Smart Seismocardiography:

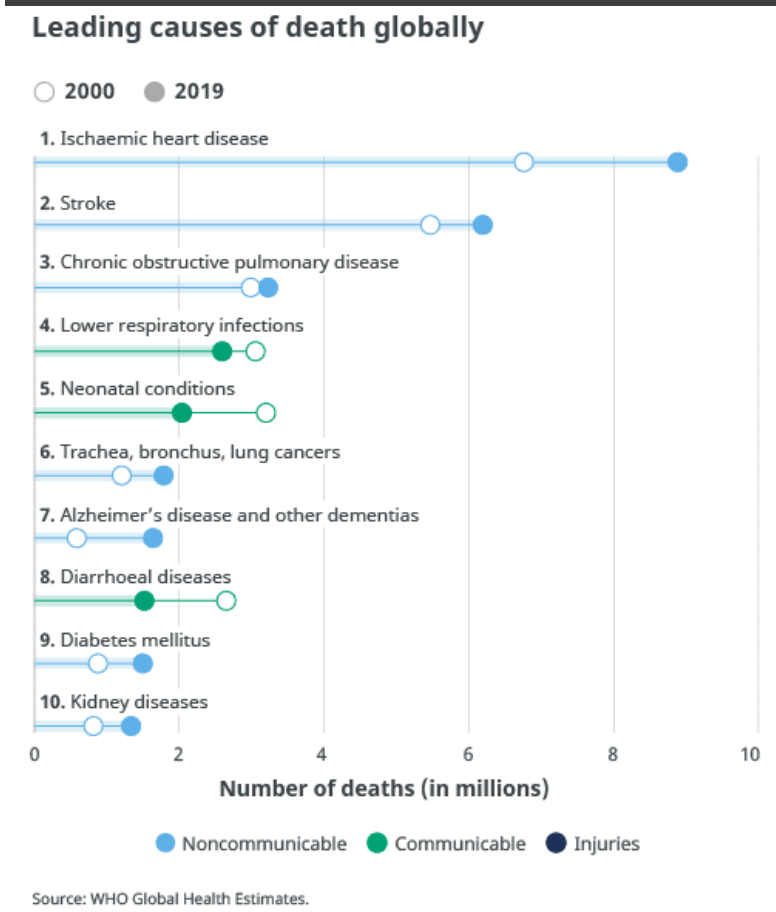
A machine learning approach for automatic data processing

Omar Y. López-Rico[1,2,*] and Roberto G. Ramírez-Chavarría[1]

[1] Instituto de Ingeniería, Universidad Nacional Autónoma de México, Ciudad de México, 04510, México; RRamirezC@iingen.unam.mx
[2] Programa de Maestría y Doctorado en Ingeniería, Universidad Nacional Autónoma de México, Ciudad de México, 04510, México
[*] Correspondence: ig.omar.lopez@comunidad.unam.mx

Cardiovascular disease (CVD)

Heart disease a major cause of death worldwide.
- World Health Organization (WHO)



Existing approaches for heart recording

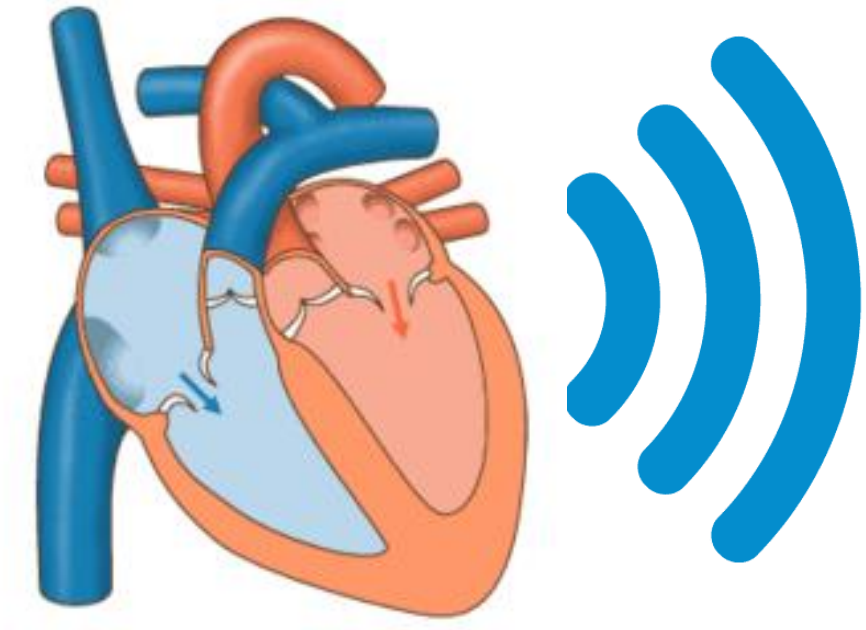
- Echocardiogram
- Electrocardiography (ECG)
- Fotopletismography (PPG)
- Seismocardiography (SCG)

Continuos heart monitoring can lower fatality rates

Seismocardiography (SCG)

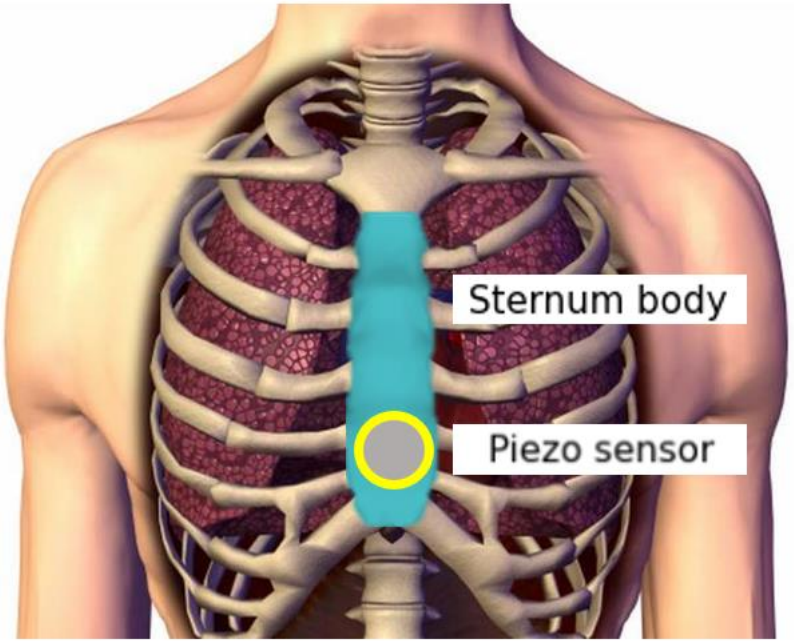
A noninvasive technique to measure vibrations on the chest wall, caused by cardiac mechanical processes

Heart cycle



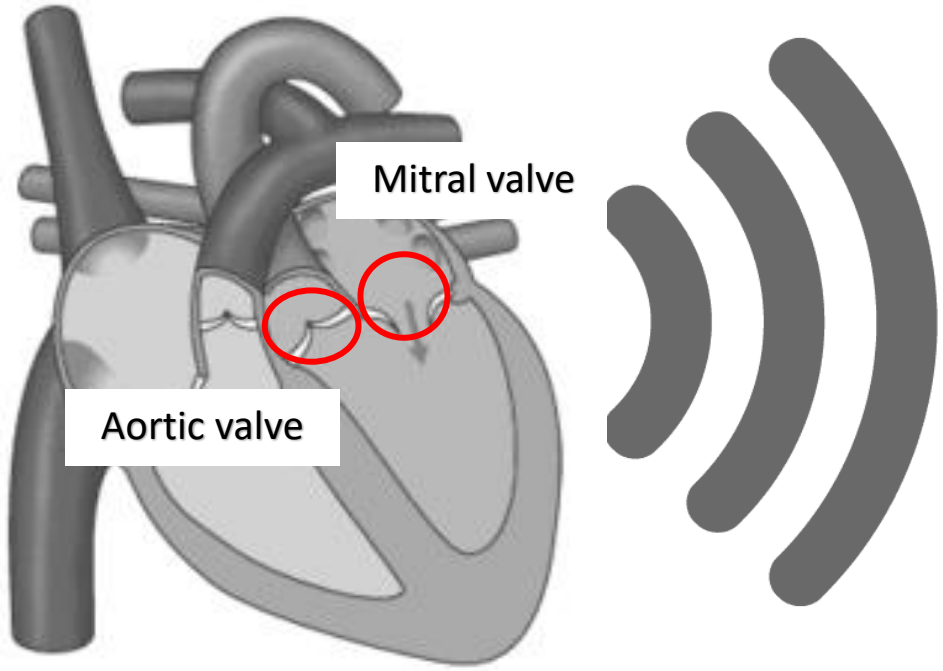
Mechanical vibrations

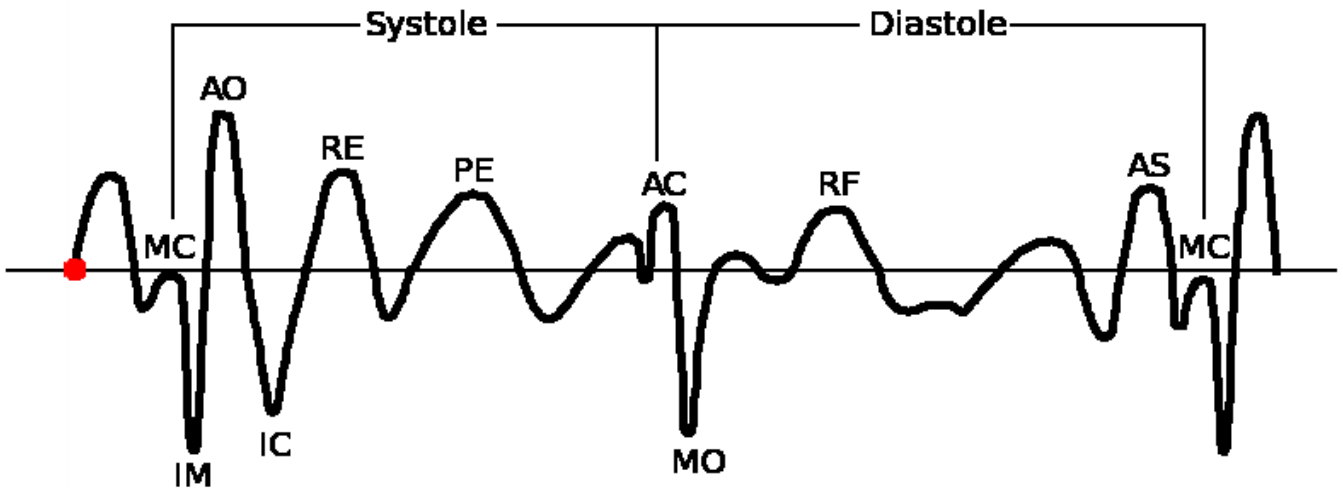
Sensor placement



Seismocardiography (SCG)

Typical labeled SCG signal at rest, two consecutive intervals are observed: systole and diastole. Peaks corresponds to heart valves closure and opening, blood momentum changes and myocardial movements.





SCG event	Cardiac Mechanical Process	SCG event	Cardiac Mechanical Process
AS	Atrial systole	RE	Rapid ventricular ejection
MC	Mitral valve closure	PE	Peak ventricular ejection
IM	Isovolumetric movement	AC	Aortic valve closure
AO	Aortic valve opening	MO	Mitral valve opening
IC	Isotonic contraction	RF	Rapid ventricular filling

Variability in SCG

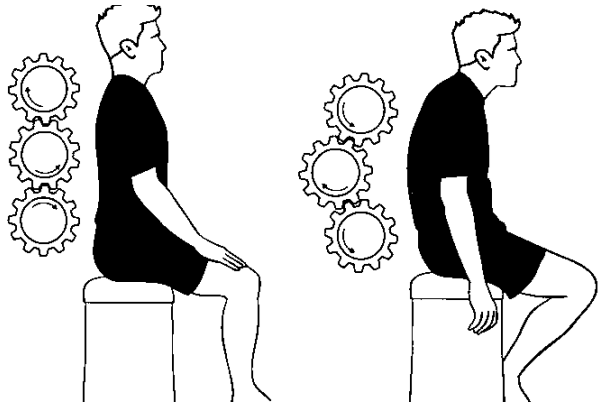
The SCG morphology is complex due to the large inter-subject and intra-subject variability.

Inter-subject

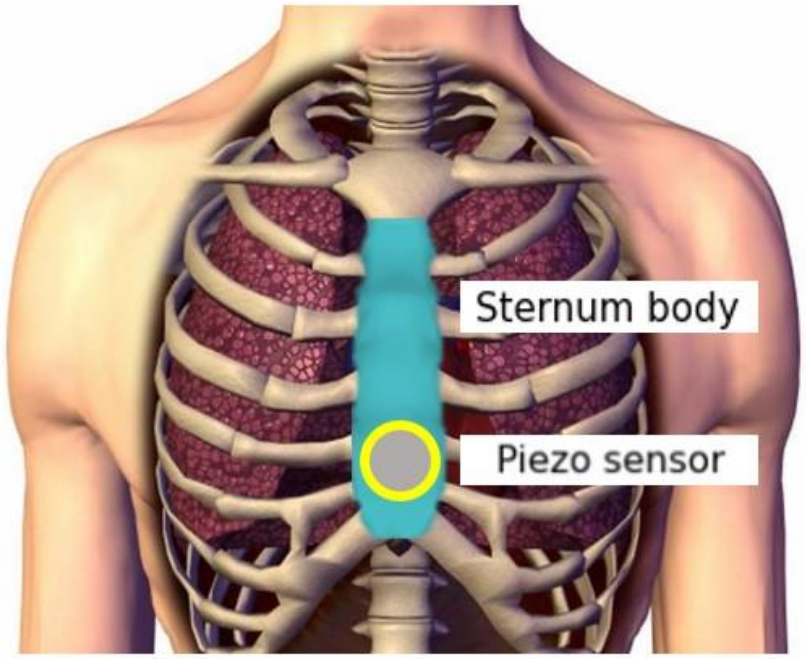
(age, weight, gender)

Intra-subject

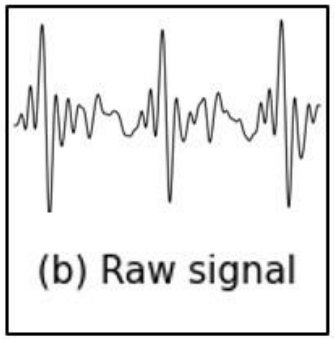
(posture, heart rate, sensor type or position)



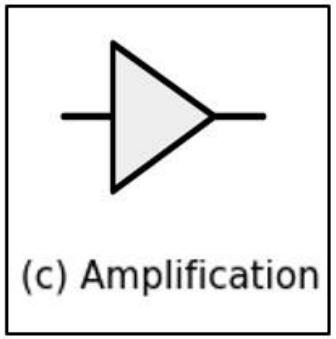
Methodology of
Smart Seismocardiography



(a) Sensor placement

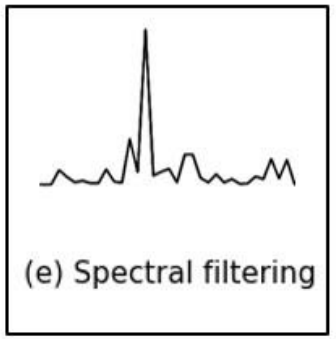


(b) Raw signal



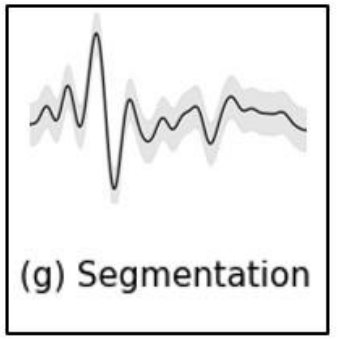
(c) Amplification

(d) Data Acquisition

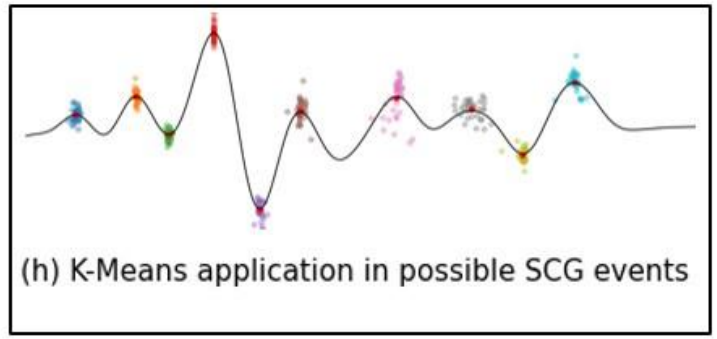


(e) Spectral filtering

(f) AO peak finder



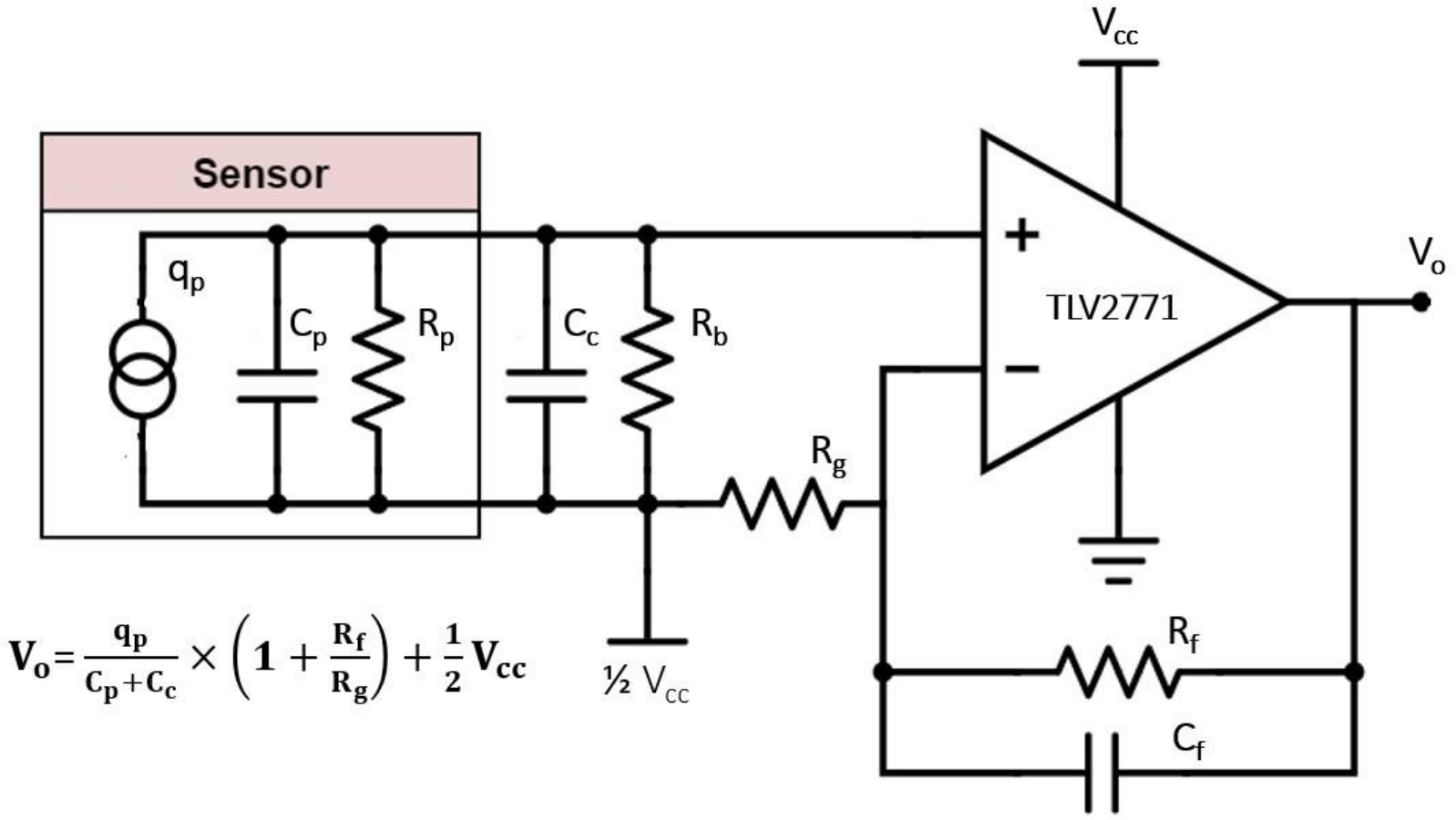
(g) Segmentation



(h) K-Means application in possible SCG events

Sensor and signal conditioning

CEB-27D44 device: Ultra-low-cost brass piezoelectric diaphragm sensor with 27 mm diameter

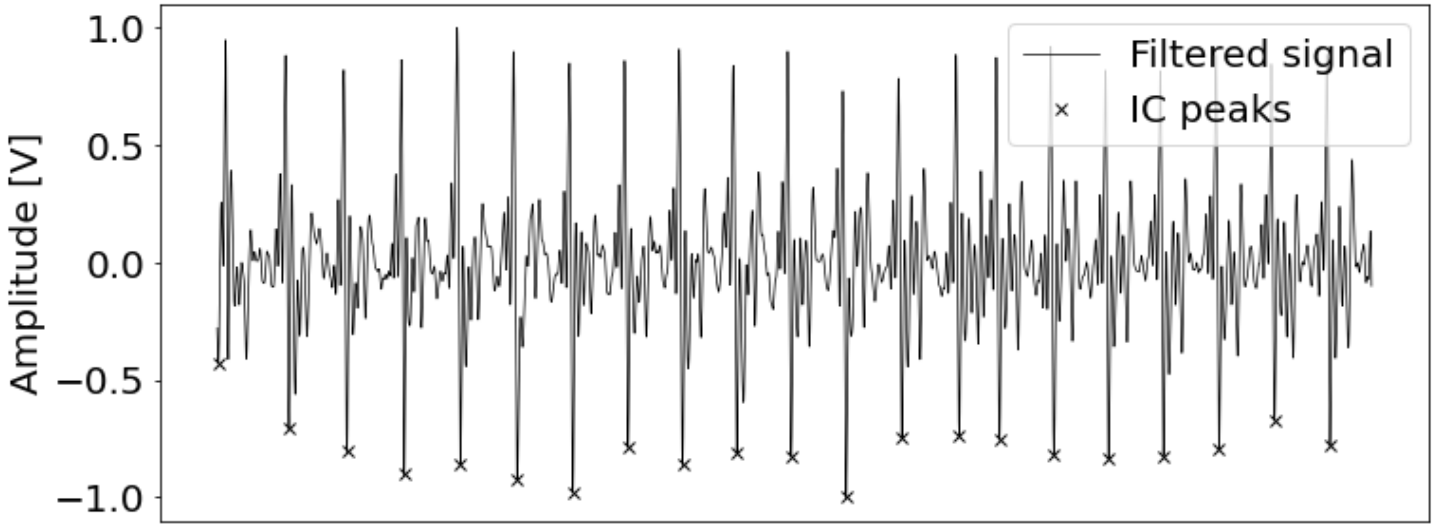


$$V_o = \frac{q_p}{C_p + C_c} \times \left(1 + \frac{R_f}{R_g}\right) + \frac{1}{2} V_{cc}$$

Voltage mode amplifier circuit.

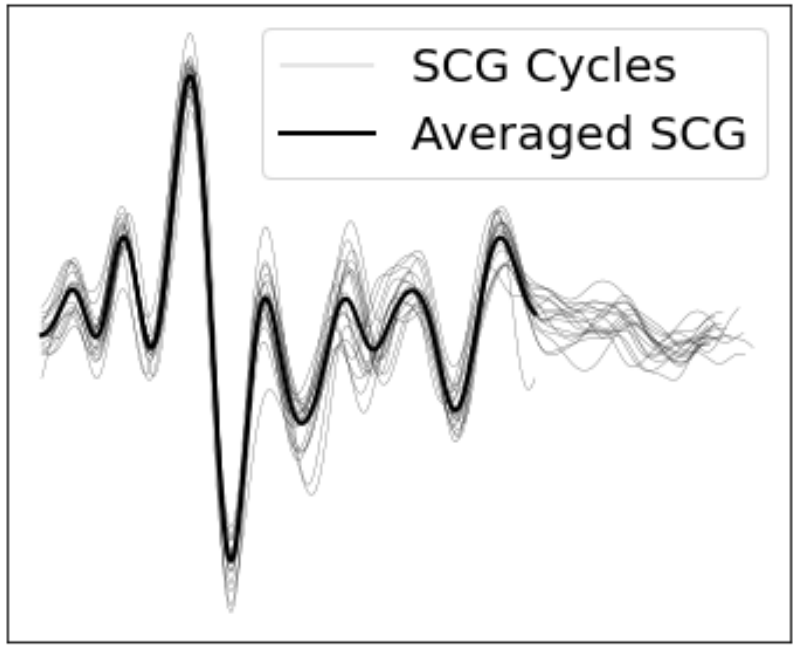
Pre-processing

Segmentation using a peak detection algorithm (PDA)



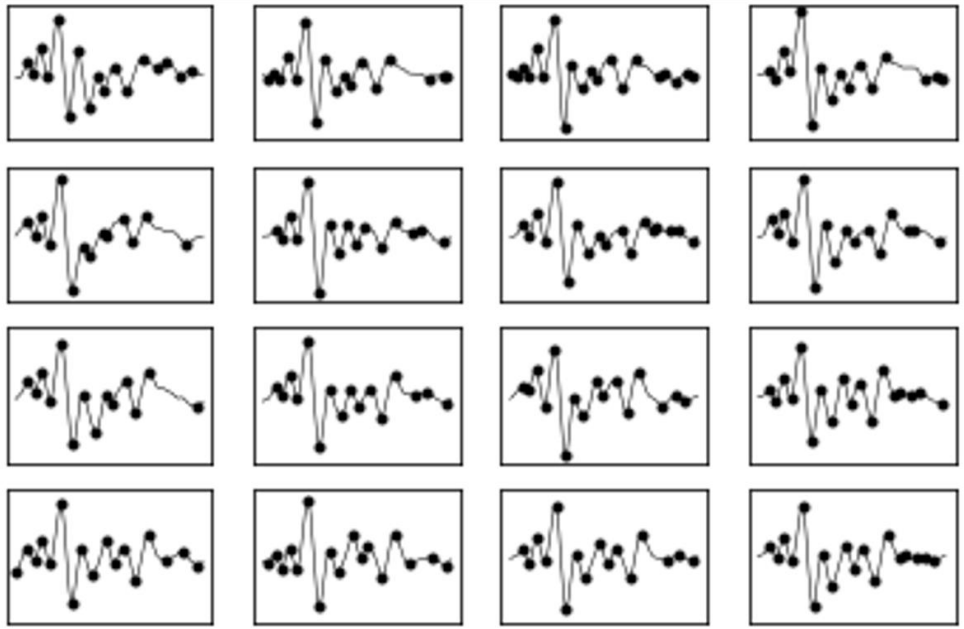
Filtered signal

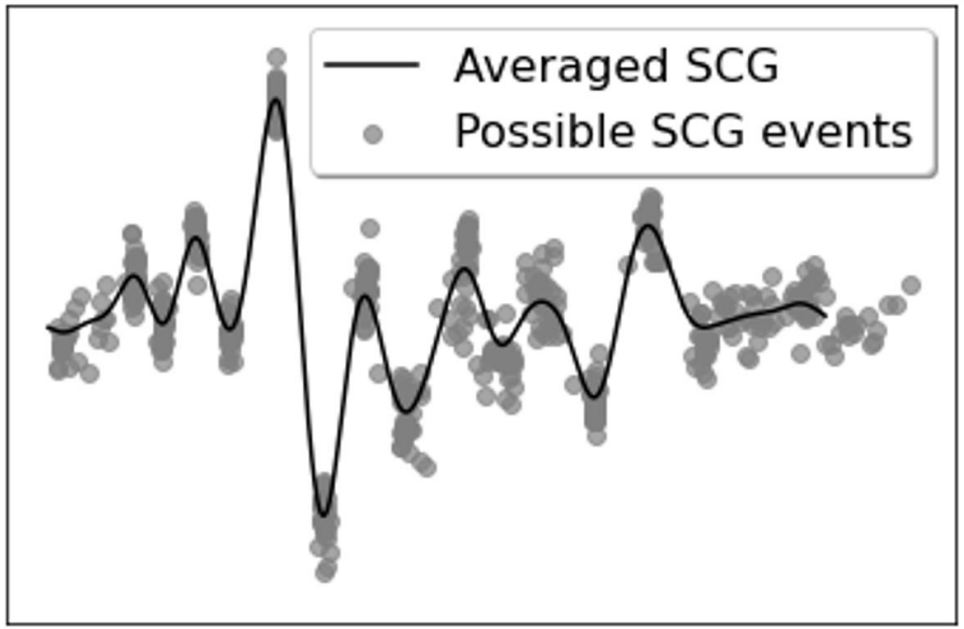
Segmented cycles



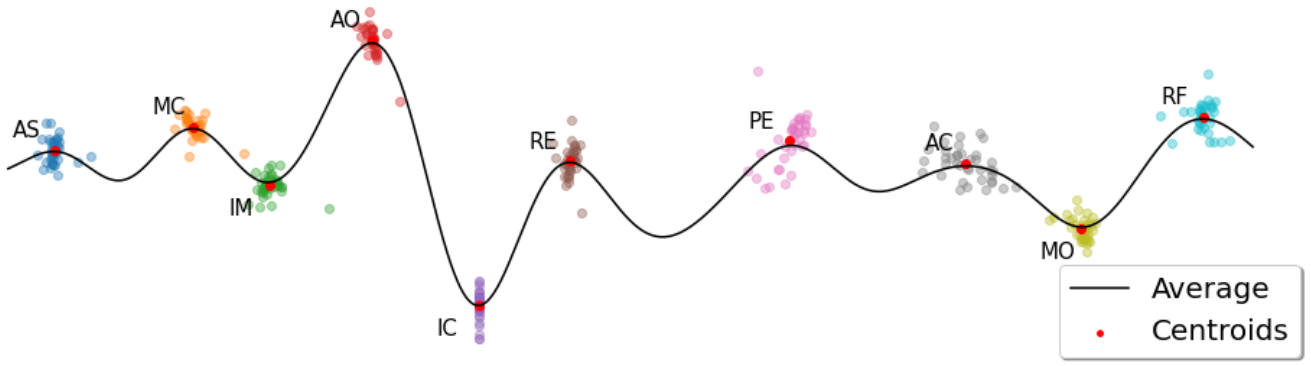
Pre-processing

Finding possible SCG events for each cycle

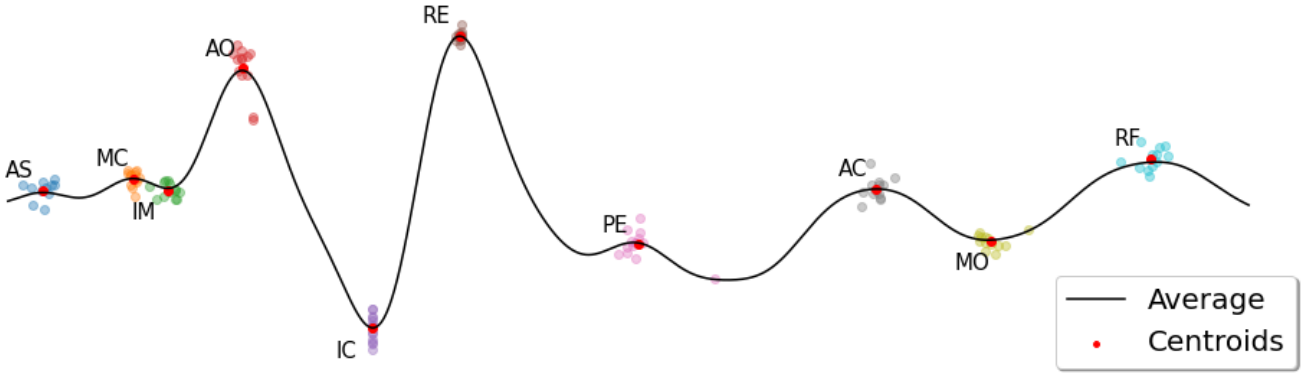




Results of the K-Means algorithm for SCG clustering from two test subjects



S1: Male, 24 years old, 70 Kg



S2: Female, 25 years old, 60 Kg

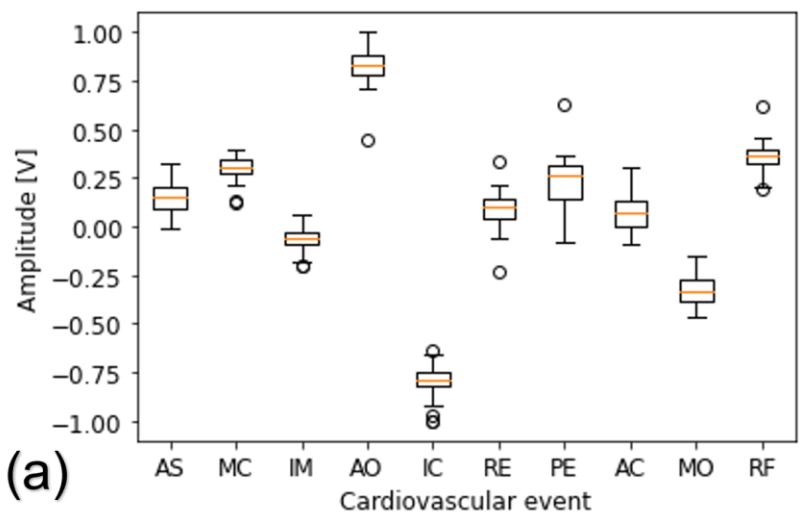
Statistical analysis

Variation of the amplitude in each cardiovascular event

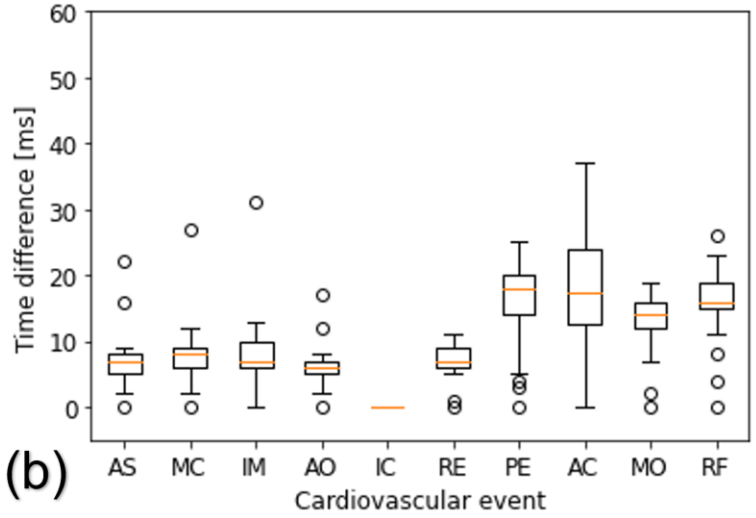
Time difference between each grouped cardiovascular event

Temporal variation in time intervals

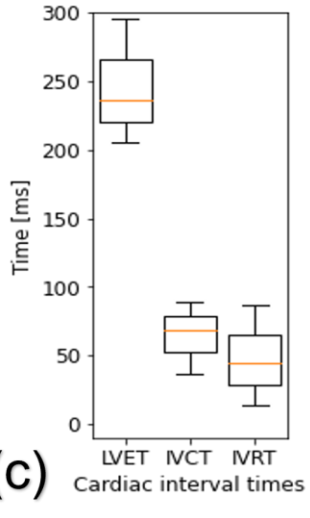
S1



(a)

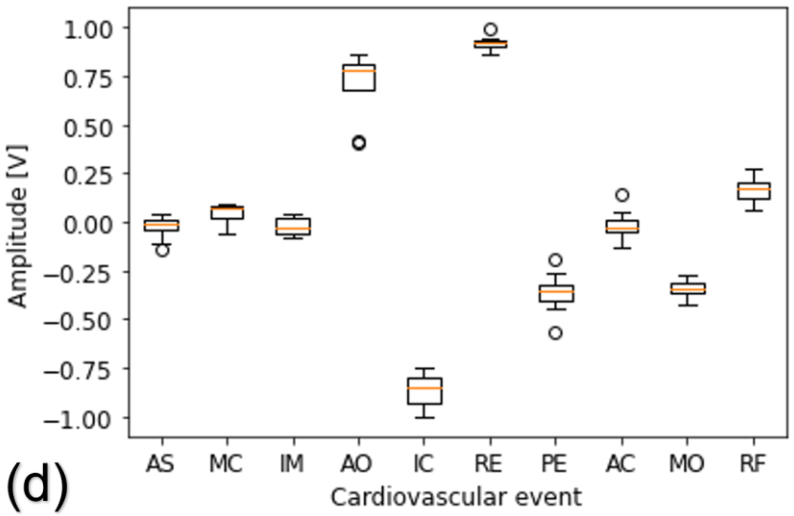


(b)

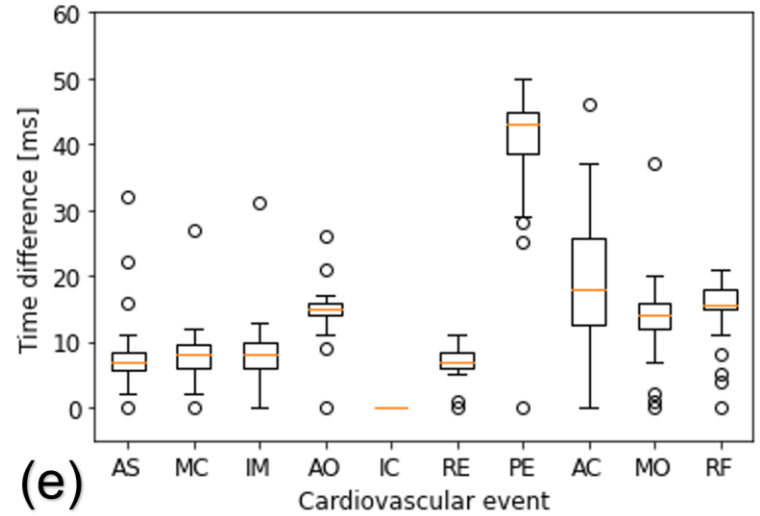


(c)

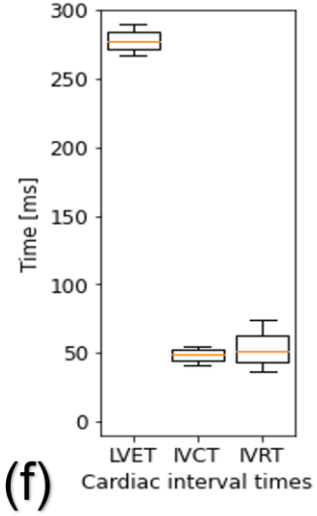
S2



(d)



(e)



(f)

Statistical analysis

S1

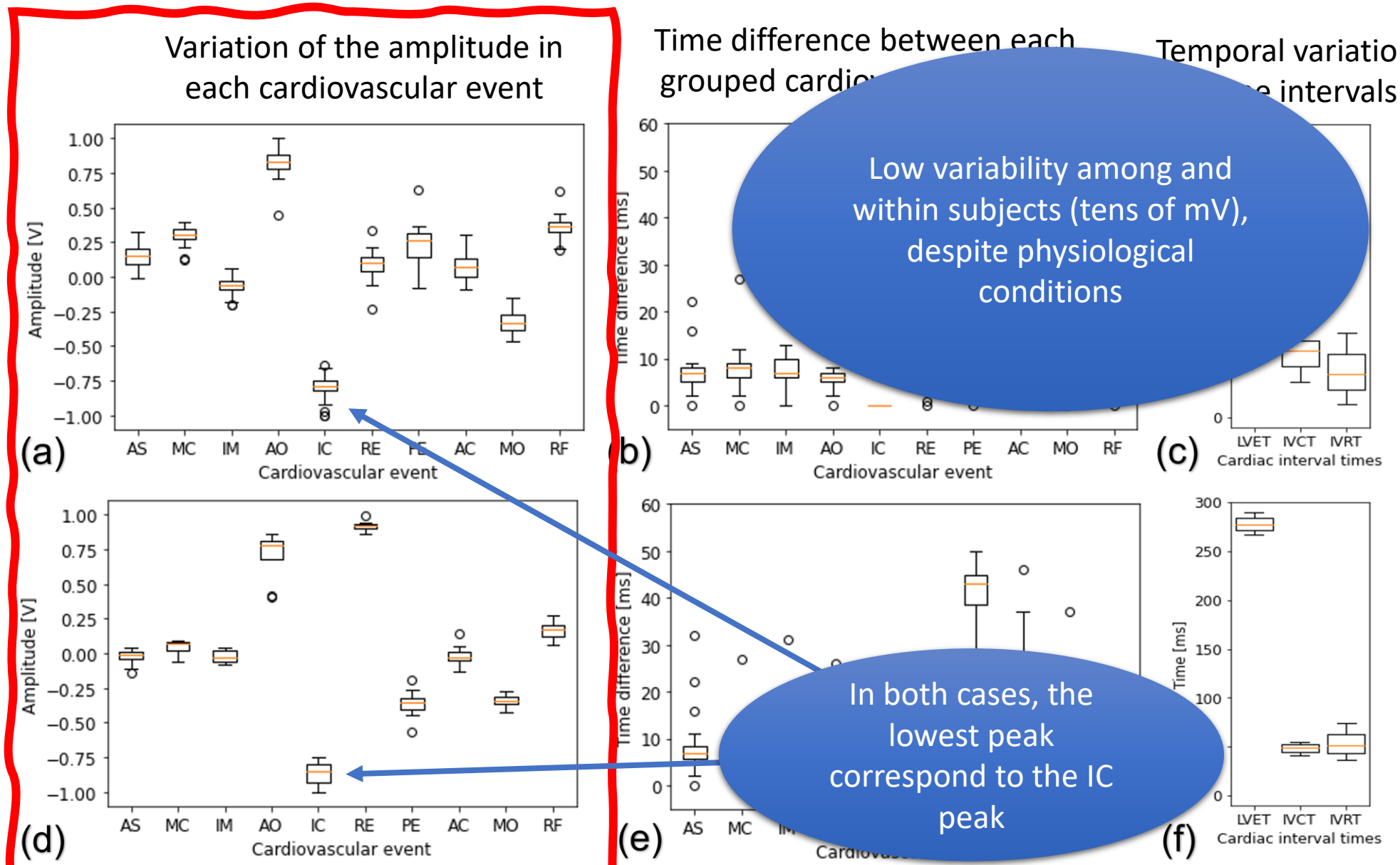
S2

Variation of the amplitude in each cardiovascular event

Time difference between each grouped cardio

Temporal variation

intervals



Low variability among and within subjects (tens of mV), despite physiological conditions

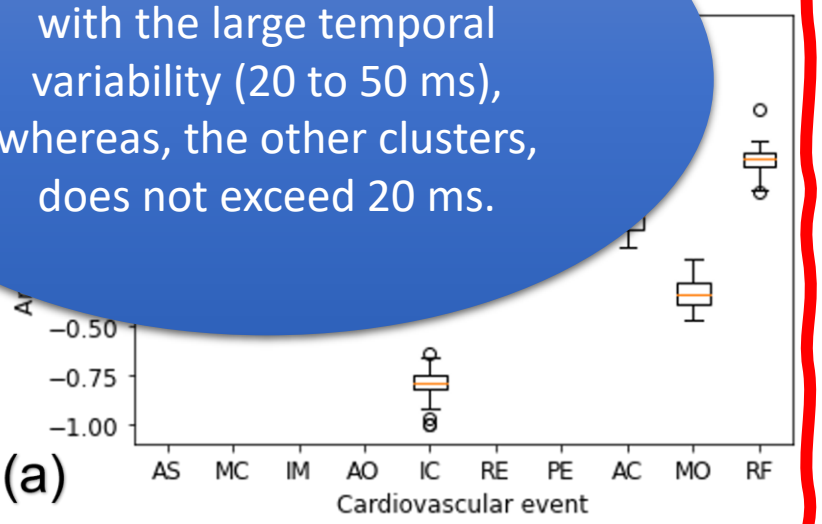
In both cases, the lowest peak correspond to the IC peak

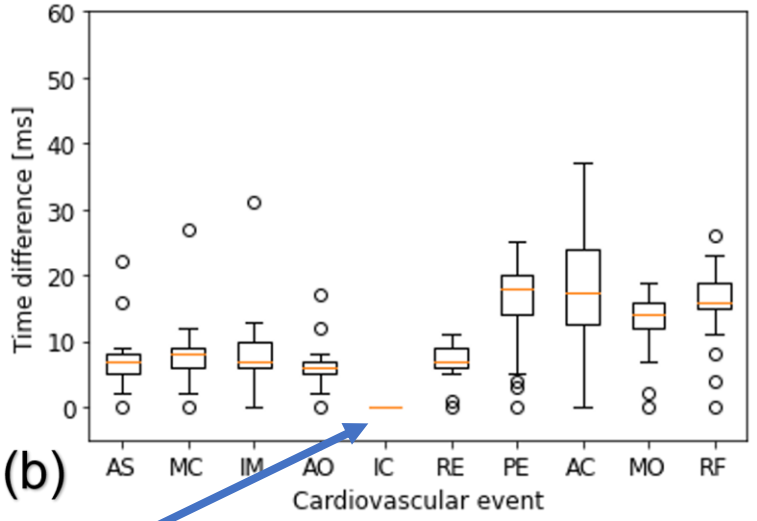
Statistical analysis

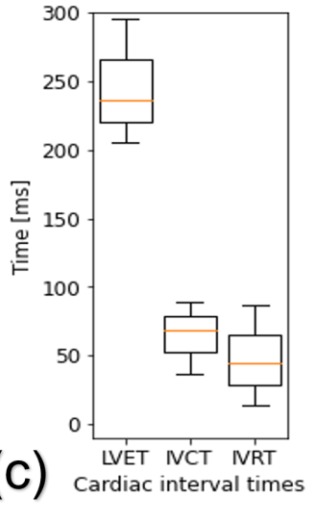
PE and AC clusters are those with the large temporal variability (20 to 50 ms), whereas, the other clusters, does not exceed 20 ms.

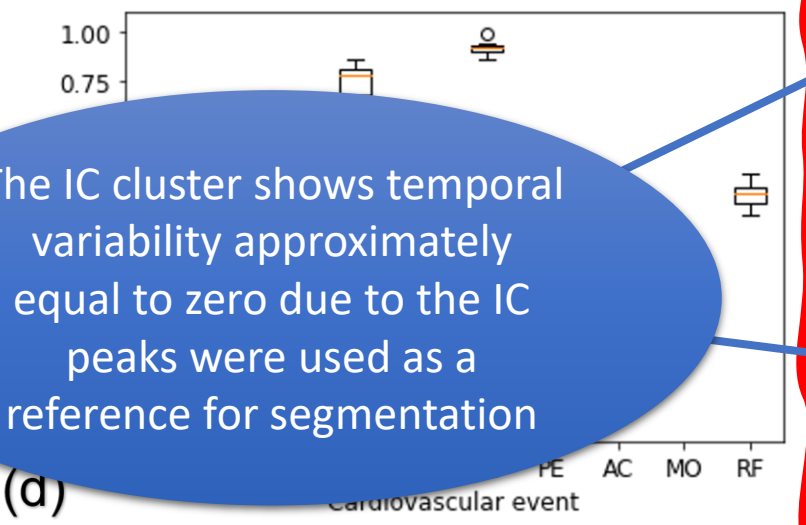
The IC cluster shows temporal variability approximately equal to zero due to the IC peaks were used as a reference for segmentation

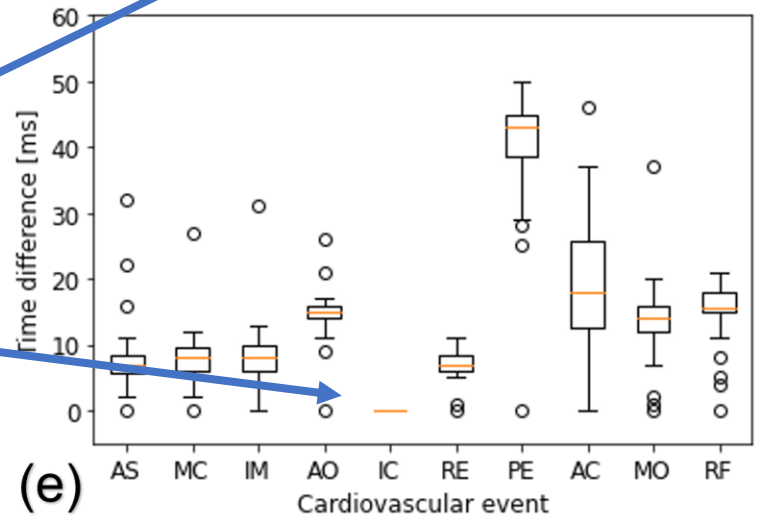
Time difference between each grouped cardiovascular event

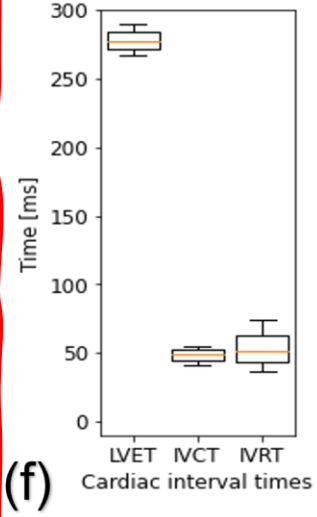










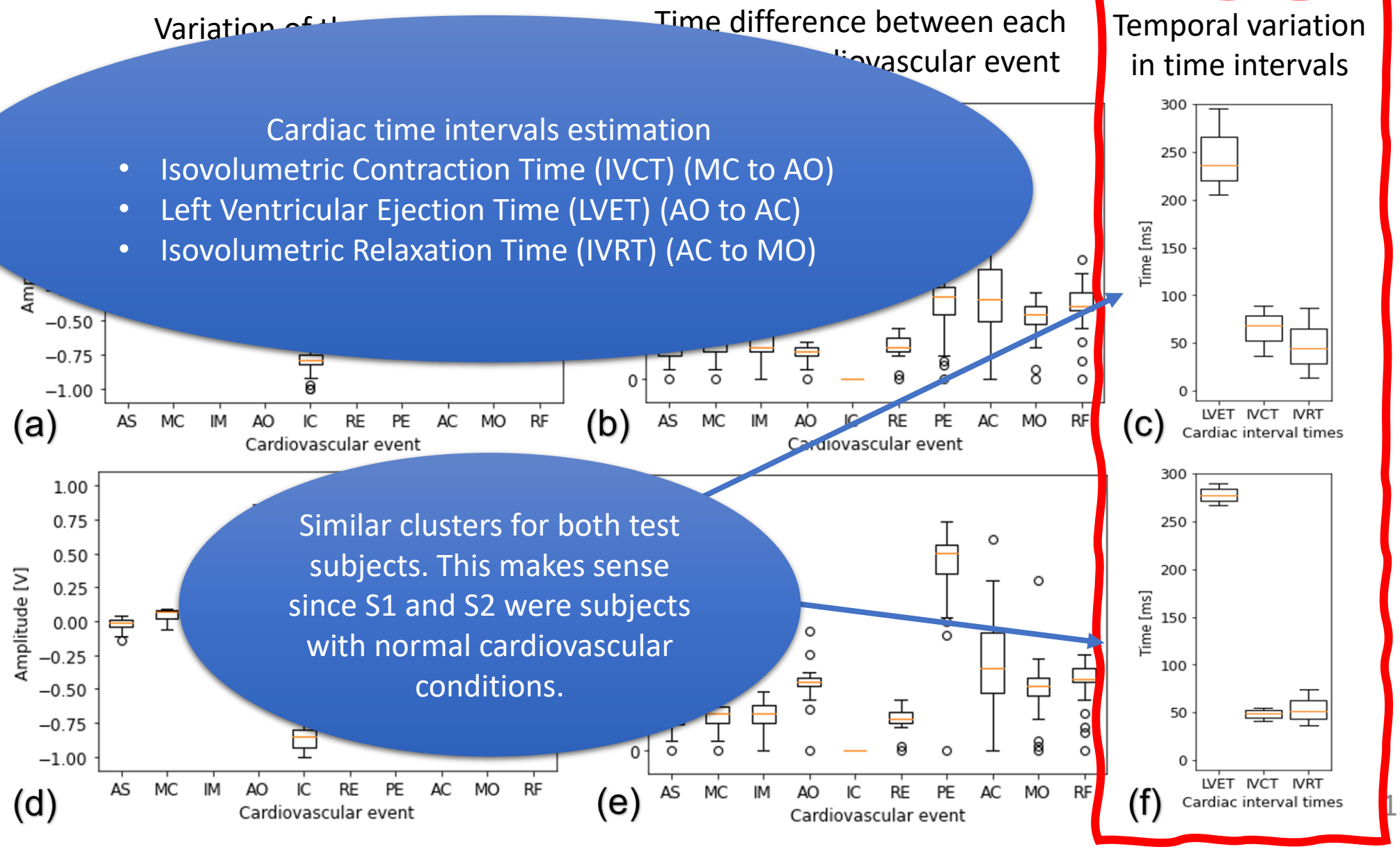


Statistical analysis

Cardiac time intervals estimation

- Isovolumetric Contraction Time (IVCT) (MC to AO)
- Left Ventricular Ejection Time (LVET) (AO to AC)
- Isovolumetric Relaxation Time (IVRT) (AC to MO)

Similar clusters for both test subjects. This makes sense since S1 and S2 were subjects with normal cardiovascular conditions.



Conclusions

The so-called smart seismocardiography (SCG) is an attractive method for clustering cardiovascular events.

- The brass piezoelectric diaphragm is capable of capturing the mechanical vibrations of the heart.
- The K-Means algorithm can automatically cluster SCG events.
- WD coupled with ML leads into a powerful tool to retrieve information on cardiac mechanical processes.
- The smart seismocardiography exhibits enough sensitivity and accuracy to automatically assess physiological signals

Acknowledgments

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Thanks for your attention!

Omar Y. López-Rico
ig.omar.lopez@comunidad.unam.mx

Roberto G. Ramírez-Chavarría
RRamirezC@iingen.unam.mx