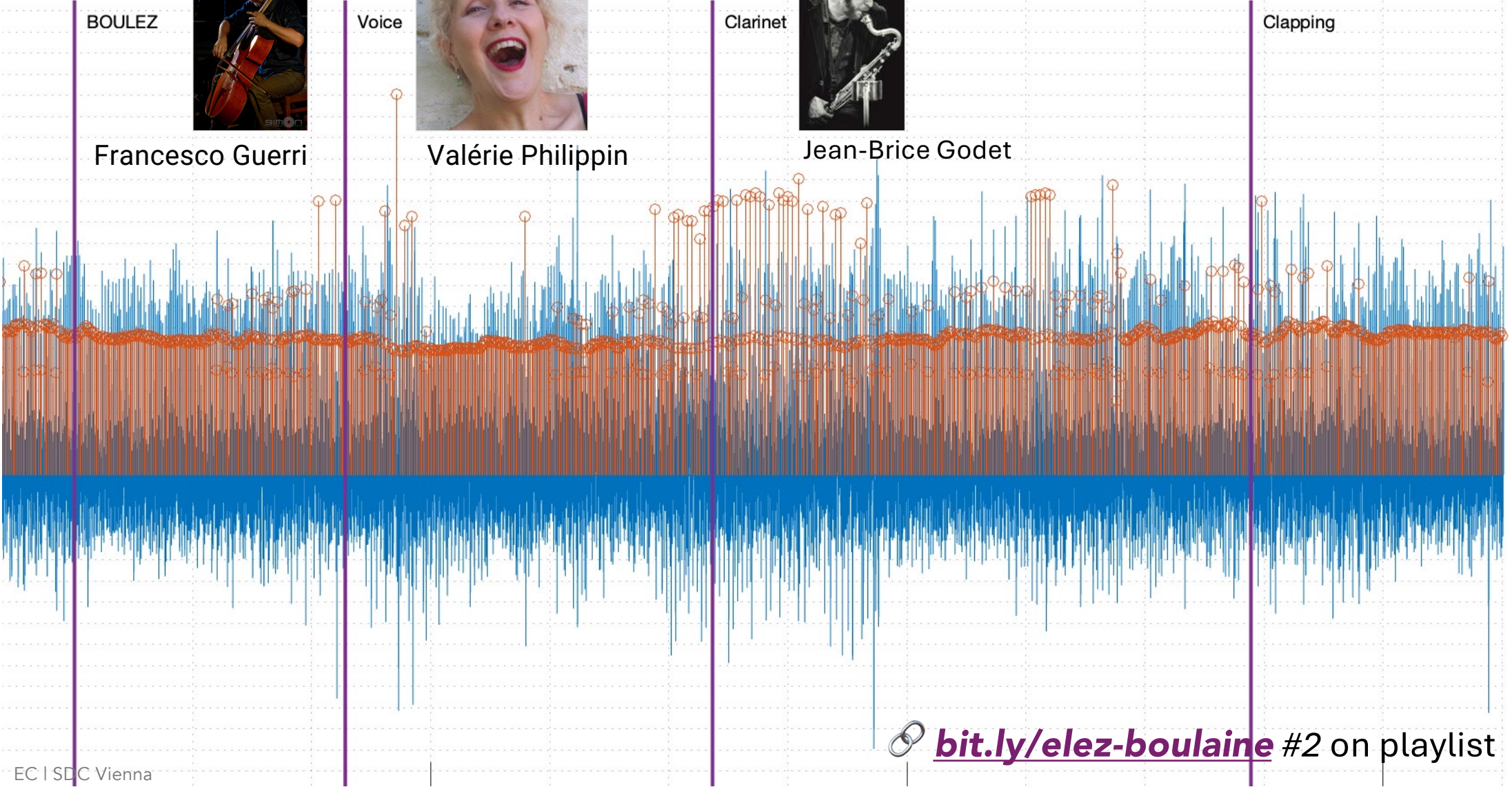
Valérie Philippin

Clarinet



Jean-Brice Godet

Clapping



BOULEZ

Voice

Clarinet

Clapping



Gérard Assayag

Elaine Chew

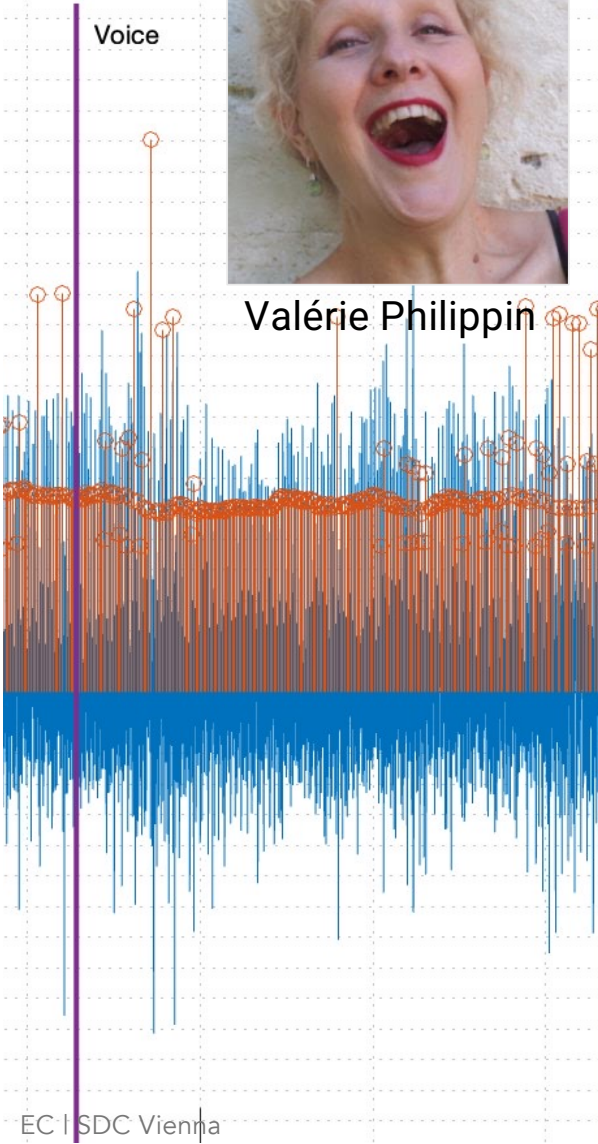
Francesco Guerri





Valérie Philippin

Voice



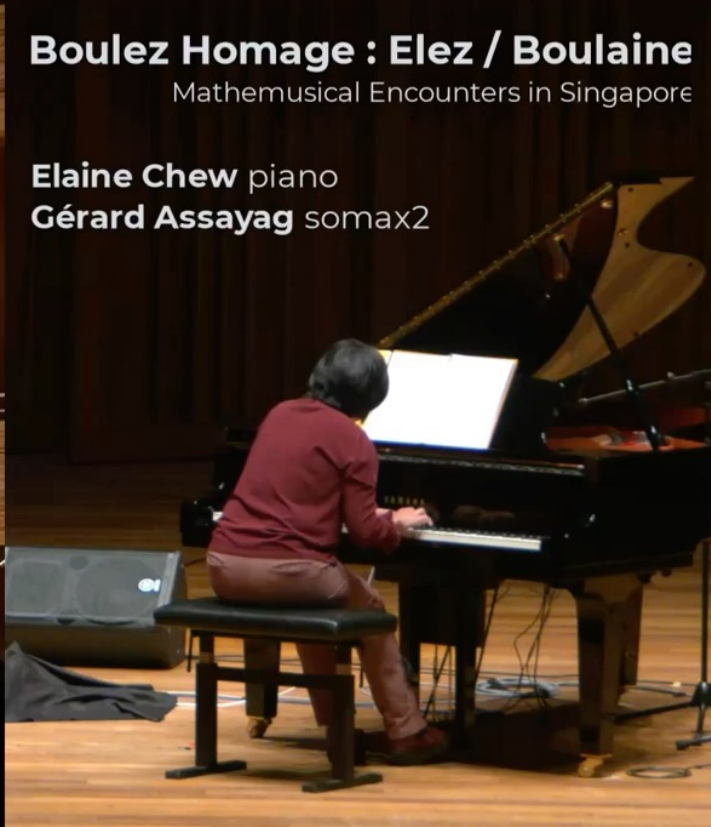
Clarinet

Clapping

Gérard Assayag Elaine Chéw

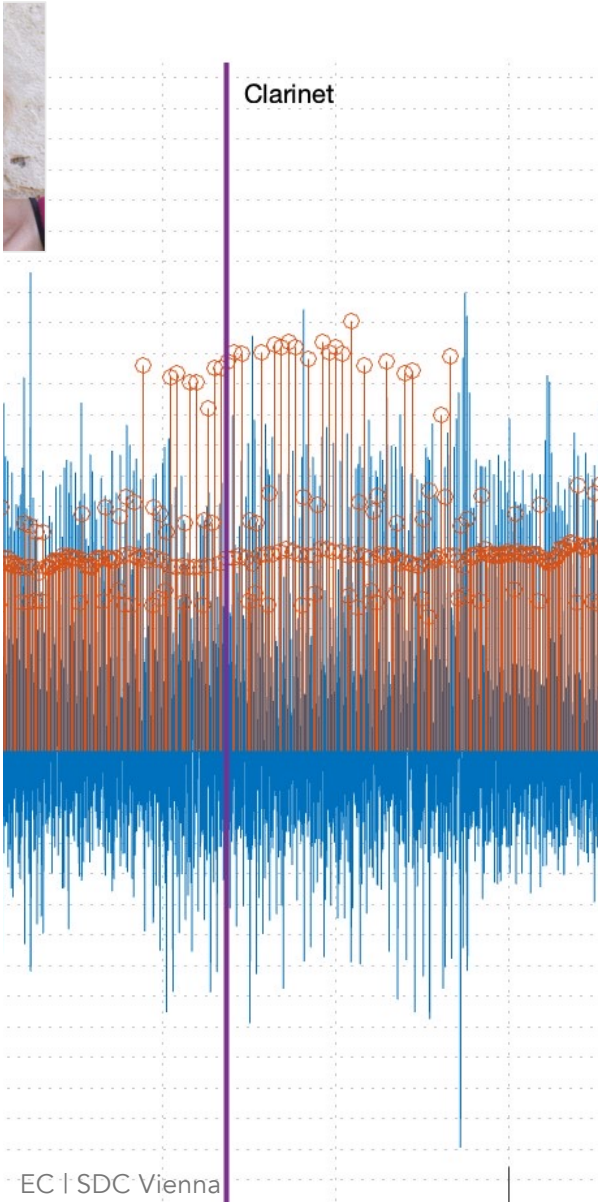
Boulez Homage : Elez / Boulaïne
Mathemusal Encounters in Singapore

Elaine Chew piano
Gérard Assayag somax2

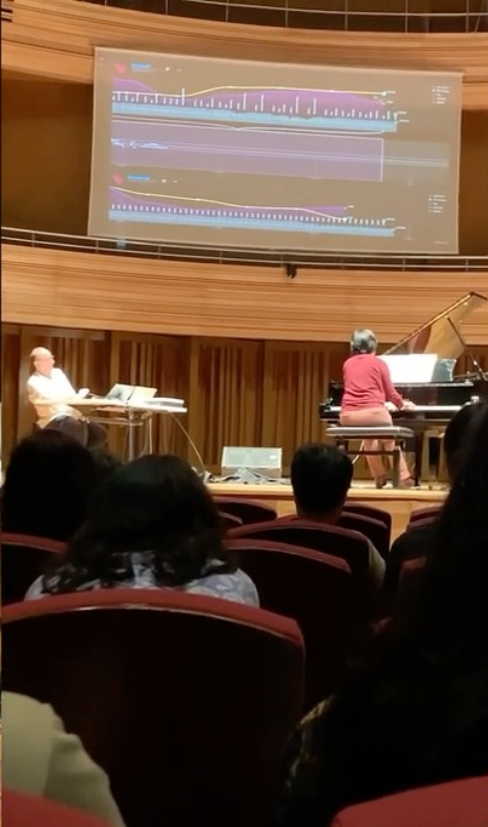


Clarinet

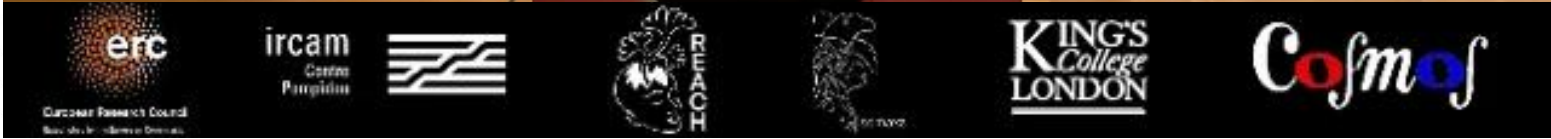
Clapping



Jean-Brice Godet



Elaine Chew



Research sites



European Research Council
Established by the European Commission



ircam
Centre
Pompidou



ERC ADG COSMOS :
Computational Shaping and
Modeling of Musical Structures



CNRS
INNOVATION



ERC POC HeartFM : Maximizing the
Therapeutic Potential of Music through Tailored
Therapy with Physiological Feedback in
Cardiovascular Disease





Cosmos 
HEART.fm



ircam
Centre
Pompidou



SORBONNE
UNIVERSITÉ



LAB
STMS



The Team

 cosmos.isd.kcl.ac.uk

 bit.ly/COSMOS-YouTube

Elaine Chew, Natalia Cotic, Mateusz Soliński, Poulomi Pal, Vanessa Pope, Pier Lambiase, Wentao Hao, Daniel Bedoya, Lawrence Fyfe, Corentin Guichaoua, Charles Picasso

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