IM-TWIN: from Intrinsic Motivations to Transitional Wearable INtelligent companions for autism spectrum disorder

a European funded project

B2B Meeting 2

Deliverable 6.13

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Acronyms of partners

CNR-ISTC	Consiglio Nazionale delle Ricerche, Istituto di Scienze e Tecnologie della Cognizione (Italy)
UU	Universiteit Utrecht (The Netherlands)
CRI	Centre de Recherches Interdisciplinaires (France)
LA SAPIENZA	Università degli Studi di Roma La Sapienza (Italy)
PLUX	Plux - Wireless Biosignals S.A. (Portugal)

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1. Overview of the deliverable

This deliverable describes the organization of the second Business-2-Business (B2B) meeting of the IM-TWIN project. The event is planned to take place on November 23, 2023 in Utrecht Science Park, Utrecht, the Netherlands. Business partners, knowledge institutes, and research partners are invited to join the event.

The deliverable presents the work that has been done on the organizational side of the workshop until October 31st, the project's end date. Only pictures of the event and the final section have been added after the project's end date.

2. The Event

The Business-2-Business (B2B) event titled "The 1st international workshop on Affective Biosignal Processing" has the following structure:

- 14:00: opening by Prof. Egon L. van den Broek
- 14:10: keynote by Prof. Albert Ali Salah, head of the Social and Affective Computing group, Utrecht University
- 15:00: main talk by Lukas P.A. Arts on the IM-TWIN project
- 16:00: a networking session with drinks, bites, and scientific posters

The event is going to be hosted in the Mezzanine of the Minnaertgebouw. This location is situated to the east of Utrecht in Utrecht Science Park making it easily accessible for people outside Utrecht. For people unable to come to Utrecht, we also broadcast a livestream of the talks and a digital poster session of the scientific posters. To engage the online audience as well, questions can be asked via specifically created Slido sessions.

To streamline the day of the event, a detailed script was made focusing on person-specific tasks. The script has been appended to this document in the appendix section.

In the following sections we discuss each part of the event in more detail.

2.1 Invitees

For the event we sent invites to several partners from industry and science. The following list provides an overview of the partners selected for this event:

PHILIPS Research
Leading research institute on biomedical applications for healthcare. It is dedicated to innovating and developing new technologies, products, and solutions in healthcare, lifestyle, and lighting. Philips Research plays a pivotal role in driving technological advancements and collaborations, with a strong emphasis on improving people's health and well-being through meaningful innovation. For this event we invite researchers from two branches of PHILIPS research.

Noldus IT
Noldus IT is a company that specializes in developing and providing tools and systems for the measurement and analysis of human and animal behavior. They are known for their advanced software, hardware, and integrated solutions, which are widely used in scientific research, especially in psychology, neuroscience, and ethology.

Bartimeus
Bartiméus is a Dutch organization specializing in support and services for individuals with visual impairments. It offers a comprehensive range of services, including rehabilitation, education, residential care, and support for both children and adults who are blind or partially sighted.

9de.Online
A small start-up company specialized in innovative web-based technology and the customized development of hard- and software solutions. Together with 9de.Online, we translated fCWT to the web and made it work cross-platform. We invited them because of their innovative character and their close connections to the industry.

HU University of Applied Sciences
The HU University of Applied Sciences is an educational institution known for its wide range of applied sciences programs. It offers bachelor's and master's degree programs across various disciplines, including business, education, healthcare, engineering, and information technology. More specifically, for this event we invited the Research Group Technology for Healthcare Innovations.

HAN University of Applied Sciences
The HAN University of Applied Sciences, located in Nijmegen and Arnhem offers a wide range of bachelor's and master's degree programs in areas such as engineering, health, education, business, and social studies. For this event, we invited researchers and students from the hardware embedded systems bachelor.

University Medical Center Utrecht
The University Medical Center Utrecht (UMC Utrecht) is a leading healthcare and research institution in the Netherlands. It is one of the largest public healthcare facilities in the country and is affiliated with Utrecht University. UMC Utrecht is renowned for its high-quality patient care, cutting-edge research, and excellent education in the field of health sciences.

University Medical Center Amsterdam
The University Medical Center Amsterdam, commonly known as Amsterdam UMC, is another leading healthcare and research institution in the Netherlands, formed by the merger of two prestigious university hospitals: the Academic Medical Center (AMC) and the VU University Medical Center (VUmc). For this event, we invited cardiologists from the child healthcare department.

Radboud University Nijmegen
Radboud University Nijmegen is a prestigious public university known for its high-quality education and research. Radboud University is particularly distinguished for its research in the field of brain and cognitive sciences. This emphasis is primarily anchored in the Radboud University Medical Center (Radboudumc) and the Donders Institute for Brain, Cognition and Behaviour, which is a part of Radboud University.

Centrum Wiskunde & Informatica (CWI)
Centrum Wiskunde & Informatica (CWI) is the national research institute for mathematics and computer science in the Netherlands. Located in Amsterdam, CWI is renowned for its high-quality research in these fields and plays a significant role in both national and international scientific communities. The institute is dedicated to theoretical development as well as practical applications, contributing to advancements in these disciplines.

2.1 Keynote

After a small opening word, the event will start with a keynote talk by professor Albert Ali Salah, head of the Affective Computing group of Utrecht University. The keynote is designed to introduce the field of affective signal processing and describe its challenges and opportunities. Its primary task is to get the audience acquainted with signal processing and the scope of the IM-TWIN. The main talk would then be a perfect continuation of the keynote. Albert's keynote gives an overview of the entire field and the main talk by Lukas Arts zooms in on a specific example of affective biosignal processing: the IM-TWIN project.

2.2 Main Talk

The main talk features an indepth look on the signal processing and machine learning parts of the IM-TWIN project (D2.2 and D3.2). The 45-minute presentation focuses on IM-TWIN's challenges, goals, and its technological methodology. In addition, it features the fast Continuous

Wavelet Transform algorithm, both its native and cross-platform version (WebfCWT) and how it is used in the IM-TWIN project. After 45 minutes, the presentation is followed by a 15 minute Q&A in which both questions from the audience as well as questions from the online livestream are being answered. Online questions are gathered using https://www.slido.com, an easy, low-effort, web-app designed for online conference Q&A.

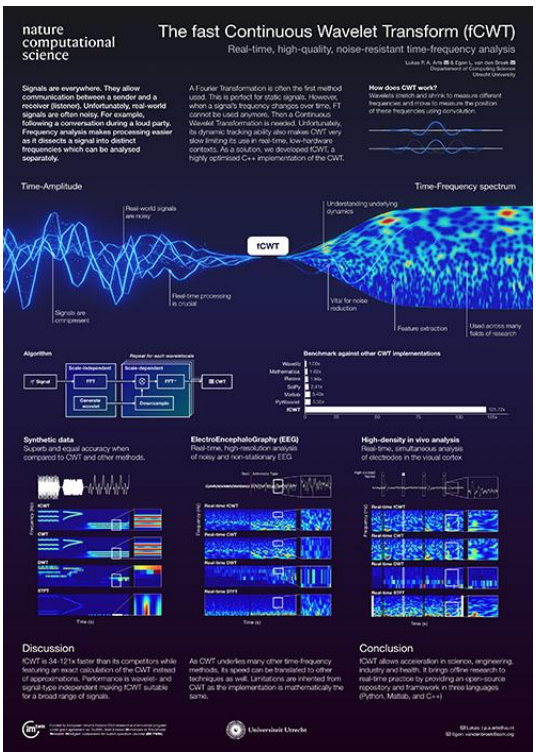
The presentation is designed to be highly visual and features several demo's and interactions to maximize the audience's engagement. The presentation touched upon many topics. Many were only mentioned to invite people for further discussions in the following networking session. The slides are appended to the appendix section.

2.3 Networking session

After the main talks, the audience will be invited for an informal networking session with drinks, bites and scientific posters. A selection of the scientific posters presents UU's research work for the IM-TWIN project. Specifically, the following posters are going to be presented as part of the IM-TWIN project:

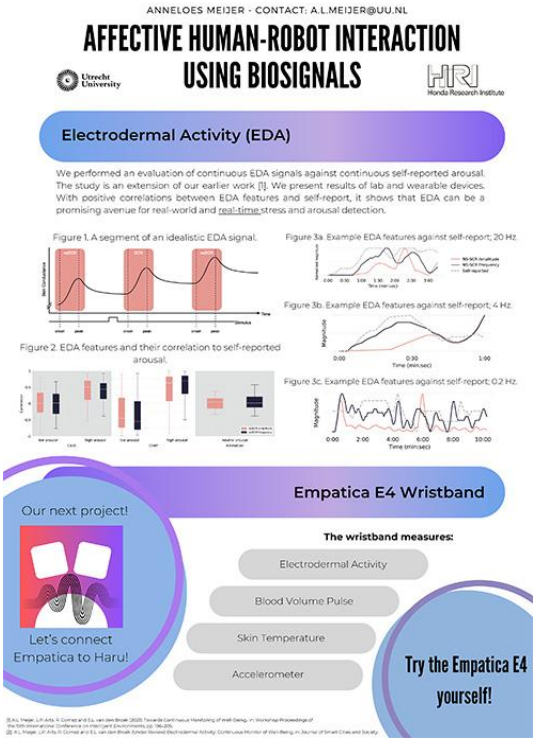
The fast Continuous Wavelet Transformation (fCWT)
L.P.A. Arts and E.L. van den Broek

Text: Signals are everywhere. They allow communication between a sender and a receiver (listener). Unfortunately, real-world signals are often noisy. For example, following a conversation during a loud party. Frequency analysis makes processing easier as it dissects a signal into distinct frequencies which can be analysed separately.
A Fourier Transformation is often the first method used. This is perfect for static signals. However, when a signal's frequency changes over time, FT cannot be used anymore. Then a Continuous Wavelet Transformation is needed. Unfortunately, its dynamic tracking ability also makes CWT very slow, limiting its use in real-time, low-hardware contexts. As a solution, we developed fCWT, a highly optimised C++ implementation of the CWT.



Affective Human-Robot Interaction using biosignals

Based on the paper: ‘Towards Continuous Monitoring of Well-Being’ by A. Meijer, L.P.A. Arts, R. Gomez, and E.L. van den Broek



Text: In human interaction, we naturally pick up on each other's feelings and adjust our responses accordingly. Our objective is to bring this intuitive skill to human-robot interaction. We believe that incorporating biosignal information, and in specific ElectroDermal Activity (EDA) is the key to achieving this goal.

In our research, we're exploring which biosignals can seamlessly capture long-term affective states in real-time, working towards practical applications. Our findings highlight the effectiveness of Electrodermal Activity (EDA) in indicating continuous arousal states. This insight is valuable for applications in mood, stress, and anxiety assessment.

The poster session is also going to be available online as a digital gallery on https://www.cyberneticslab.info/workshop-posters. The digital gallery has been designed as a landing page showing all posters and authors. Subsequently, visitors can ‘take a closer look’ by clicking the link that leads to the poster’s unique page. This page shows the poster in high-detail and explains its context, corresponding research, and conclusions in a few sentences.

2.4 Livestream

Thumbnail designed to promote the livestream.

To make our workshop accessible to our international consortium partners and international partners in industry, we will also broadcast a professional livestream of both talks and have created a digital environment for people to stroll along the scientific posters. The livestream features a professional hardware setup to provide one of the best online conference experiences.

[Added after November 23] Introduction slide shown to the people waiting for the livestream. The introduction slide was broadcasted from 13:30 until the beginning of the program.

[Added after November 23] Ending slide shown right after the main talk (around 16:00). The online audience was invited to visit the online poster session while the event in Utrecht continued with the network session.

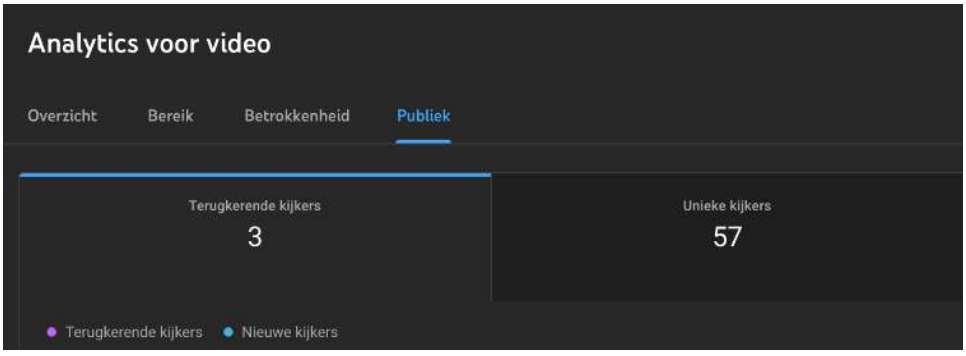
[Added after November 23] Actual snapshot of the livestream during the event showing the customized picture-in-picture view to show both the slides and the speaker simultaneously.

3. Outcomes

This section has been added after November 23 to present the event's statistics and outcomes.

3.1 Statistics

Overall, the majority of the invitees responded positively to our invitations. In total, 30 people from 10 affiliations attended the event in person and 57 unique people visited the online livestream. The latter had a consistent viewer-count of 15 people during the main talk. All in all, the event reached a combined total of 87 people coming from all over Europe having many different backgrounds in science and industry.



In total, 57 unique people attended the event online. In combination with the 30 people attending the event in-person, the event reached a total of 87 people.

A customized picture-in-picture view will be presented to the online audience to allow both the speaker and its slides to be visible. During the event, a dedicated person will be in charge of the livestream at all times to provide an optimal viewing experience. This person will switch cameras and views depending on a pre-made script. This script is appended to the appendix section.

The audience during the opening keynote talk of the event.

Hardware setup in the back of the room to control the online livestream.

Table of attendees

Number of attendees	*Affiliation*
2	PHILIPS Research
2	UMC Utrecht
1	Radboud University Nijmegen
3	HAN University of Applied Sciences
3	HU University of Applied Sciences
1	Centrum Wiskunde & Informatica
3	9de.Online
2	Bartimeus
1	Noldus IT
12	University Utrecht
30	**on site participants**
57	**online participants**
87	**Total number of participants**

3.2 Connections

Besides being an informative event, the workshop was also designed to foster new collaborations and research-industry connections regarding the IM-TWIN project. In this section, we present a couple promising new leads.

Working together to make fCWT accessible for all

Together with the innovative web-development company 9de.Online, we developed a new, web-based implementation of fCWT. The company showed great interest in fCWT and proposed an in-kind collaboration on an innovative web-based solution to run fCWT in the browser using WebAssembly.

The collaboration provided fruitful insights for 9de.Online on the efficiency and capabilities of WebAssembly as well as a published research paper for the UU. The result is www.fcwt.app, a serverless web-application designed for researchers to upload and analyze their own data in a safe and easy manner. Data never leaves the client's system and the user does not have to install specialized software-packages or have experience with code.

Collaboration in the clinical world

Already before the event, UU visited the Erasmus Medical Centre in Rotterdam, and the University Medical Centre in Utrecht to talk about possible applications of fCWT in the brain and cognition, cardiology, and magnetic resonance imaging fields.

The initial discussions were promising and future collaborations are a real possibility. During the networking session of the event, we lay new foundations for several promising collaborations between the UU and other research and clinical partners.

4. Appendices

The following appendices are added to this document:

- Organizational script
- Livestream storyboard script
- Slides main talk
- High-resolution posters

Draaiboek International Workshop on Affective Biosignal Processing

Wanneer	Wat	Lukas	Egon	Video	Hulp 1	Hulp 2	Colleague 1	Colleague 2	Colleague 3	Colleague 4	Keynote
09:30	Aanwezig en koffie drinken	x									
10:00	Opbouw livestream	x		x							
11:00	Technische doorloop (zie technisch draaiboek)	x		x							
11:00-12:00	Klaarzetten: Posterborden				x	x					
11:00-12:00	Klaarzetten: Tafels + Statafels				x	x					
11:00-12:00	Ophangen posters en klaarzetten demo's	x		x			x	x	x	x	
12:00-13:00	LUNCH	x	x	x	x	x	x	x	x	x	
13:00	Ontvangen Albert	x	x								x
13:00-13:15	Klaarzetten: Stoelen				x	x					
13:00-13:15	Klaarzetten: Naambadges				x	x					
13:00-13:15	Klaarzetten: koffie en thee				x	x					
13:00-13:15	Ophangen wegwijsbordjes				x	x					
13:00-13:15	Technische doorloop met Albert	x									x
13.15-13.30	Buffer										
13:30	Begin inloop	x	x	x	x	x	x	x	x	x	x
13:45	Laatste technische doorloop slides	x		x							x
14:00	Opening		x								
14:15	Keynote Albert			x							x
14:45	Q&A Keynote Albert			x							
14:45	Q&A Keynote Albert (Slido)	x									
15:00	Bedanken Albert	x	x								x
15:00	Korte pauze										
15:10	Main presentation Lukas	x		x							
15:55-16:15	Q&A Main presentation Lukas	x		x							
15:55-16:15	Q&A Main presentation Lukas (Slido)			x							
15:55	Opzetten borrel				x	x					
16:15	Begin postersessie	x		x			x	x	x	x	
16:15	Bijhouden Slido vragen	x									
17:00	Ophalen alcoholrijke dranken				x	x					
17:00	Einde livestream	x		x							
17:00	Afbouw livestream	x		x							
18:00	Einde event										
18:00	Afbouw postersessie	x			x	x					
18:30	Naar huis	x			x	x					

Digital Storyboard for the

LIVESTREAM

of the

INTERNATIONAL WORKSHOP ON
AFFECTIVE BIOSIGNAL PROCESSING

INTRODUCTIE

Donderdag 23 november zal er naast het evenement in de Minnaert Mezzanine ook een livestream worden uitgezonden. De livestream zal de inloop, beide presentaties en het dankwoord verslaan. Gedurende de inloop en een gedeelte van de poster sessie zal de livestream ook broadcasten.

Het document voor u bevat een gedetailleerd storyboard die de livestream-operator precies verteld wanneer welk beeld moet worden uitgezonden. Het document geeft een overzicht van de verschillende software en hardware elementen die tijdens de livestream geopereerd moeten worden. In dit geval betreft het OBS Studio en ATEM Software Control qua software en de BlackMagic ATEM Mini Pro qua hardware. De ATEM Mini Pro brengt de camera feed en computer feed samen en stuurt deze naar de MacBook pro die de input als een webcam ziet. Met ATEM Software Control wordt de ATEM Mini Pro control board bestuurd. In dit geval hoe de camera, de computer feed en de grafische overlay moeten worden samengevoegd. Alles komt uiteindelijk samen in OBS Studio waar er kan worden geschakeld tussen de output van de ATEM Mini Pro en de van tevoren opgenomen intro en outro.

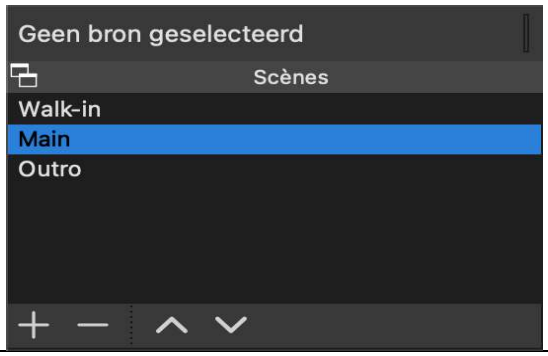
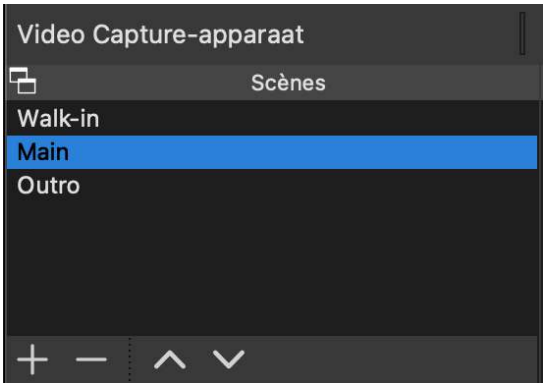
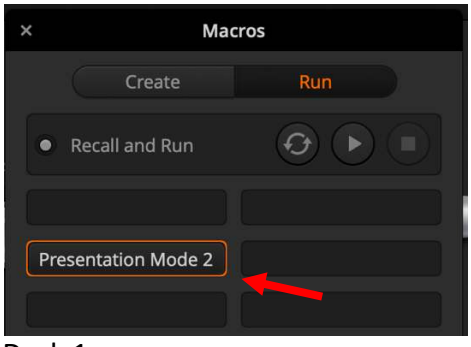
Vanwege de verschillende software- en hardwarematige onderdelen bestaat het storyboard, een tabel, uit drie kolommen: de tijd waarin de handeling moet worden uitgevoerd, welke handeling er in OBS Studio wordt verwacht en welke handeling er in ATEM Software Control moet worden uitgevoerd.

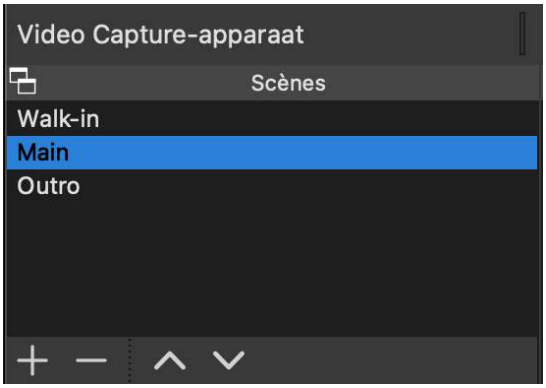
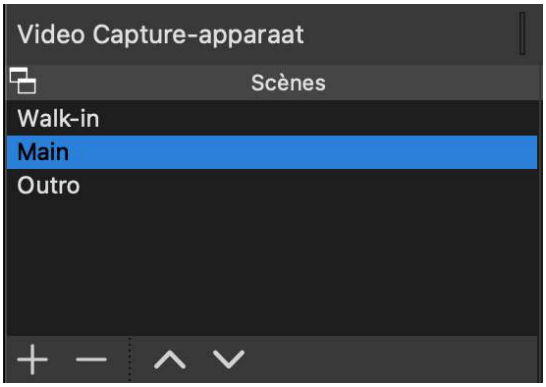
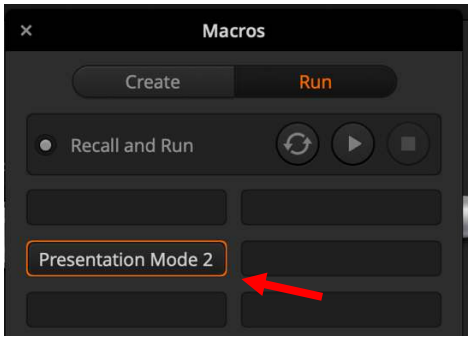
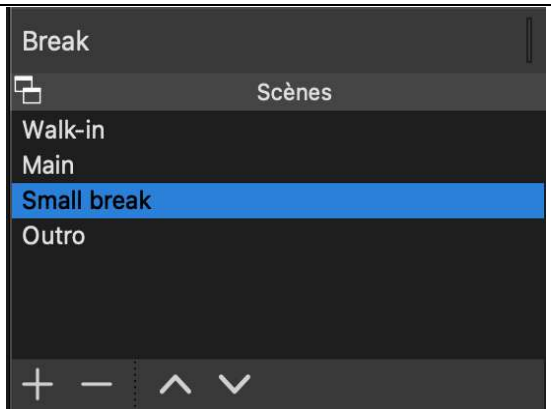
Succes!

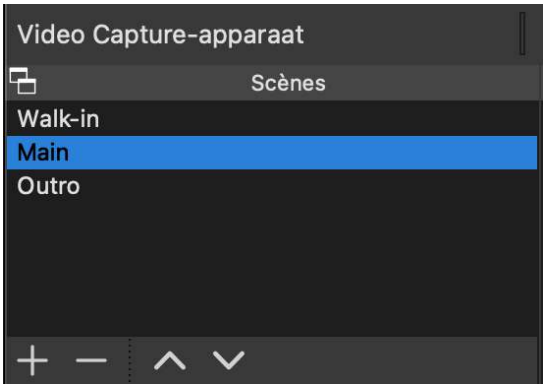
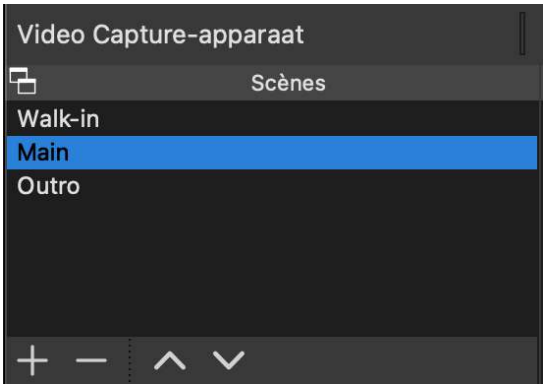
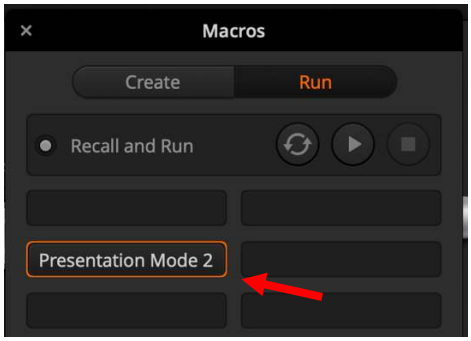
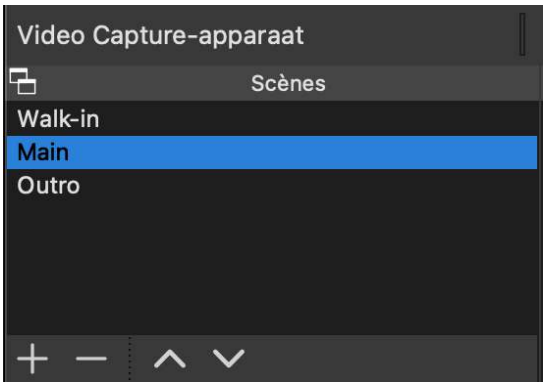
TECHNISCHE DOORLOOP

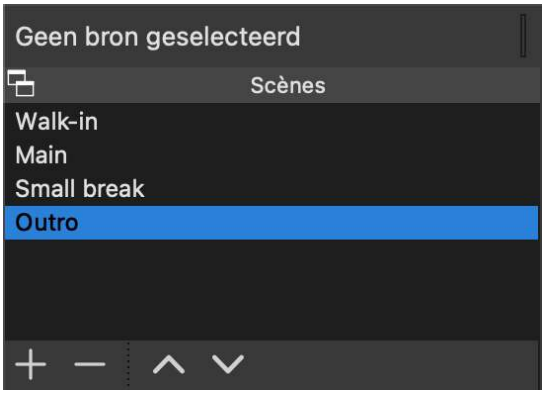
1. Check audio
2. Doe een max audio calibratie
3. Check audio range
4. Check camera view range
5. Check camera focus
6. Check camera LUT
7. Clean camera lens
8. Calibrate ISO
9. Calibrate WB
10. Check batteries
11. Check camera:
    a. FPS 24
    b. Shutter 1/50
    c. IRIS: _____
    d. ISO: _____
12. Check Video Control Monitor
13. Test channel 1 en 2 van de ATEM Mini Pro
14. Doorloop Storyboard
15. Test Youtube Live
16. Check:
    a. MIC 1 OFF
    b. MIC 2 OFF
    c. Alle mics van alle channels OFF
    d. CUT
    e. Picture in Picture OFF
    f. Key OFF
    g. Video out M/V

STORYBOARD

X	Tijd	Wat	OBS Studio	ATEM
	13:30	Inloop	Beeld: In OBS Studio klik op: **Stream Starten**	 Geluid: MIC 1 OFF
	14:00	Opening	Beeld:  	Geluid: MIC 1 ON
	~14:15	Start Keynote	Beeld:  	Beeld:  Druk 1x op: MACRO: **Presentation Mode 2** Geluid: MIC 1 ON

	~14:45	End Keynote + Q&A	Beeld:  YouTube Live Chat: Put Slido URL in the comments: https://app.sli.do/event/izDpxwPKLGvmw1kLNS4Suk	 **Druk 1x op Channel 1** Geluid: MIC 1 ON
		If slides needed during Q&A	Beeld:  	Beeld:  Druk 1x op: MACRO: **Presentation Mode 2** Geluid: MIC 1 ON
	~15:00	Small break	 	Geluid: MIC 1 OFF

	~15:10	Start Lukas	Beeld: 	 **Druk 1x op Channel 1** Geluid: MIC 1 ON
	~15:12	Start Lukas Slides	Beeld: 	Beeld:  Druk 1x op: MACRO: **Presentation Mode 2** Geluid: MIC 1 ON
	~15:50	End Lukas + Q&A	Beeld:  Youtube Live Chat: Put Slido URL in the comments: https://app.sli.do/event/aE358enL212SSkJVrqms9L	 **Druk 1x op Channel 1** Geluid: MIC 1 ON

	~16:15	Start poster session	Beeld:  	 Geluid: MIC 1 OFF
	17:00	End Livestream	In OBS Studio klik op: **Stream Stoppen**	

Co-funded by the Horizon 2020 programme
of the European Union

IM-TWIN:

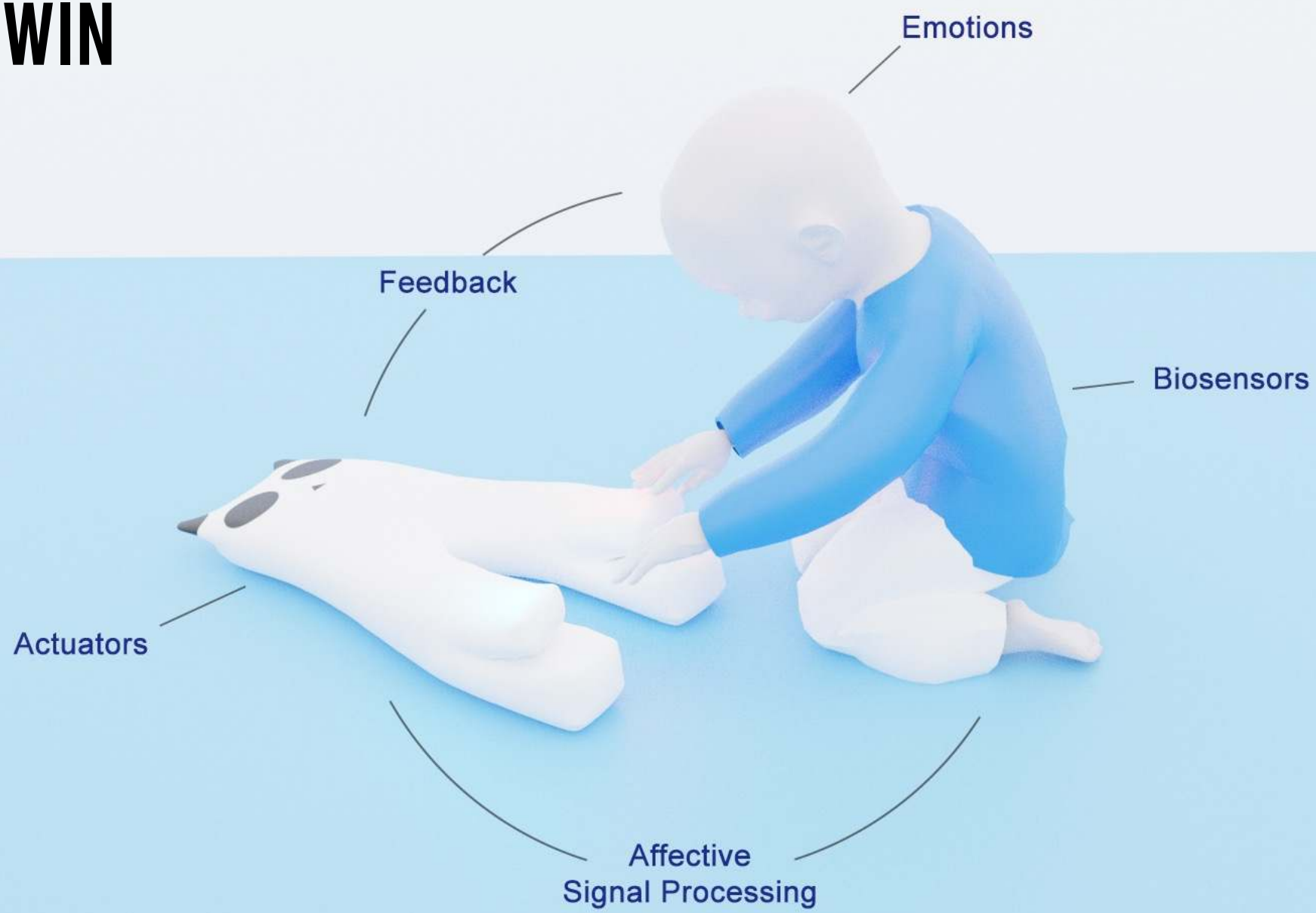
A Real-world Affective Biosignal Processing Application

Lukas P.A. Arts

IM-TWIN:

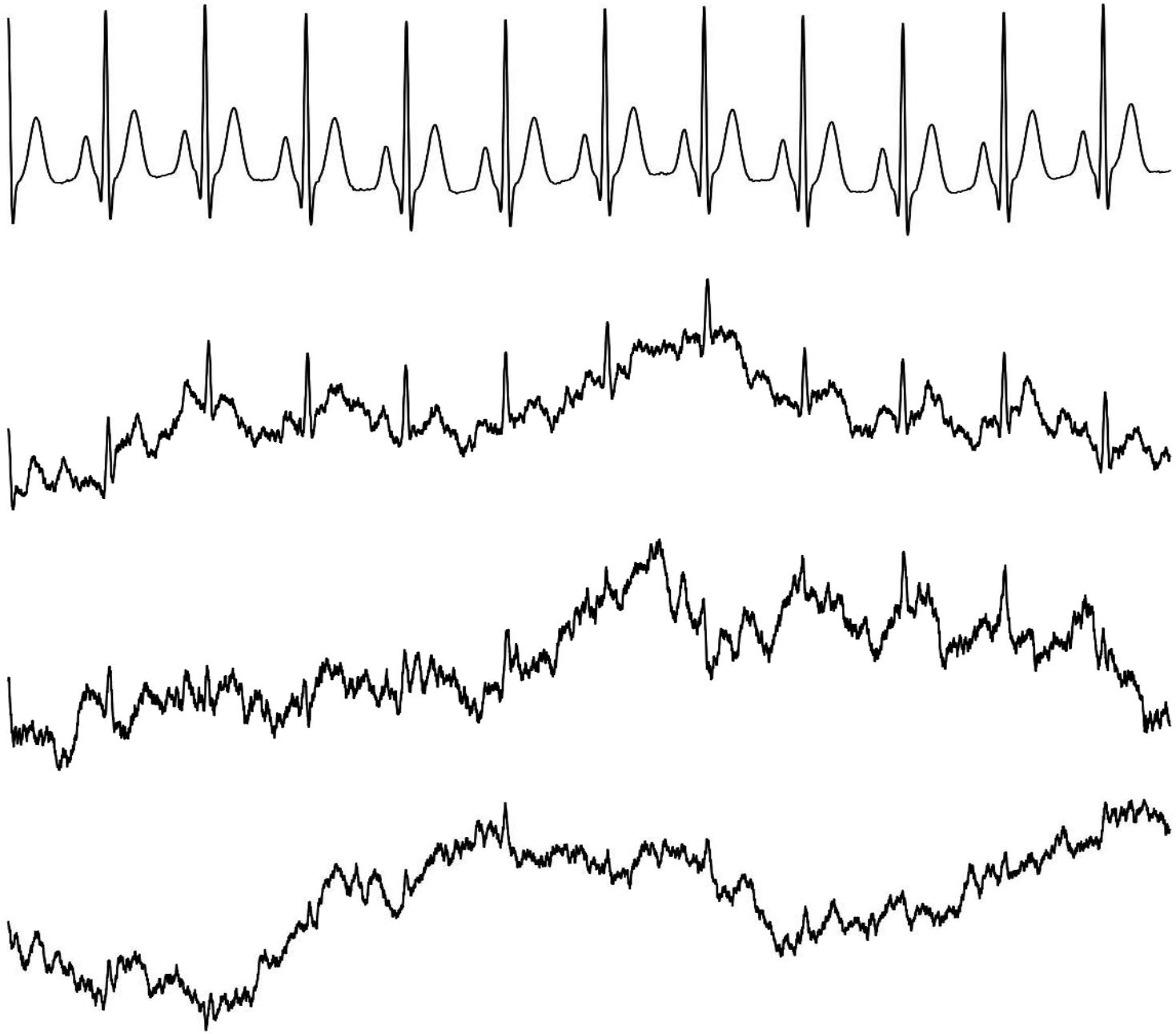
from Intrinsic Motivation to Translational Wearable Intelligent companions for autism spectrum disorder

IM-TWIN

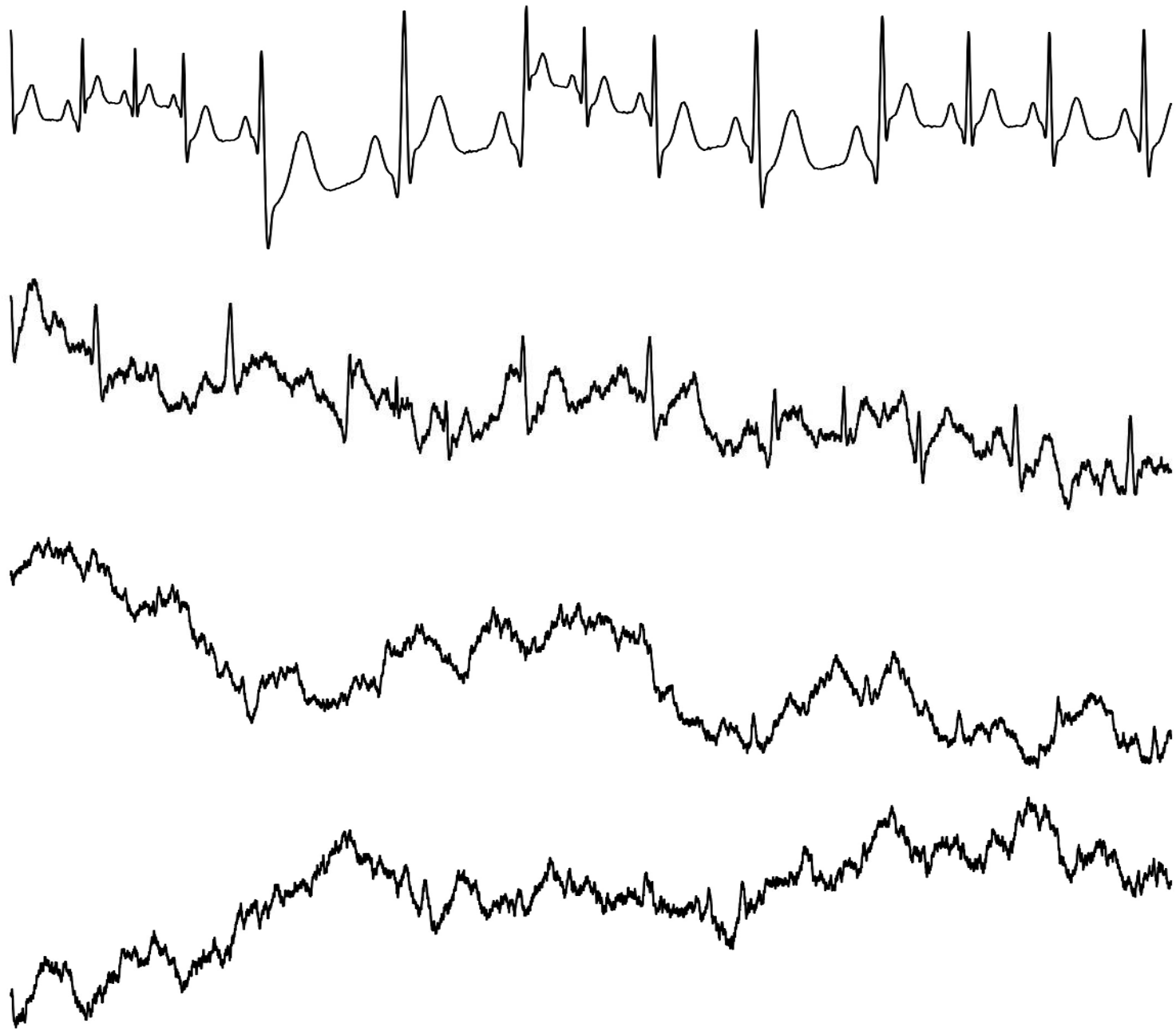

Emotions
Feedback
Biosensors
Actuators
Affective
Signal Processing

IT’S HARD

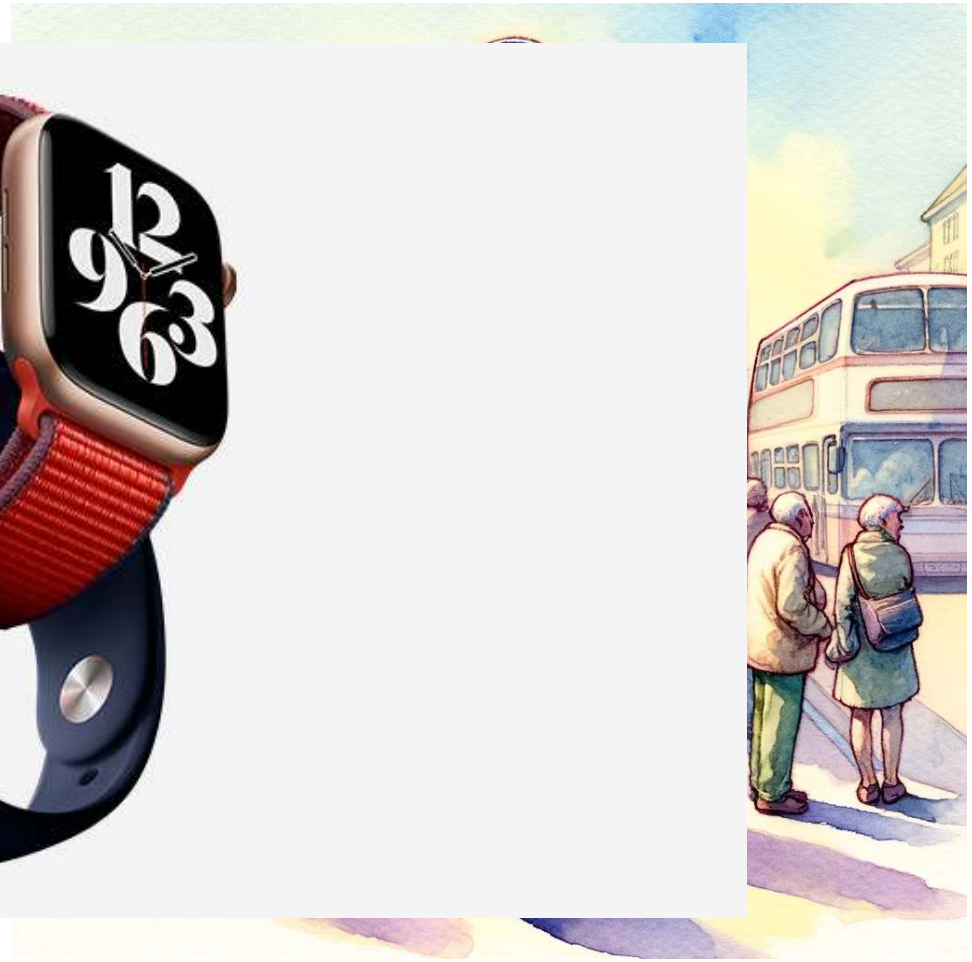
1. BIOSIGNALS ARE WEAK



2. BIOSIGNALS ARE NON-STATIONARY



3. MEASUREMENTS SHOULD BE COMFORTABLE



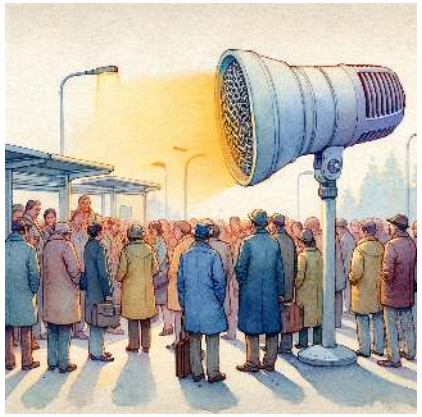
4. PEOPLE ARE DIFFERENT

5. MEASUREMENTS SHOULD BE REAL-TIME

1. BIOSIGNALS ARE
WEAK

2. BIOSIGNALS ARE
NON-STATIONARY

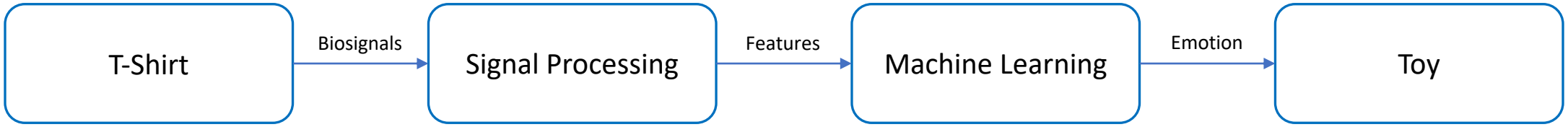
3. SHOULD BE
COMFORTABLE



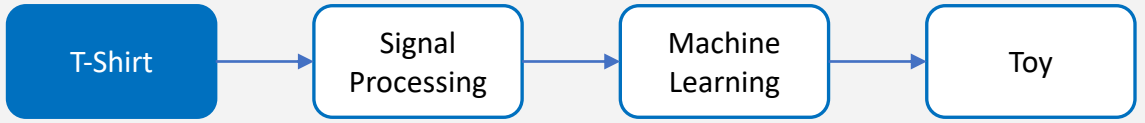
4. PEOPLE ARE
DIFFERENT

5. SHOULD BE
REAL-TIME

The system

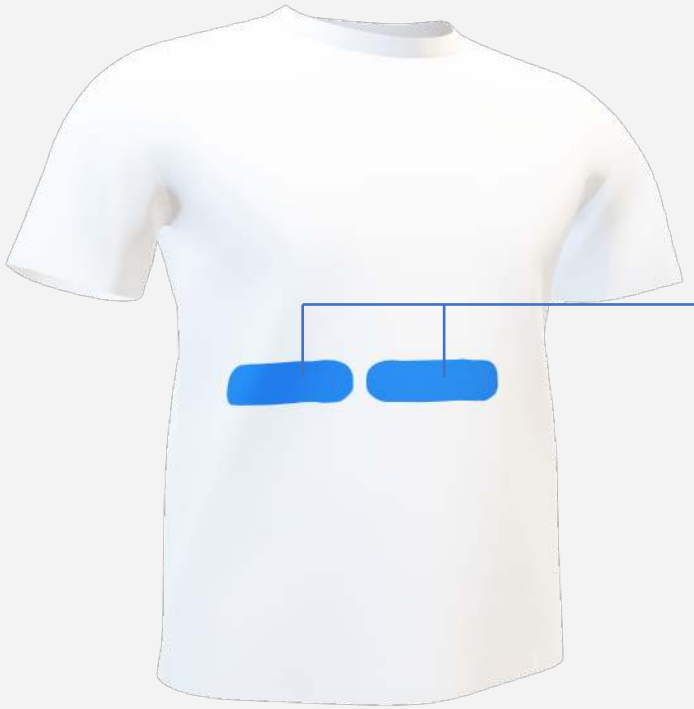

T-Shirt
Biosignals
Signal Processing
Features
Machine Learning
Emotion
Toy

The system



plux
WIRELESS BIOSIGNALS S.A.

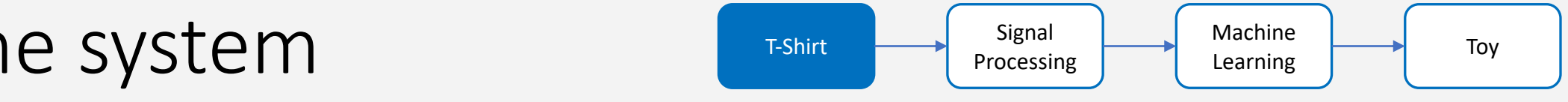
The system

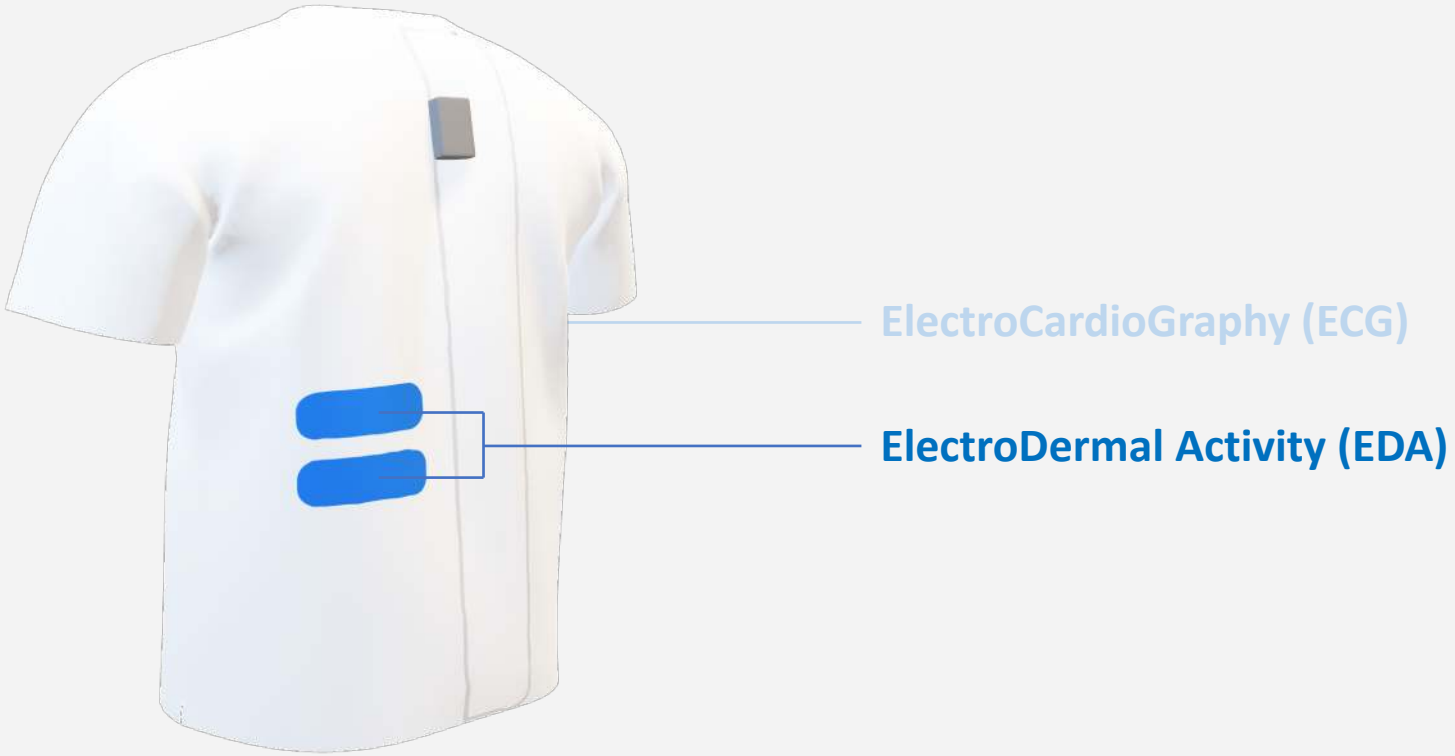


ElectroCardioGraphy (ECG)

plux
WIRELESS BIOSIGNALS S.A.

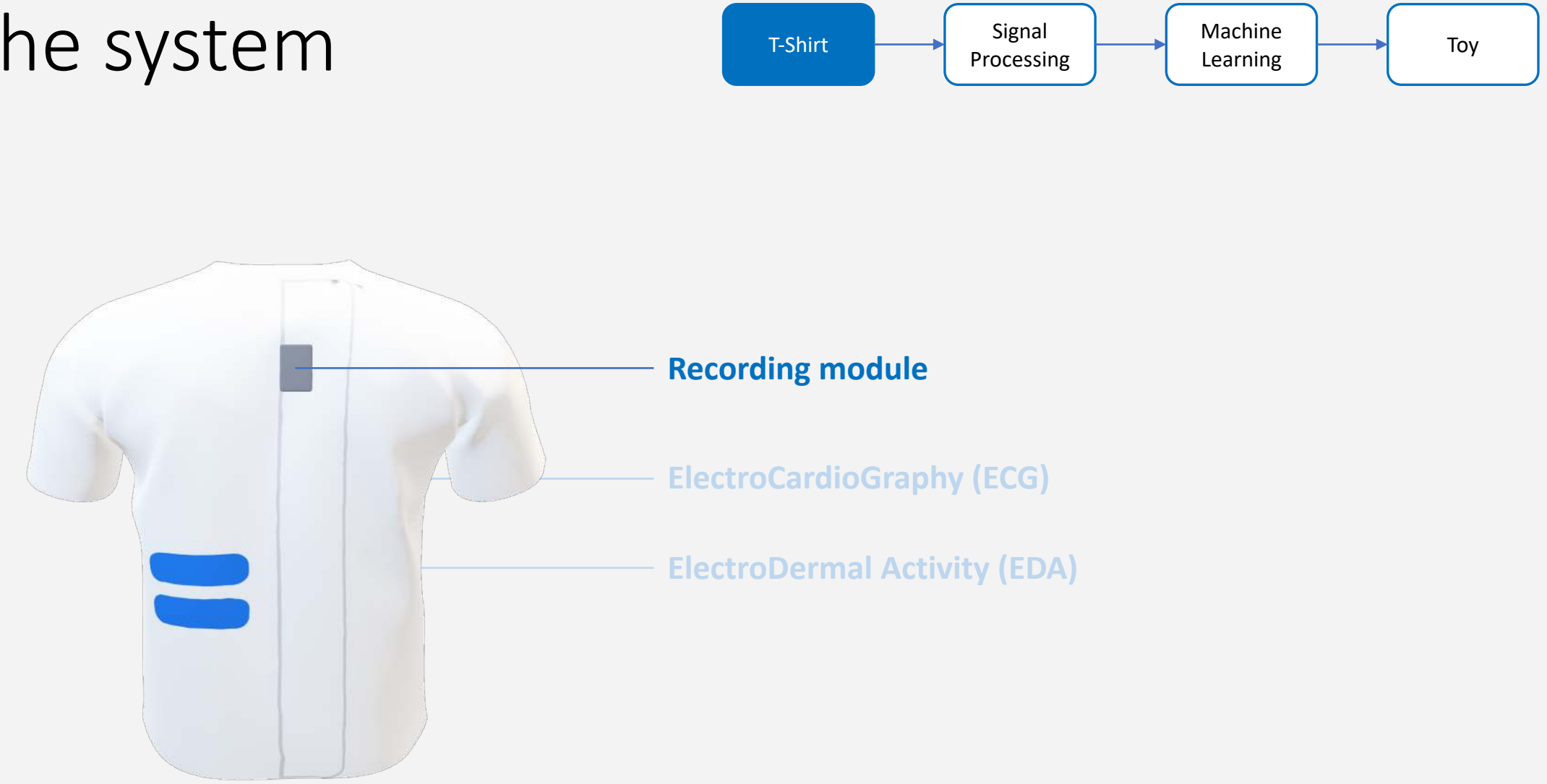
The system





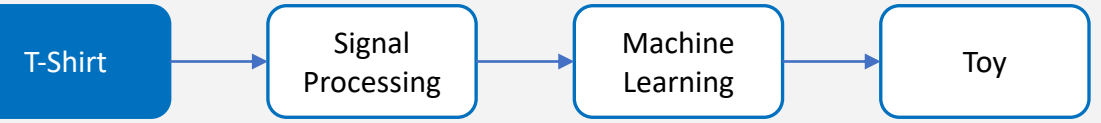
plux
WIRELESS BIOSIGNALS S.A.

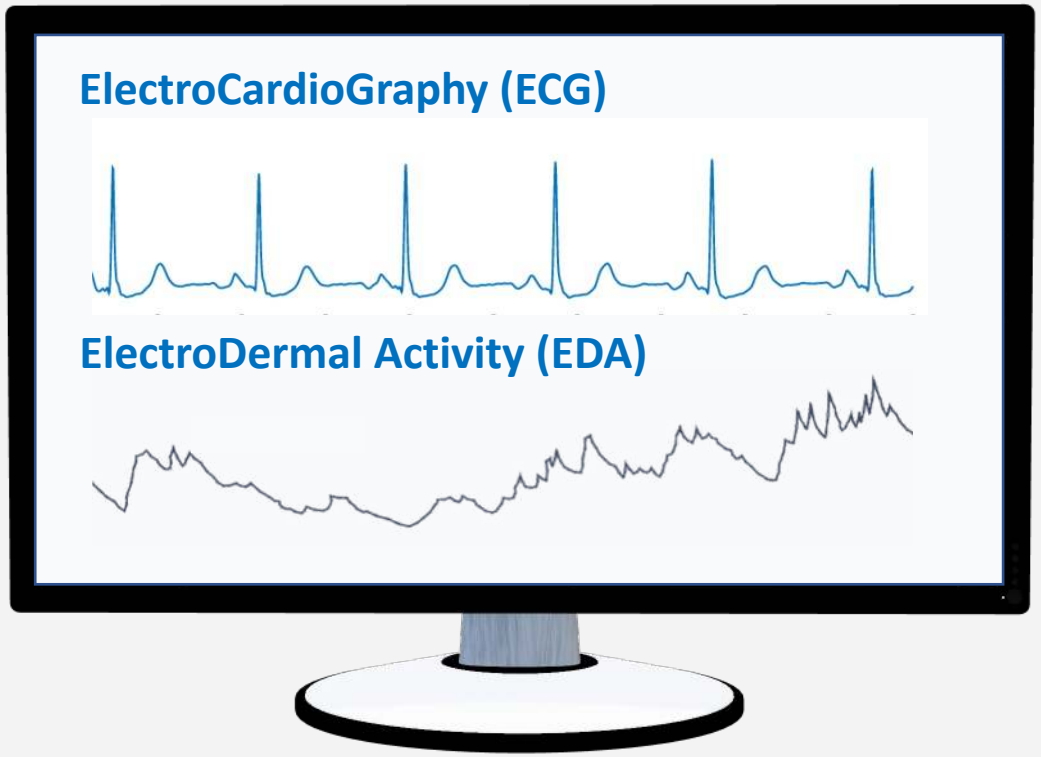
The system



plux
WIRELESS BIOSIGNALS S.A.

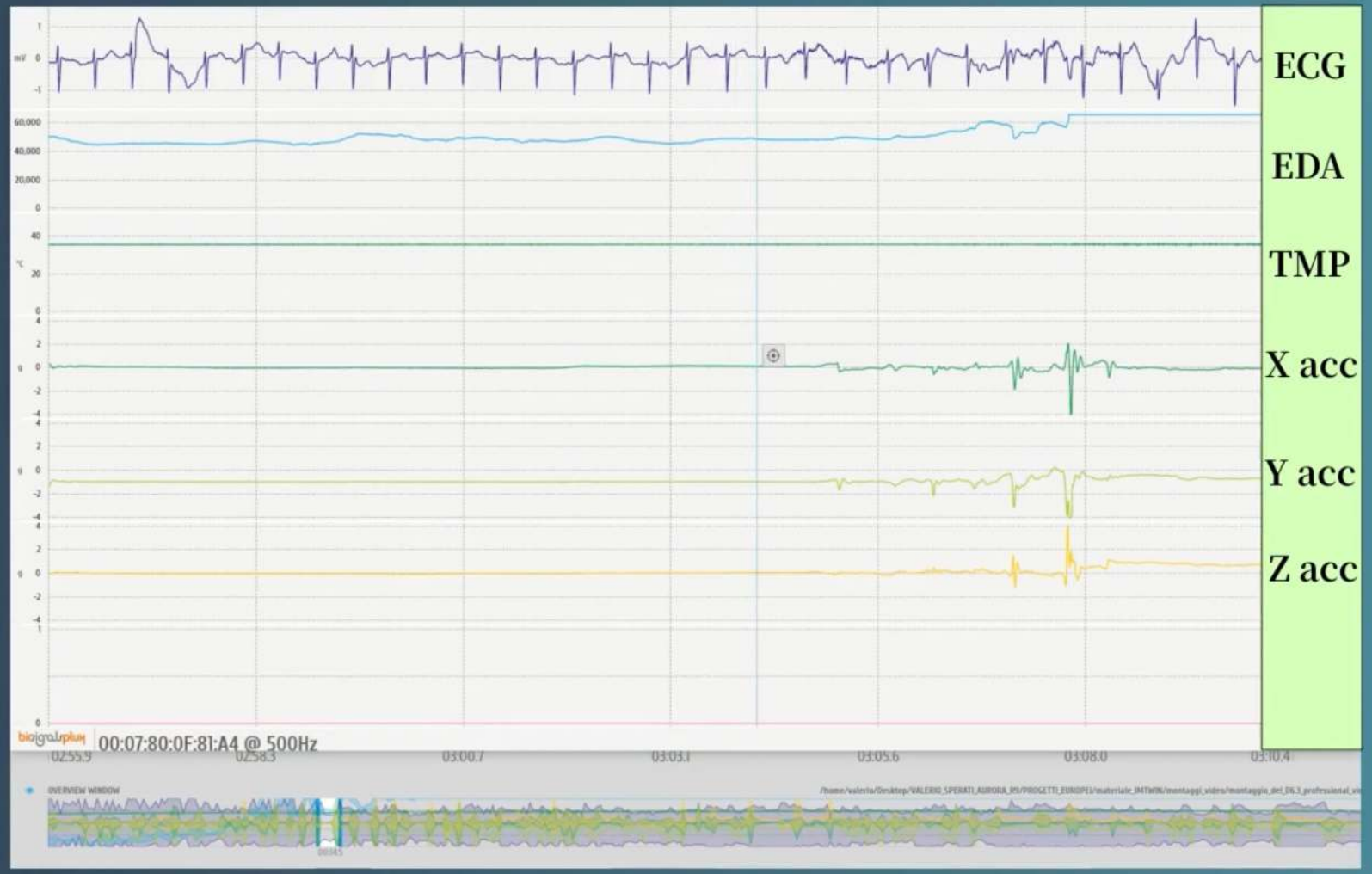
The system



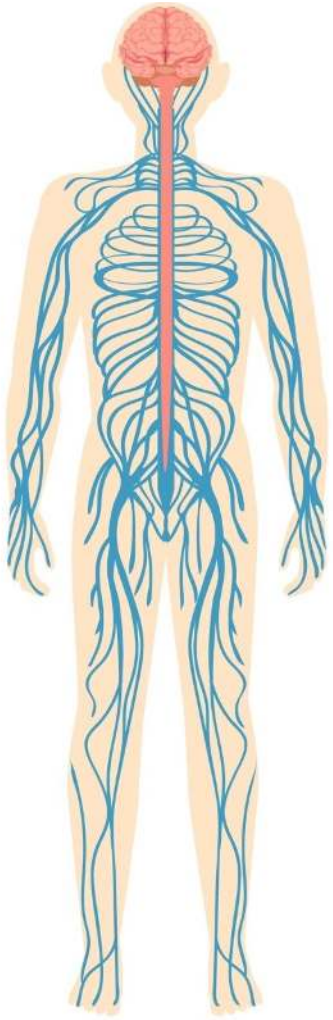


plux
WIRELESS BIOSIGNALS S.A.

...and a test with a ASD child playing with Panda PlusMe.



Autonomic Nervous System



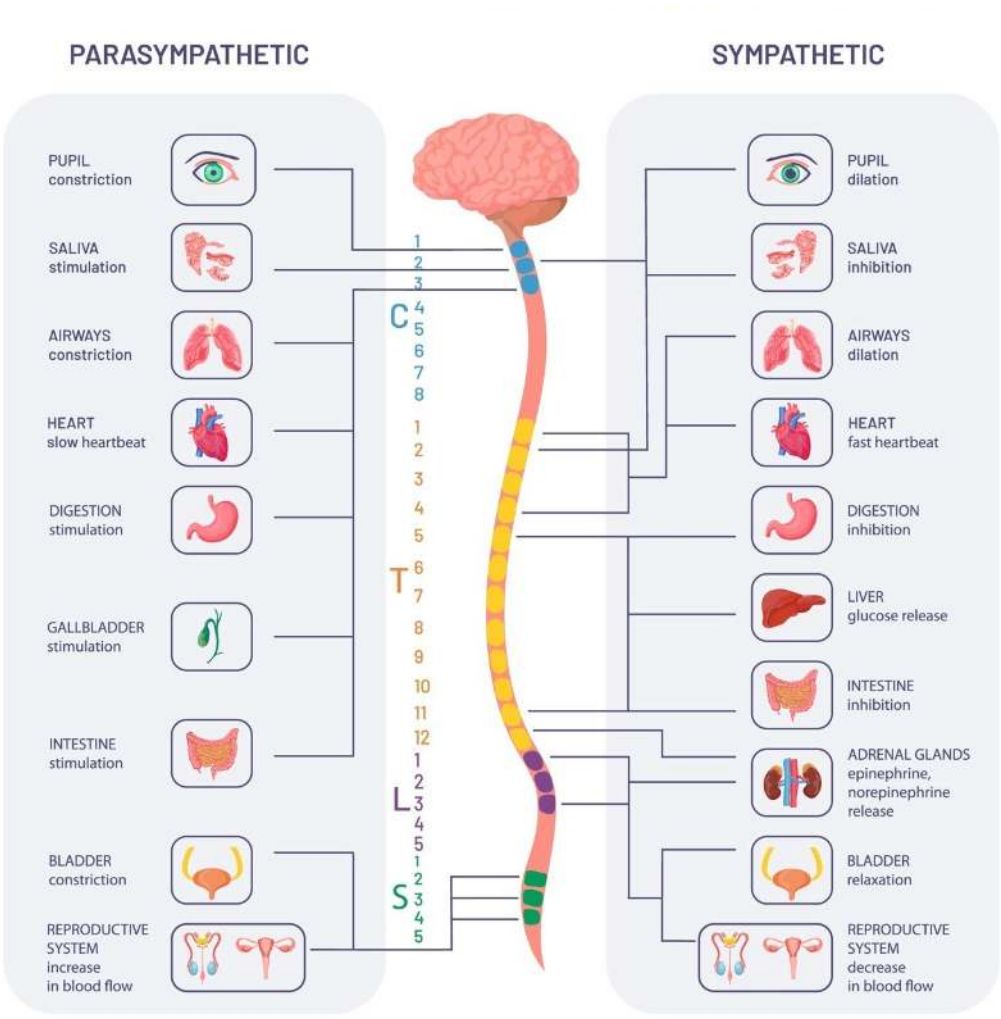
Autonomic Nervous System

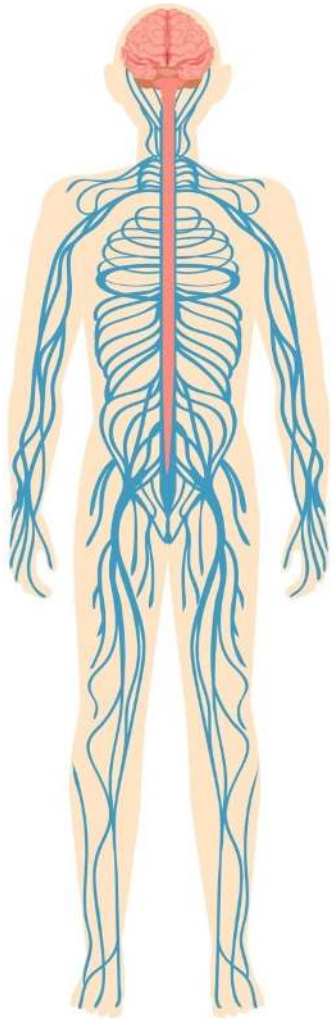
PARASYMPATHETIC

- State of rest

SYMPATHETIC

- State of stress





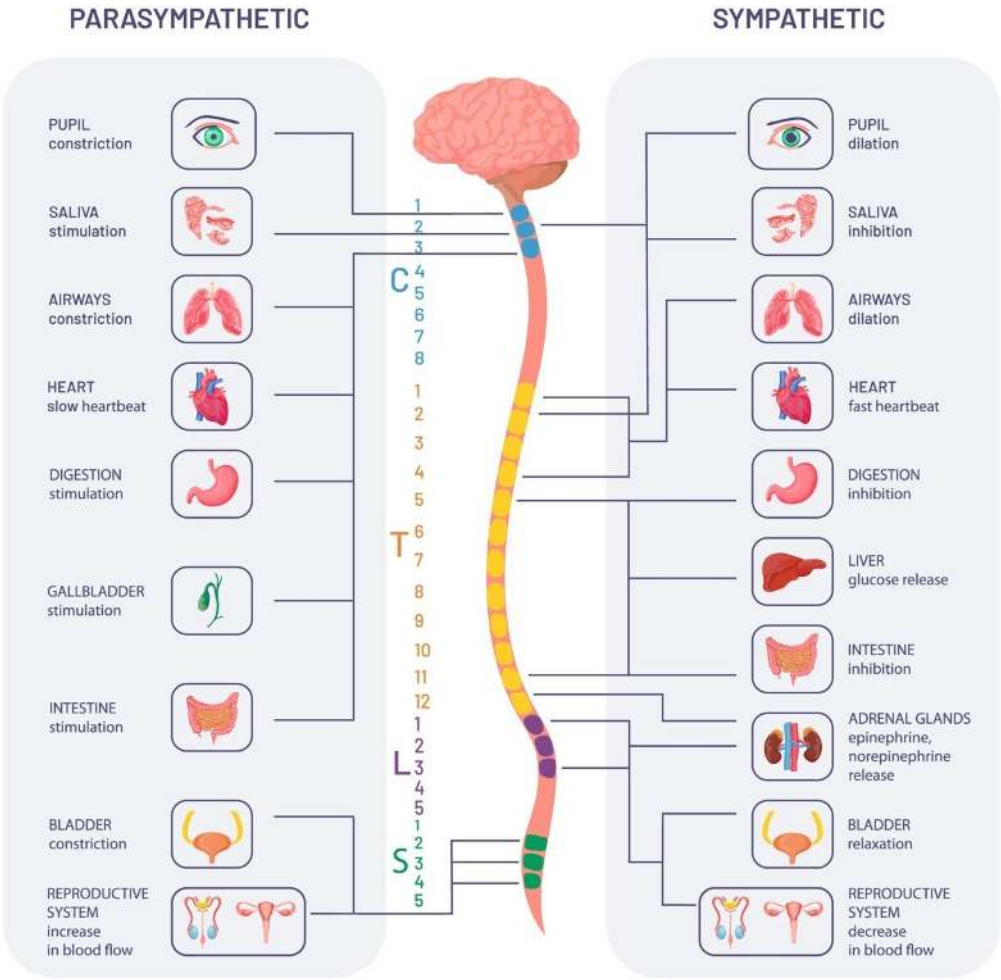
Autonomic Nervous System

PARASYMPATHETIC
Rest

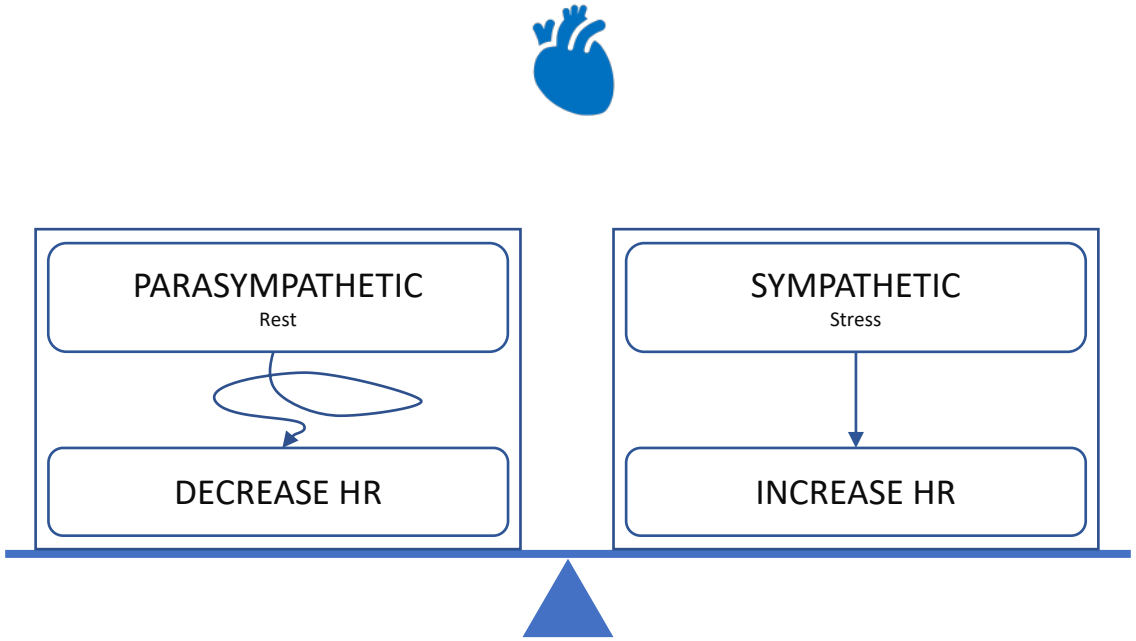
DECREASE HR

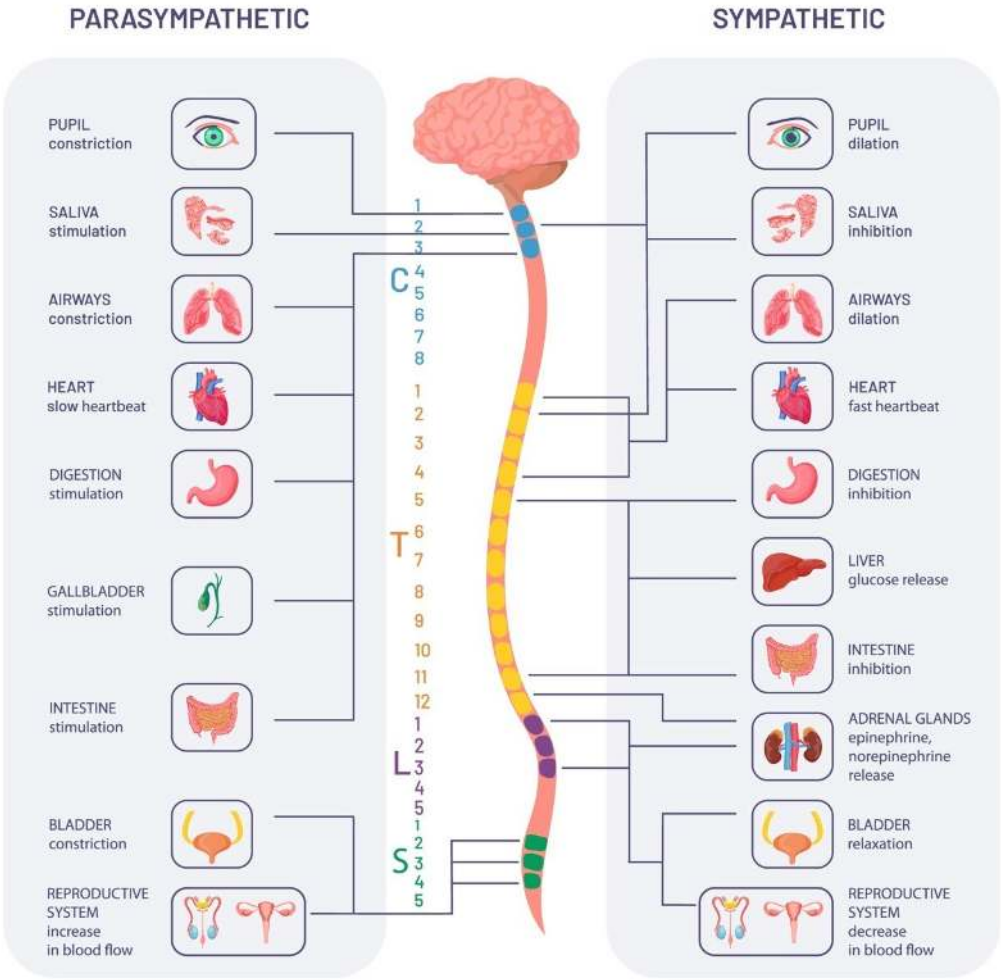
SYMPATHETIC
Stress

INCREASE HR

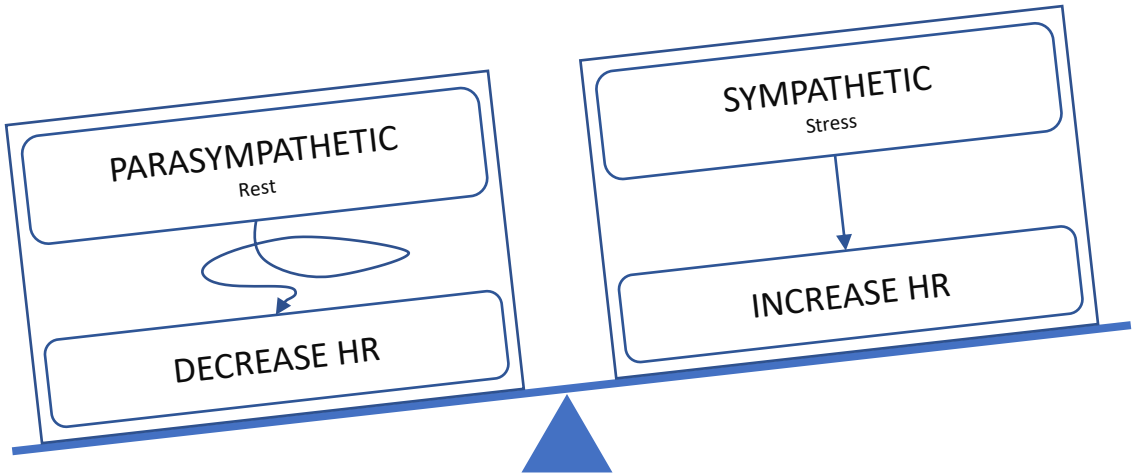


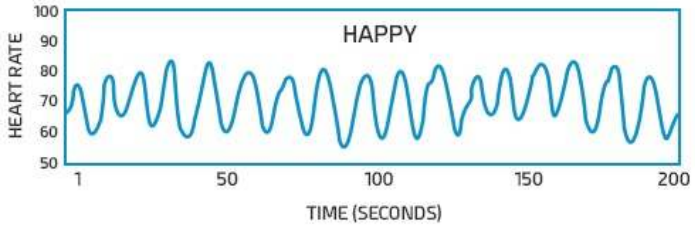
Autonomic Nervous System

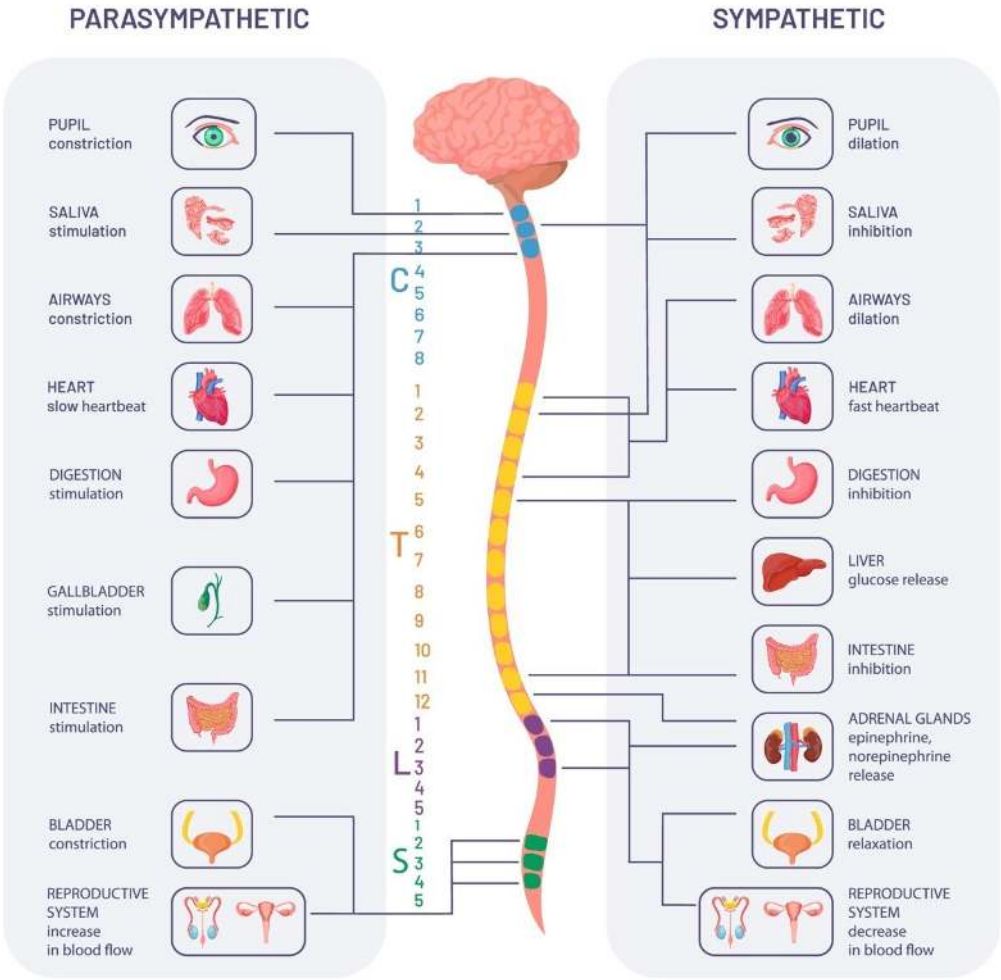




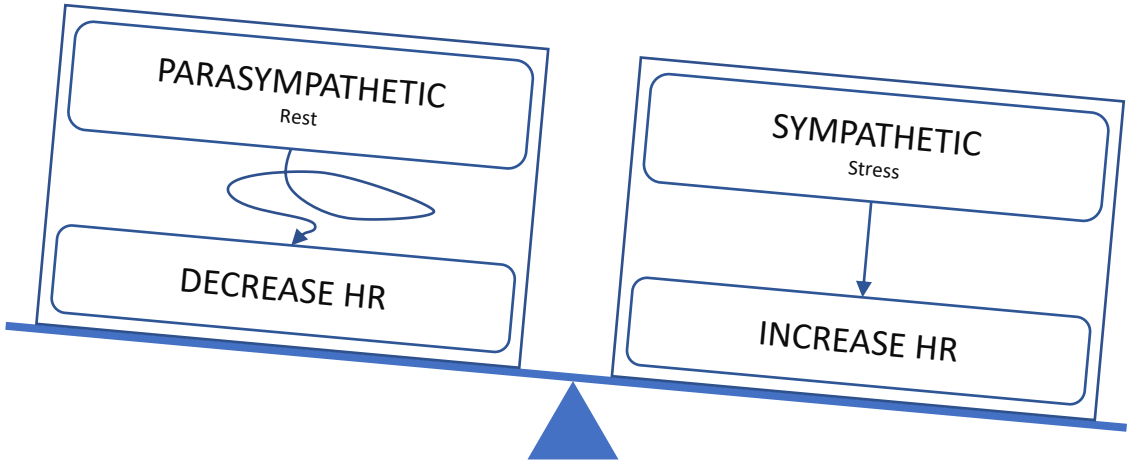
Autonomic Nervous System

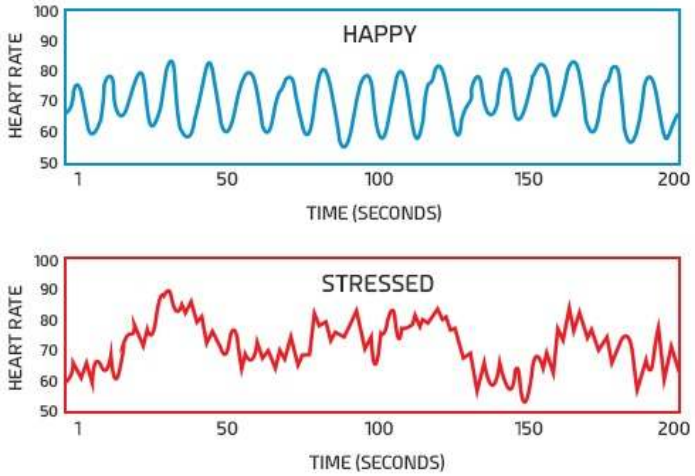


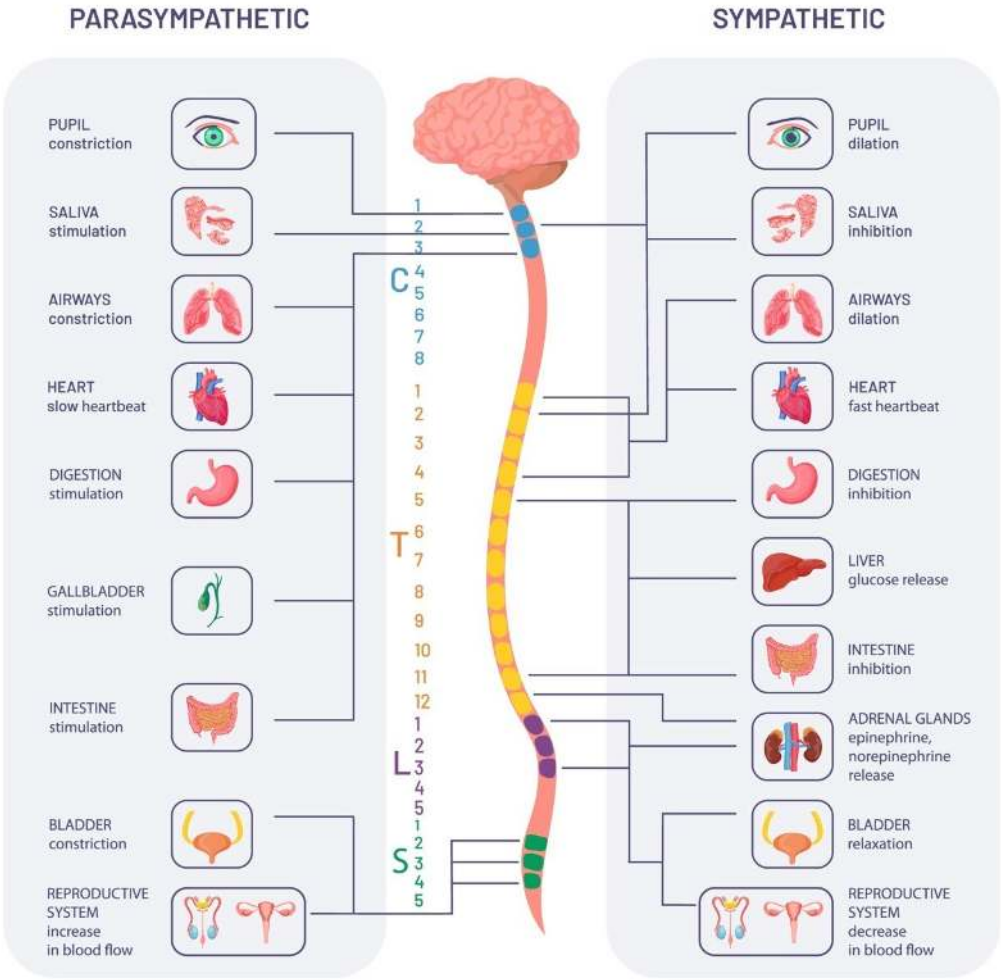




Autonomic Nervous System







Autonomic Nervous System

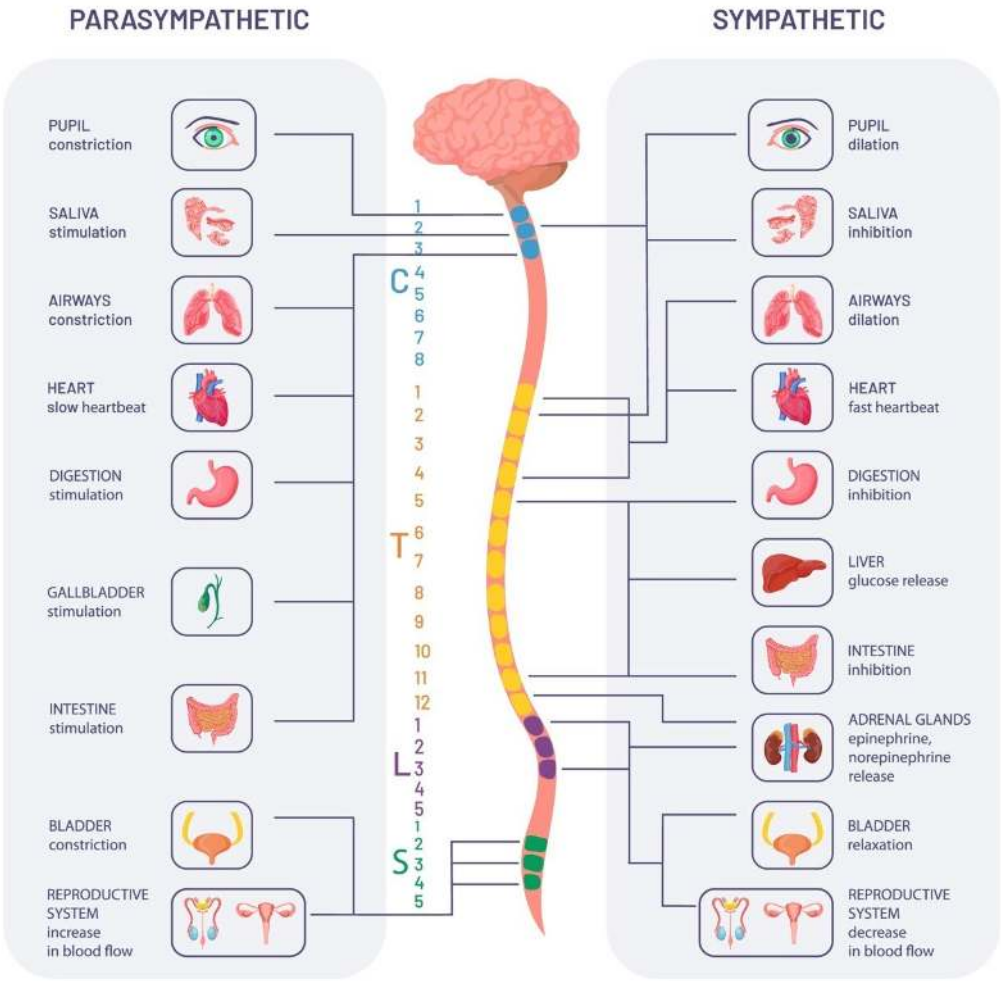
PARASYMPATHETIC
Rest

SYMPATHETIC
Stress

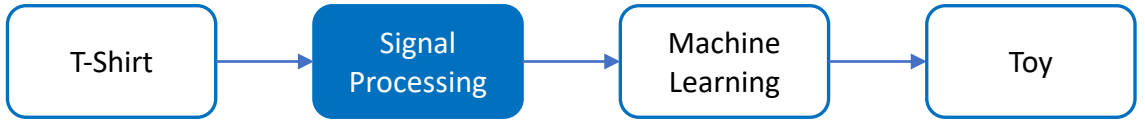
SUDOMOTOR FIBERS

INCREASE SWEATING

INCREASE SKIN CONDUCTIVITY



The system

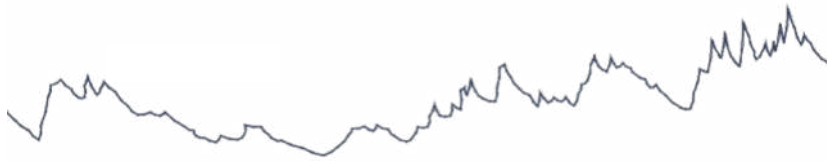


ElectroCardioGram (ECG)

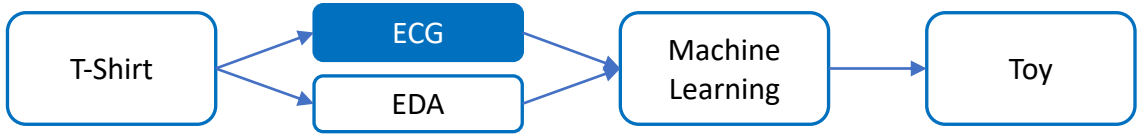
- Measures heart muscle activity
- Sympatho-vagal balance
- Fast responding
- Reflects arousal (and valence?)

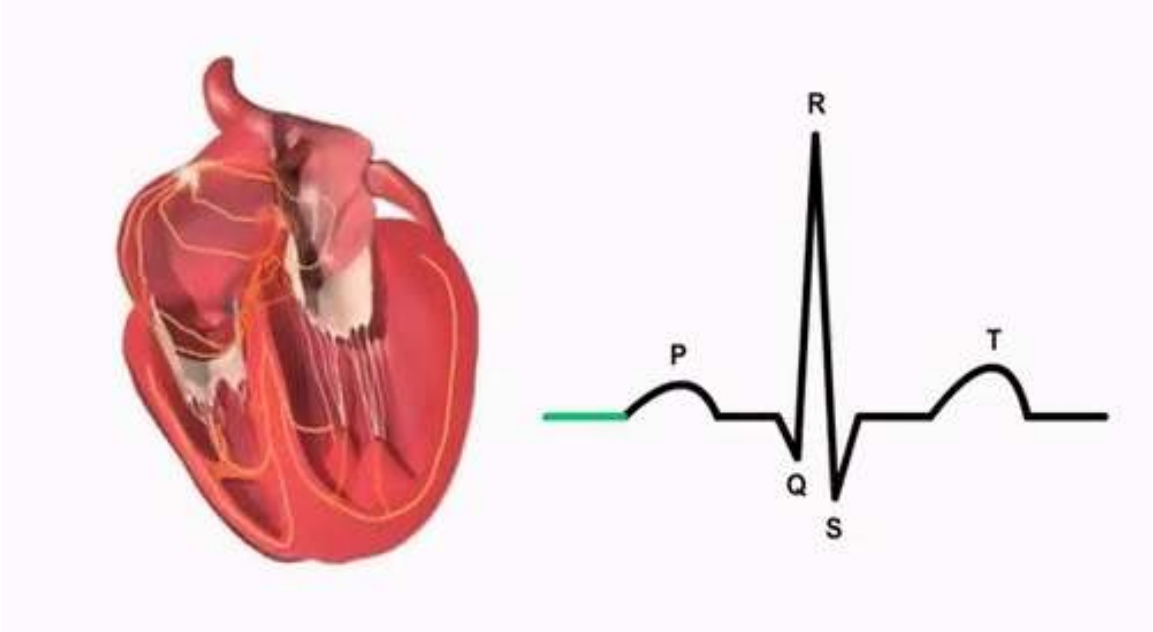
ElectroDermal Activity (EDA)

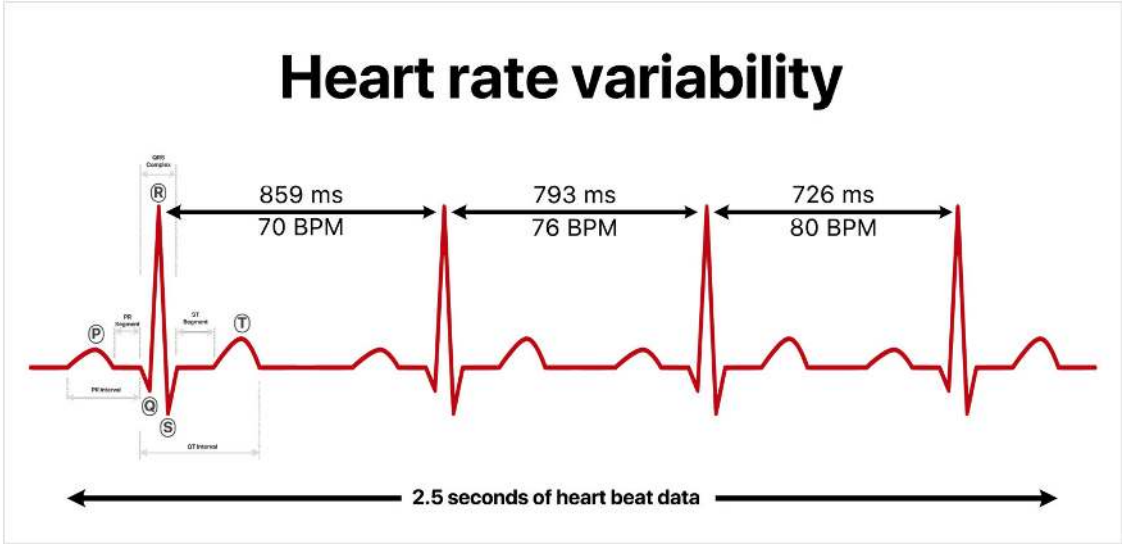
- Measures skin conductivity
- Sympathetic activity
- Slow responding
- Reflects arousal



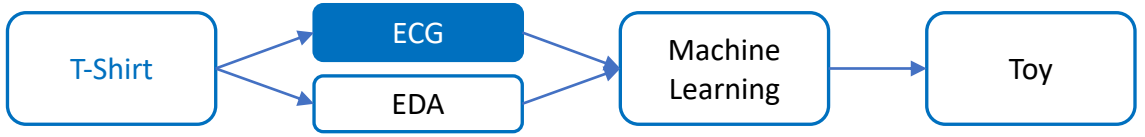
ECG Signal


T-Shirt
ECG
EDA
Machine Learning
Toy

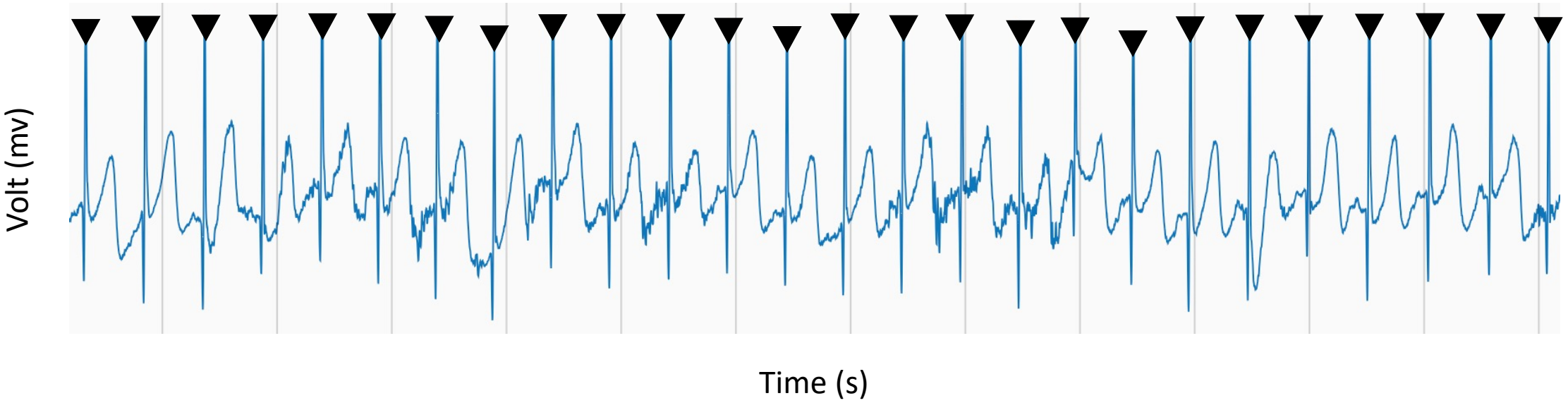

R
P
T
Q
S


Heart rate variability
859 ms
70 BPM
793 ms
76 BPM
726 ms
80 BPM
2.5 seconds of heart beat data

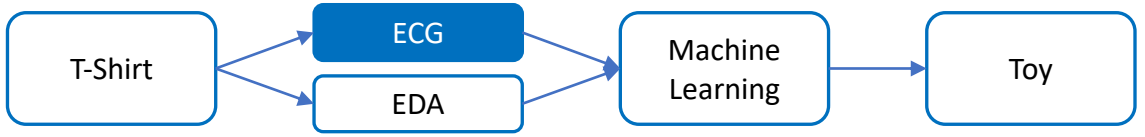
ECG Signal



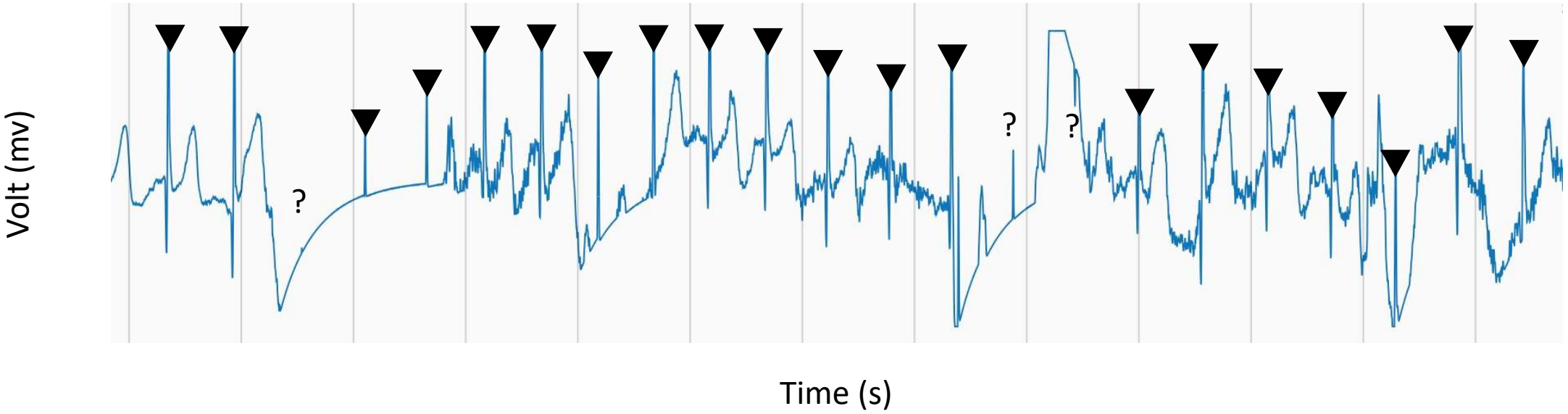
Actual ECG of T-Shirt



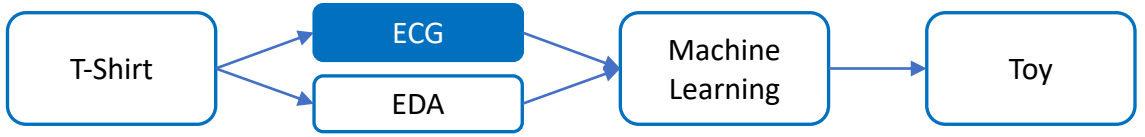
ECG Signal



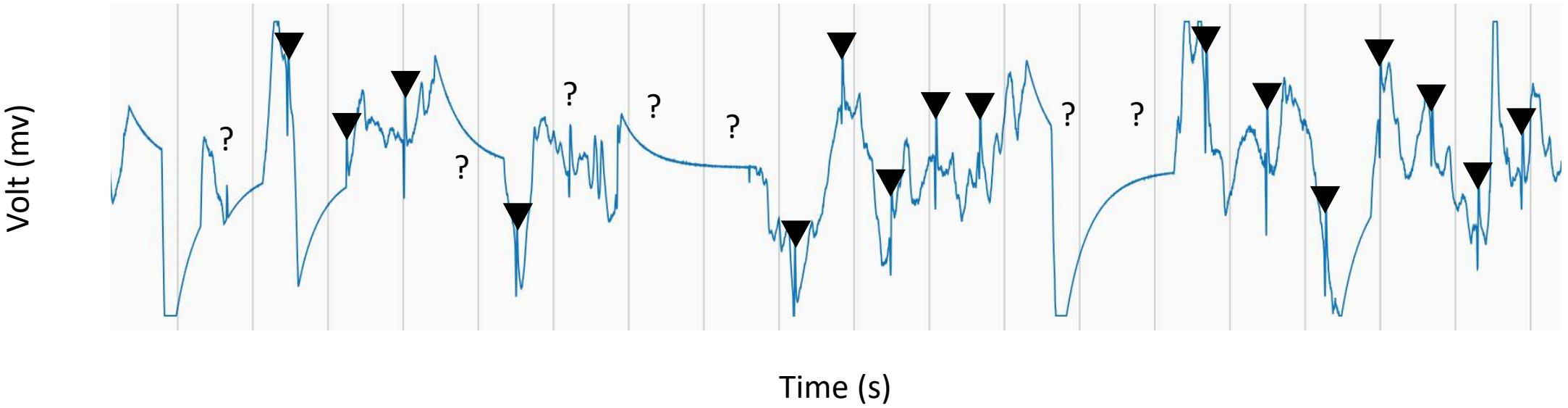
Actual ECG of T-Shirt



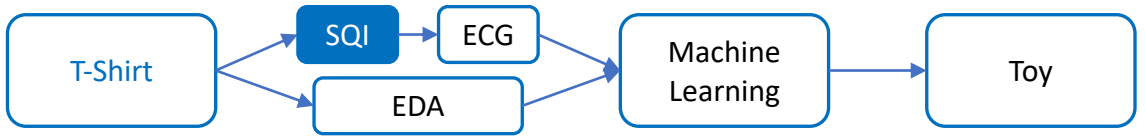
ECG Signal

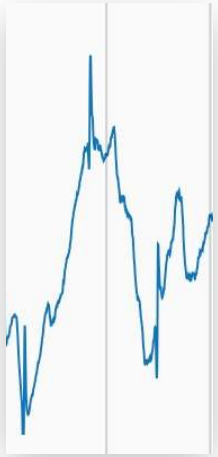


Actual ECG of T-Shirt



ECG Signal



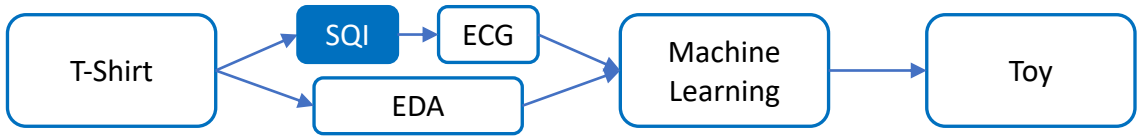


Something/somewhat that analyses quality

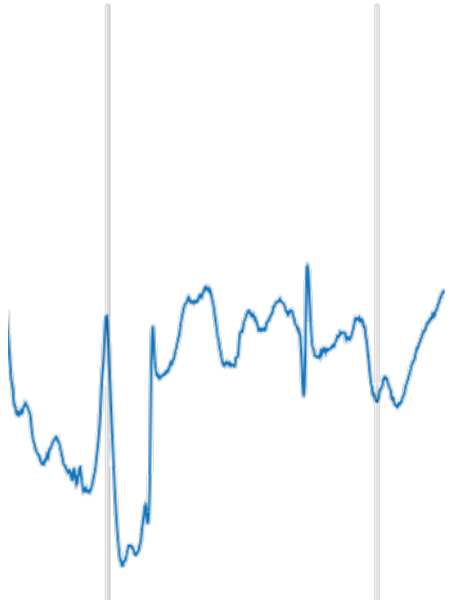
Good signal

Bad signal

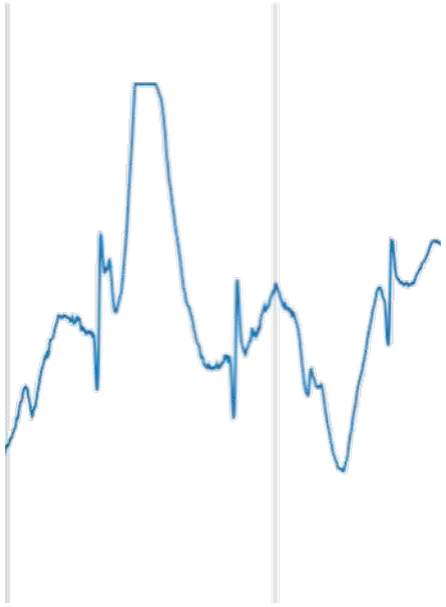
ECG Signal



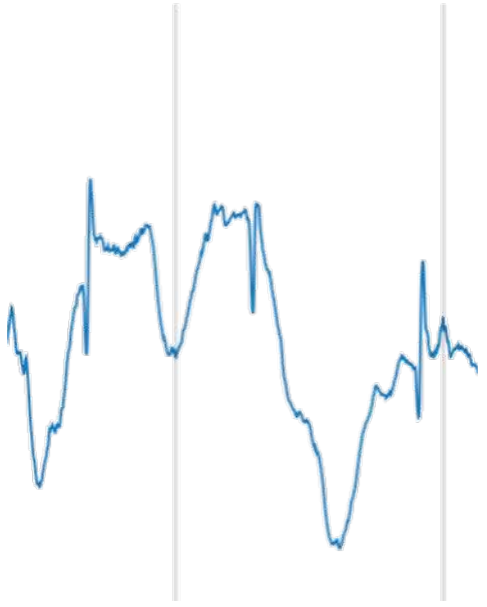
Bad



Good

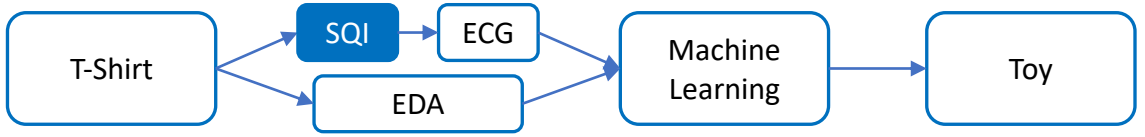


Okayish

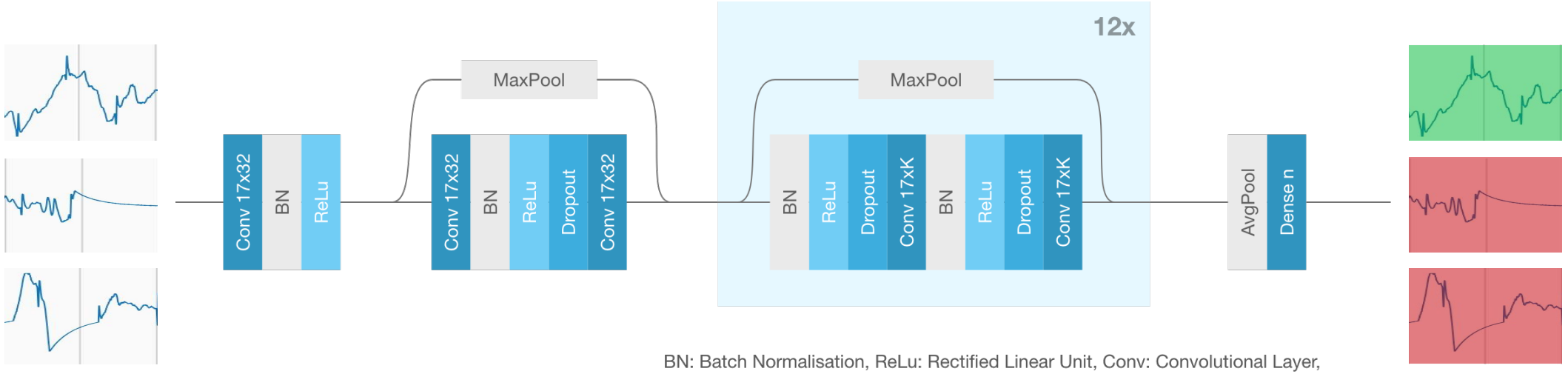


Difficult to find good rules…

ECG Signal



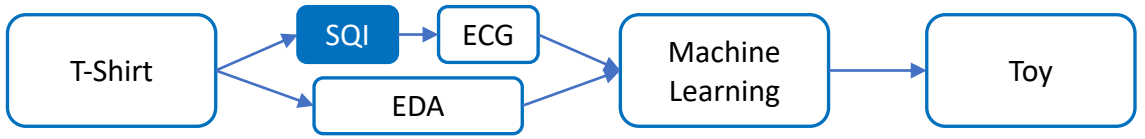
Accuracy: 96%!

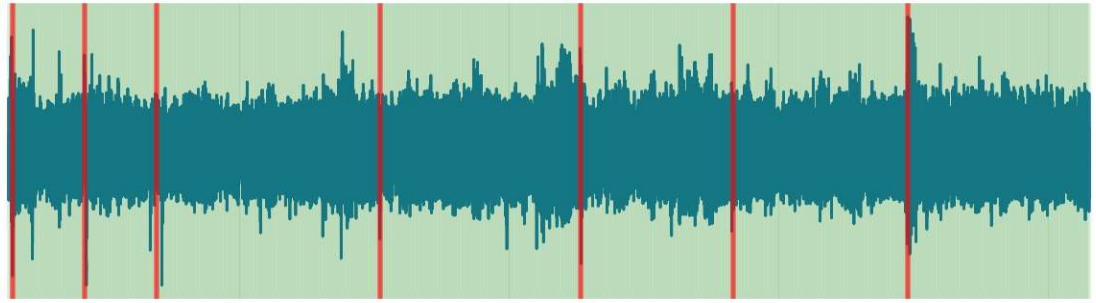


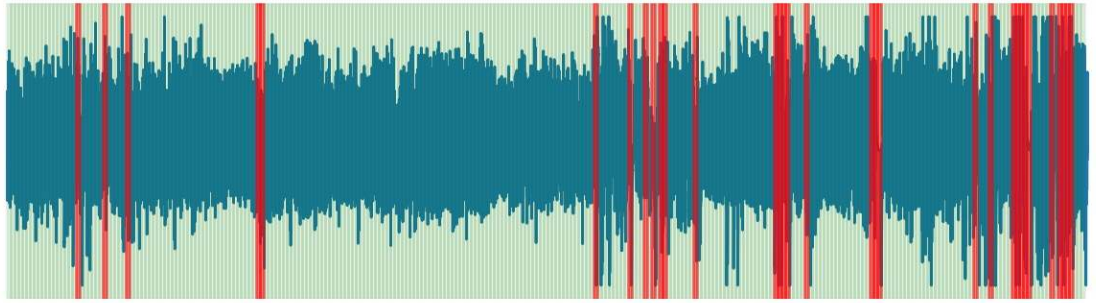
BN: Batch Normalisation, ReLu: Rectified Linear Unit, Conv: Convolutional Layer,
MaxPool: Maximum pooling layer, AvgPool: Average pooling layer

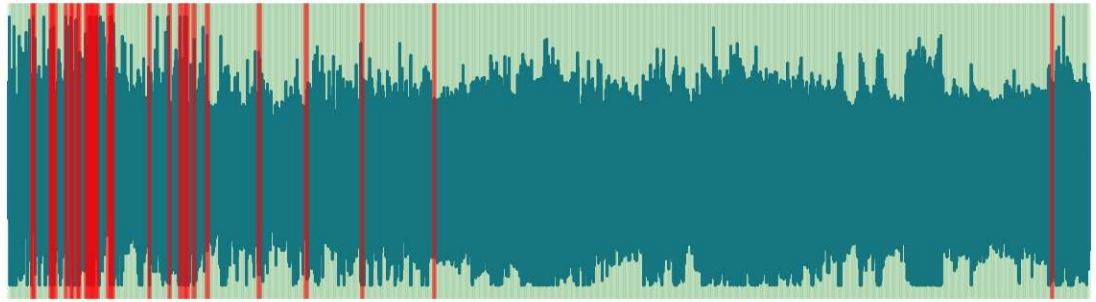
Deep Neural Network

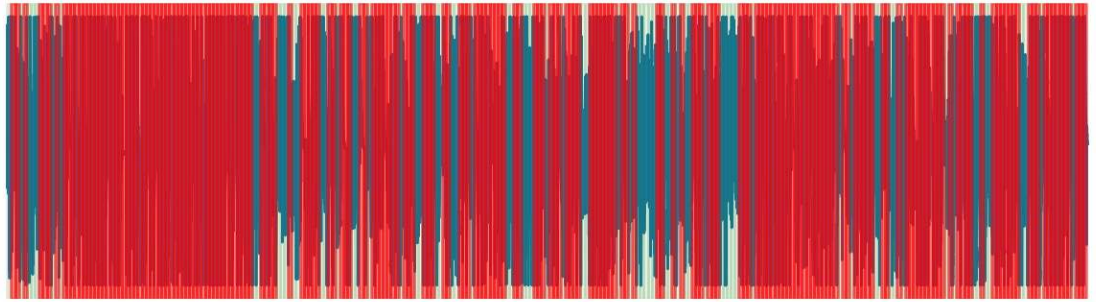
ECG Signal



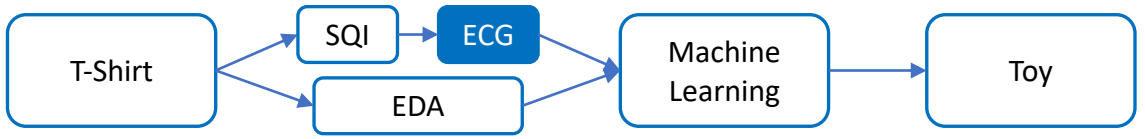




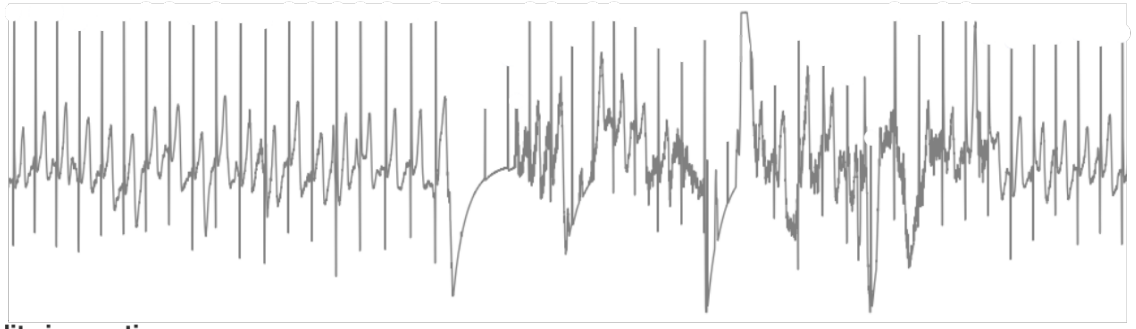




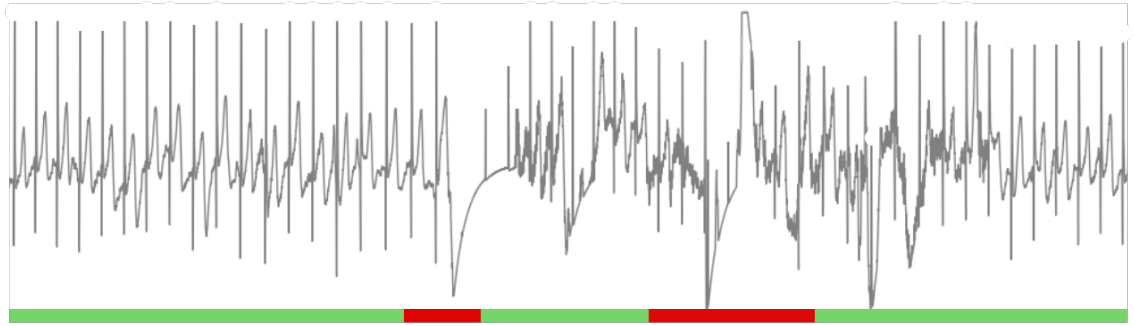
ECG Signal



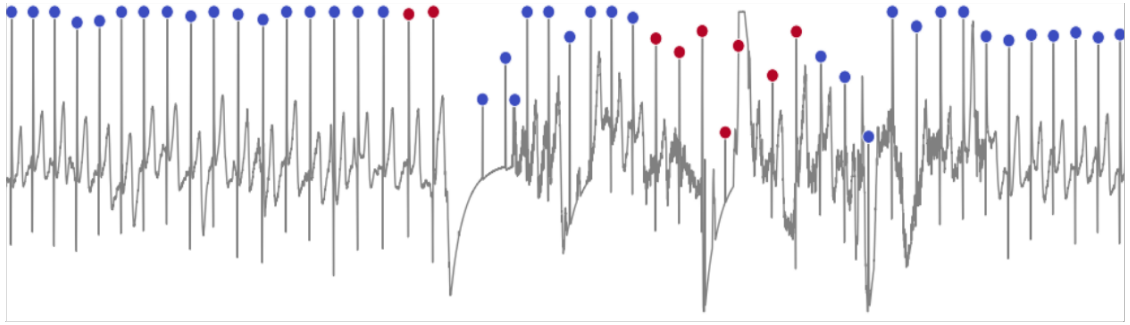
Segmentation



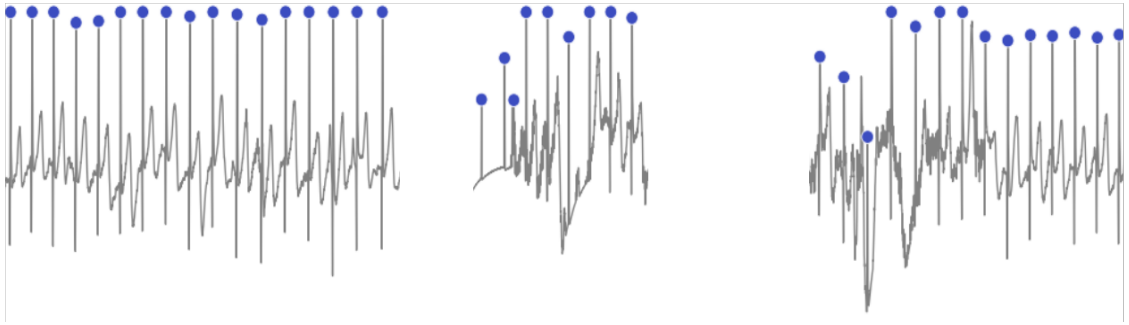
Quality inspection



Peak detection

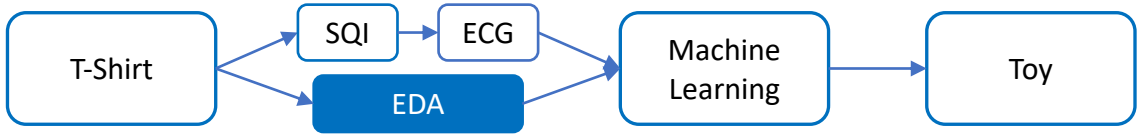


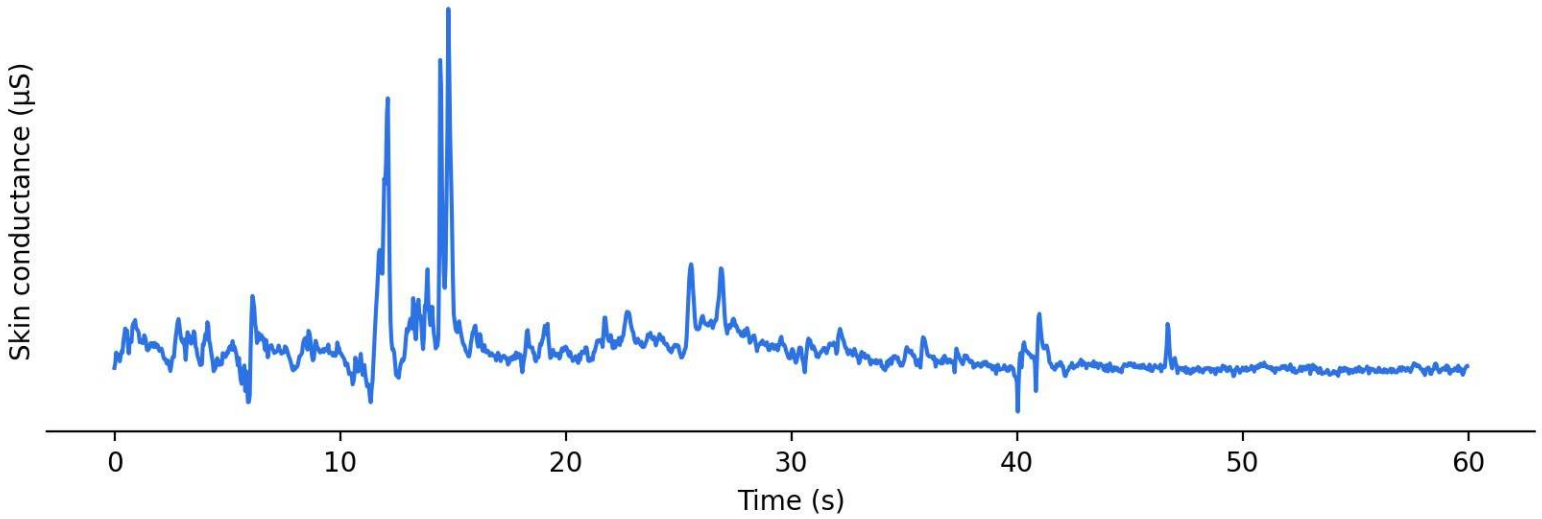
Interbeat Interval calculation



Calculate various HR and HRV features

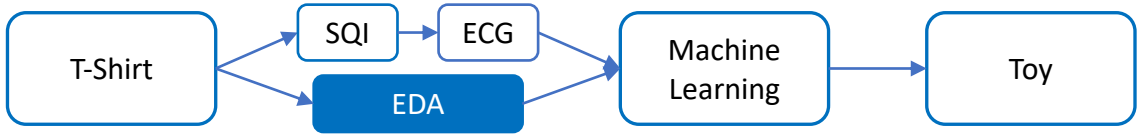
EDA Signal

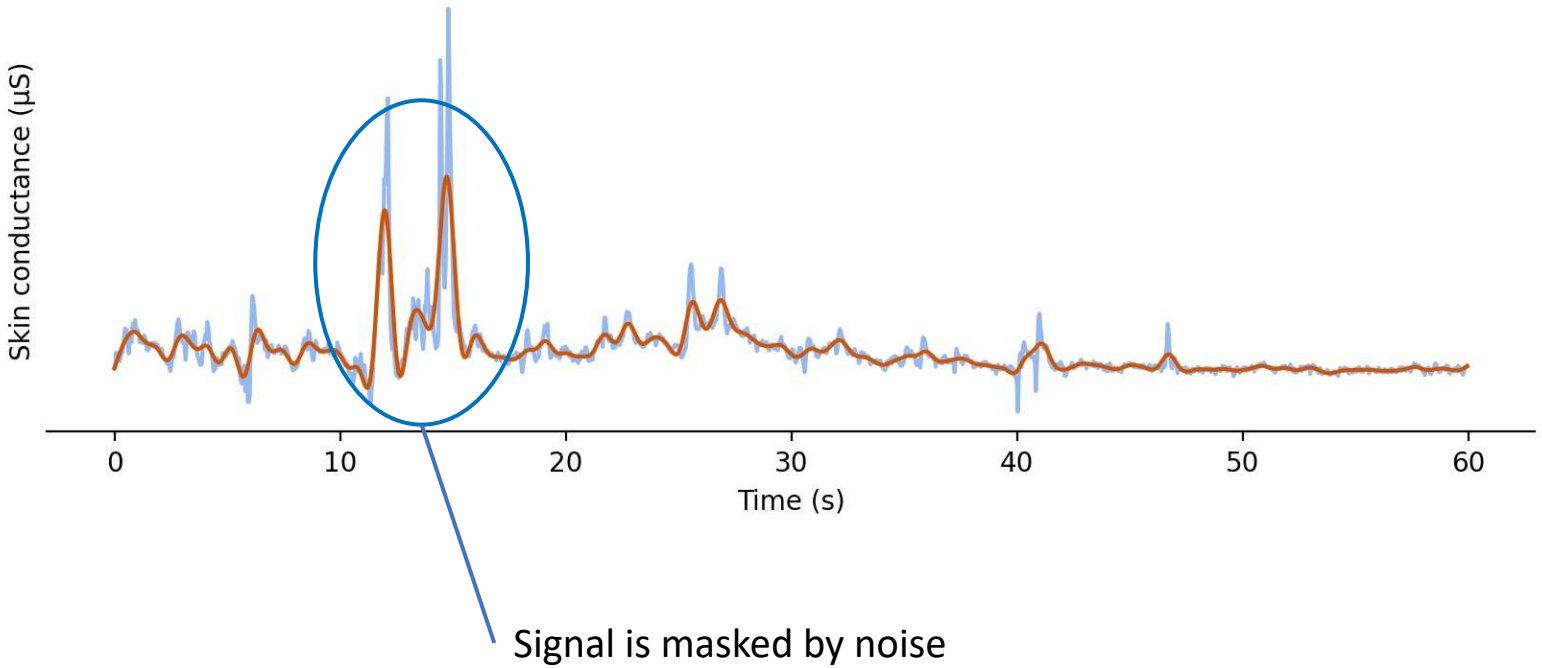




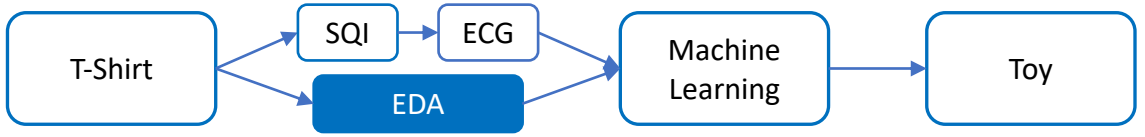
stimulus

EDA Signal

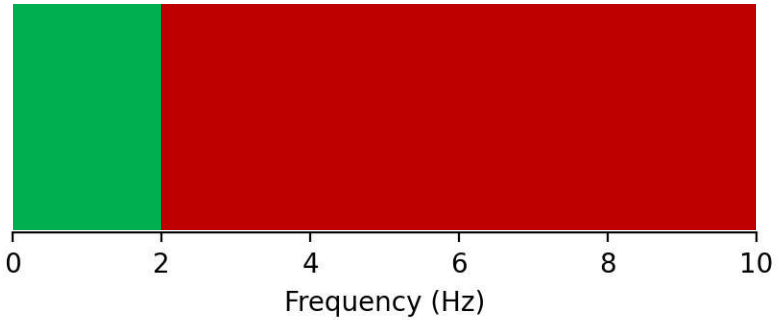

T-Shirt
SQI
ECG
EDA
Machine Learning
Toy


Skin conductance (µS)
0
10
20
30
40
50
60
Time (s)
Signal is masked by noise

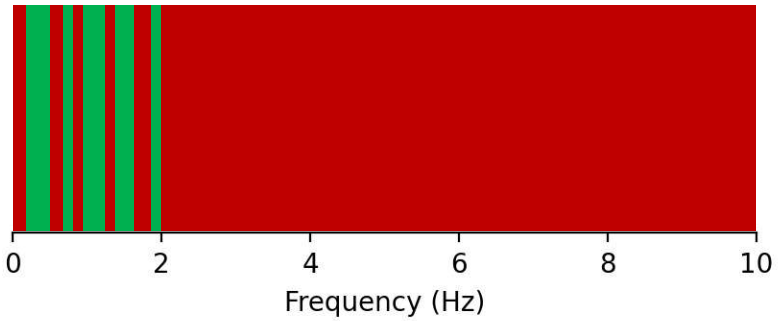
EDA Signal



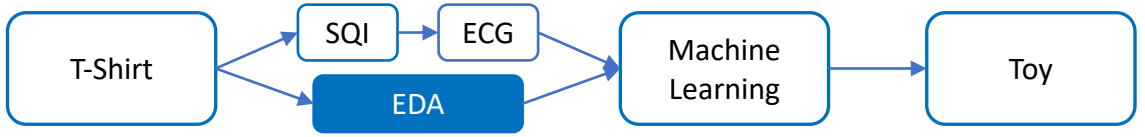
Currently:



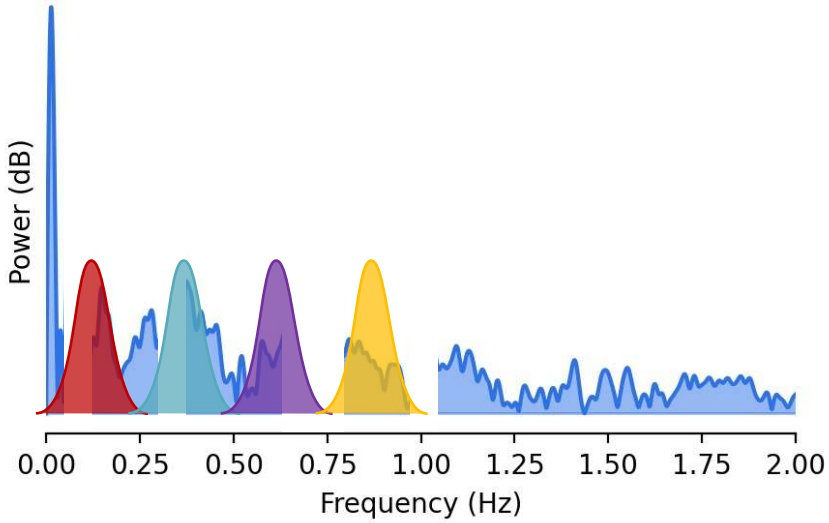
What we want:



EDA Signal

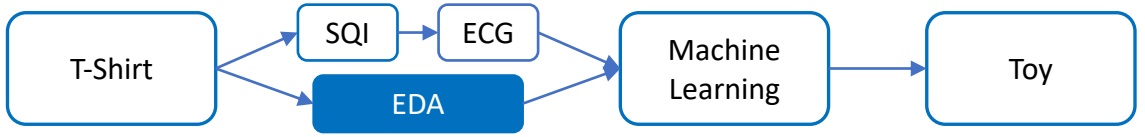


Fourier Transform



However... this won't work... why?

EDA Signal



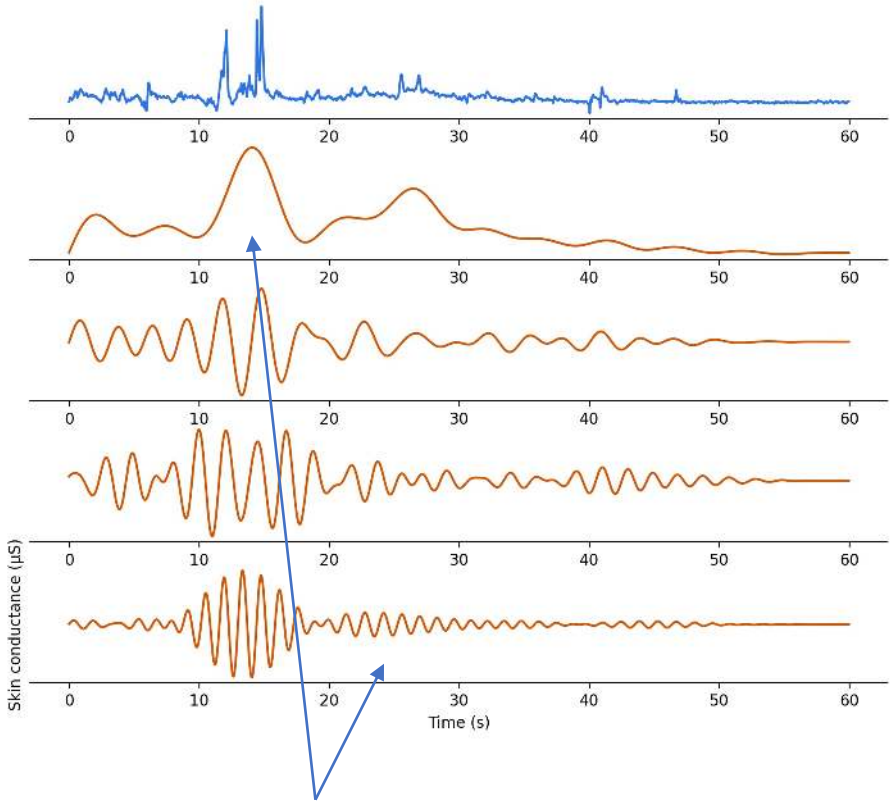
Raw signal

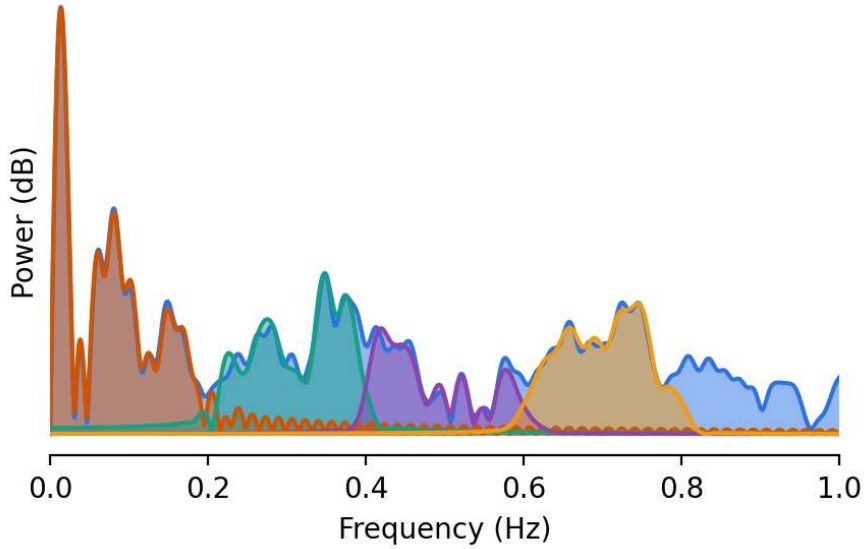
Bandpass [0.0-0.2]Hz

Bandpass [0.2-0.4]Hz

Bandpass [0.4-0.6]Hz

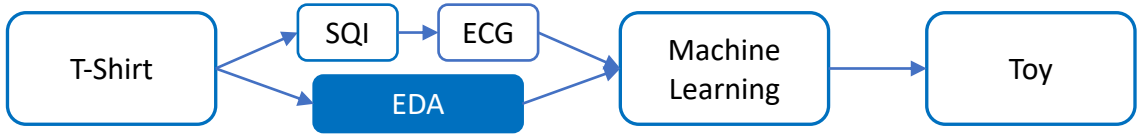
Bandpass [0.6-0.8]Hz





But… where (when) are the frequencies exactly?

EDA Signal



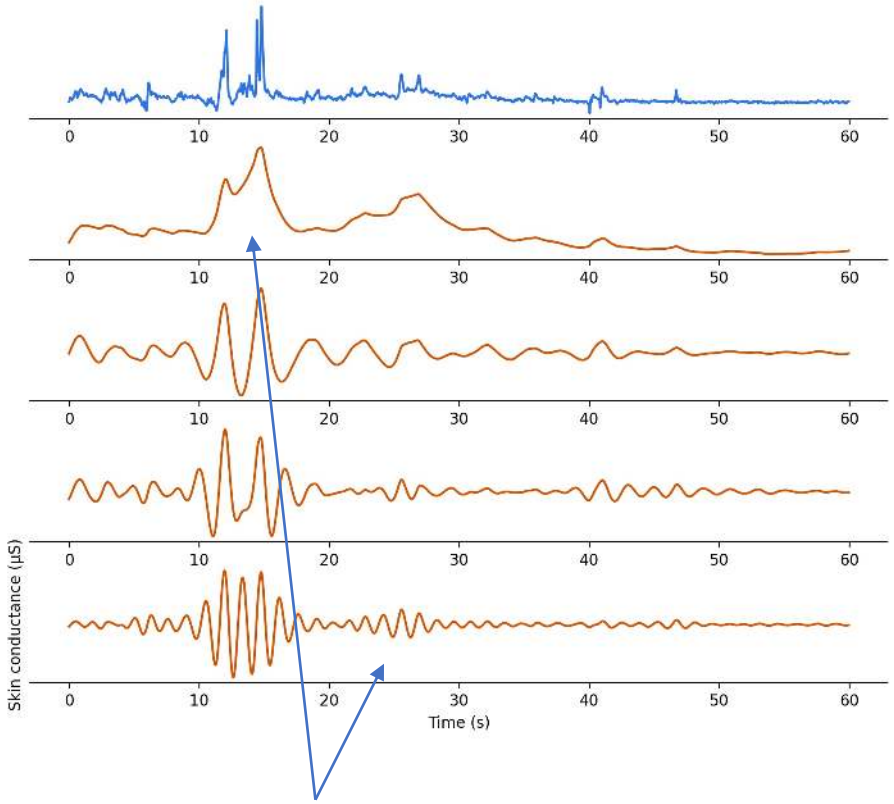
Raw signal

Bandpass [0.0-0.2]Hz

Bandpass [0.2-0.4]Hz

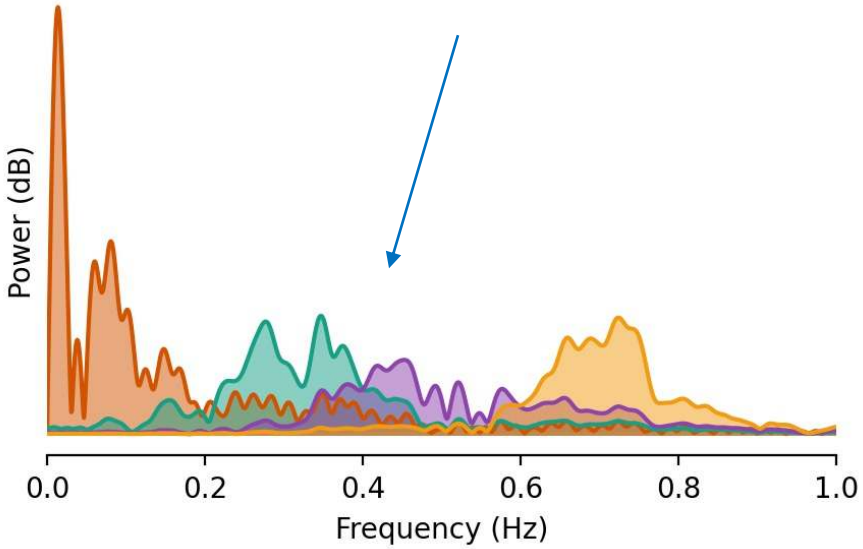
Bandpass [0.4-0.6]Hz

Bandpass [0.6-0.8]Hz



Better time resolution!

But, what… a… mess…



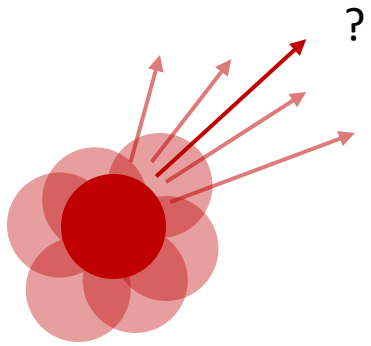
We should (and can) do better…

Intermezzo: Quantum Mechanics!

Heisenberg uncertainty principle

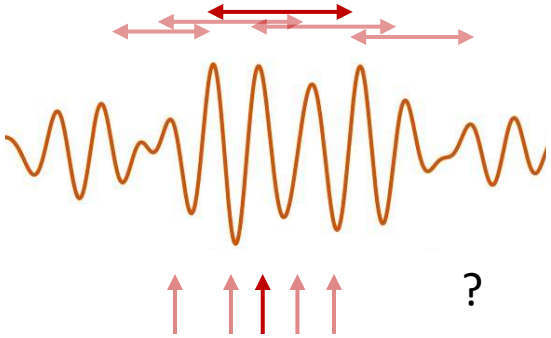
One can never know both the exact position and momentum of a particle simultatenously.

$$\sigma_x^2 \sigma_p^2 \geq \frac{\hbar^2}{4}$$



One can never know both the exact time and frequency of a wave simulatenously.

$$\sigma_t^2 \sigma_f^2 \geq \frac{1}{4}$$



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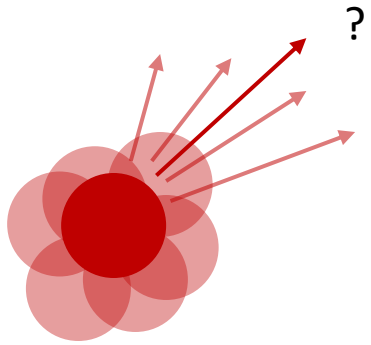
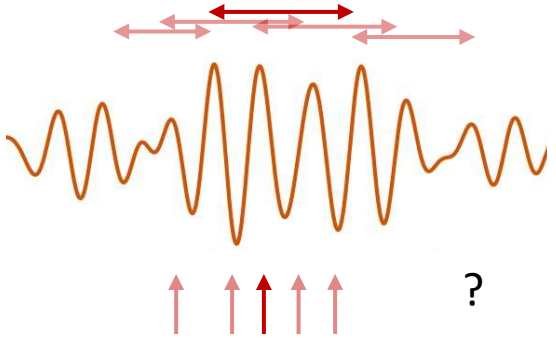
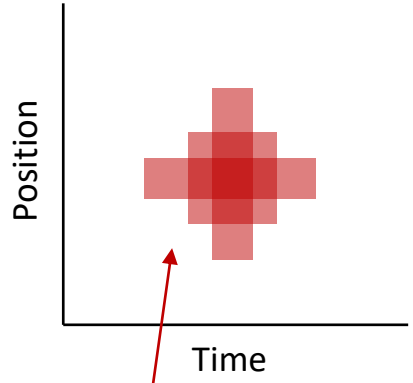
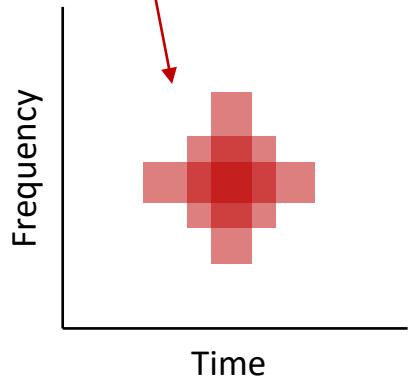


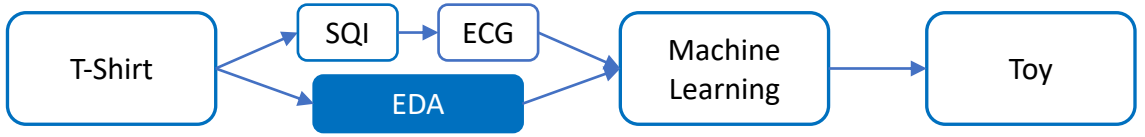




Always the same area!

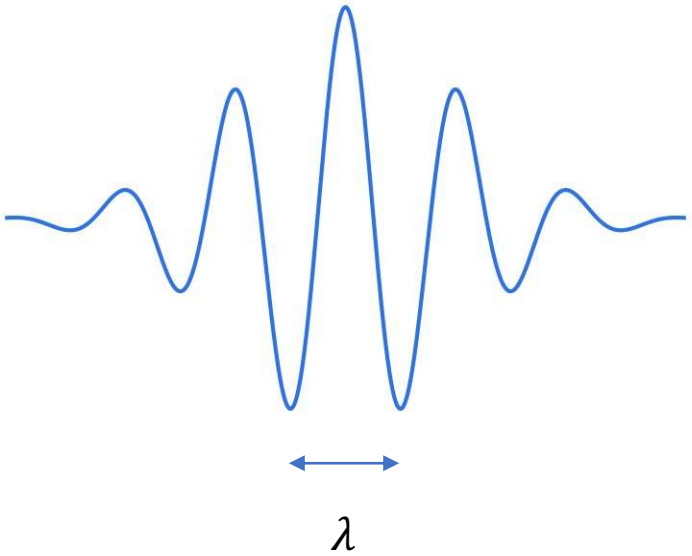


EDA Signal

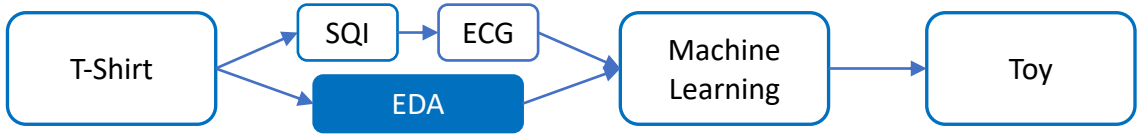


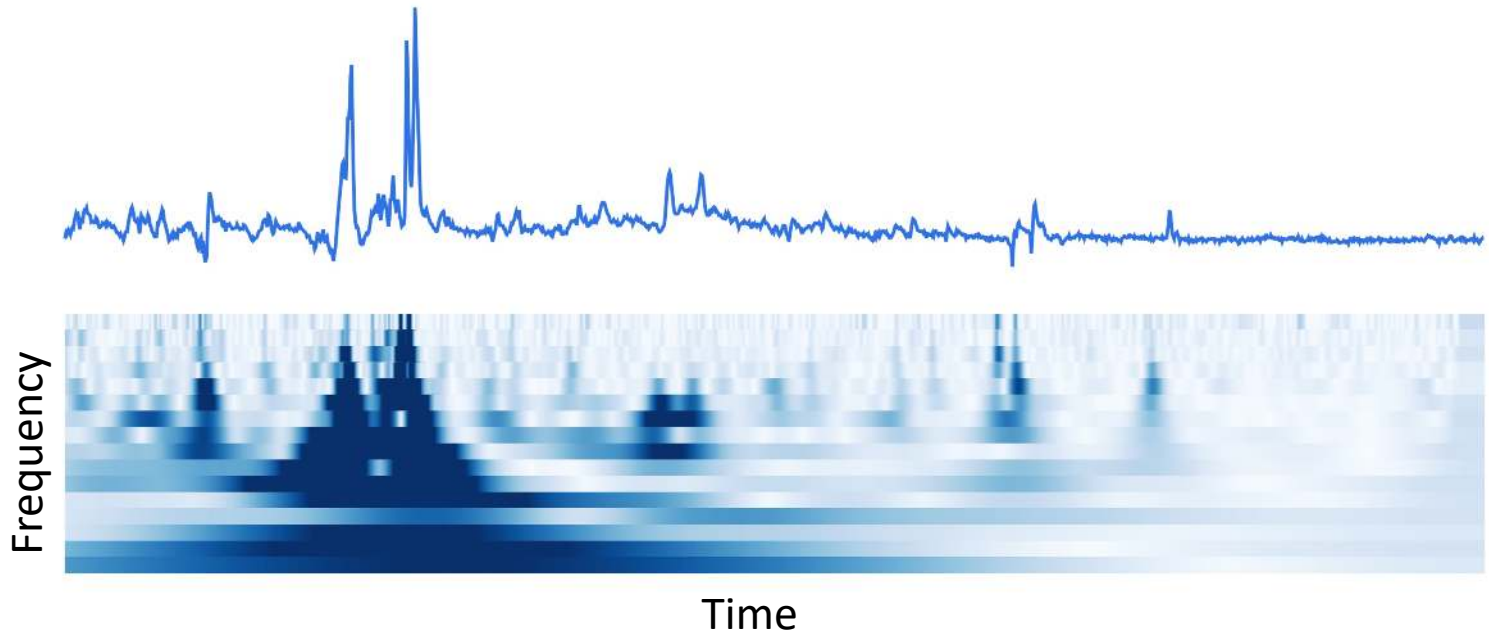
Wavelet

- Optimal time-frequency resolution trade-off
- Shrinks & Stretches



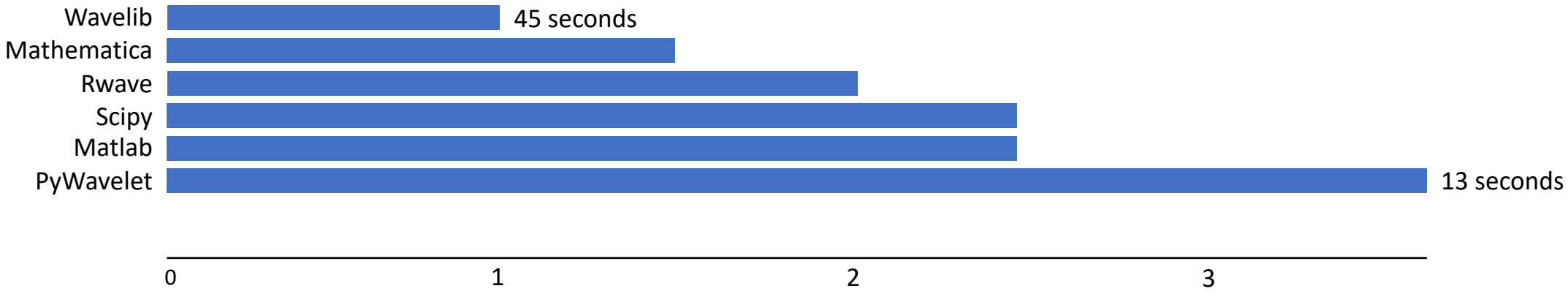
EDA Signal



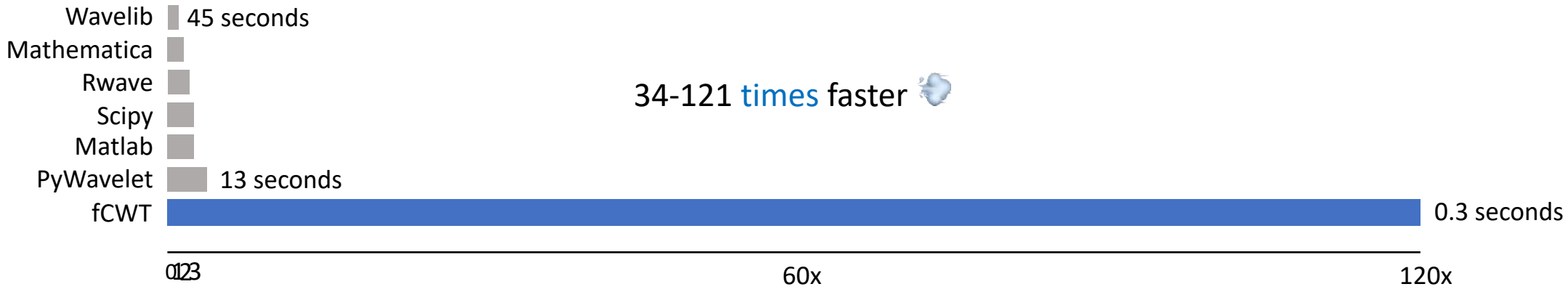


But… it's slow 🐌

CWT Implementations

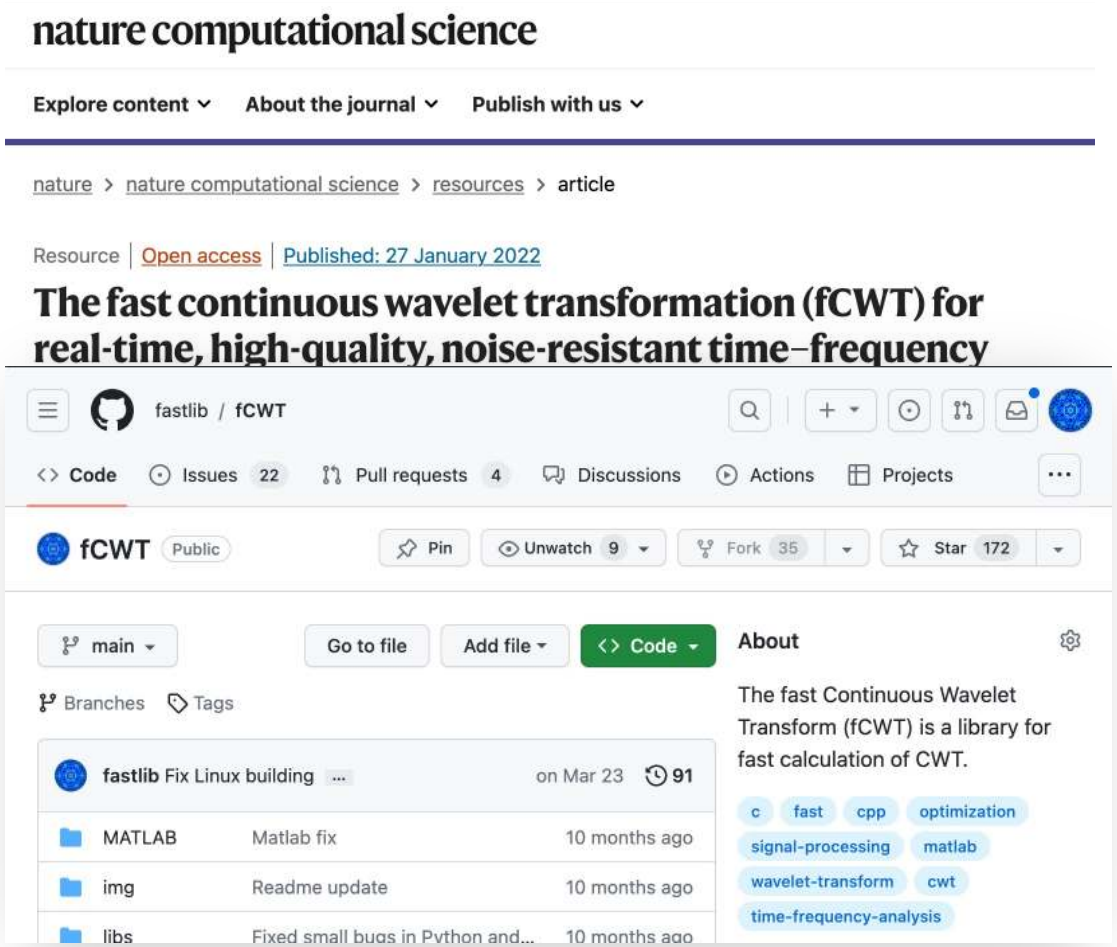


fCWT



More info during poster session: www.cyberneticslab.info/workshop-posters

fCWT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The fast continuous wavelet transformation (fCWT) for real-time, high-quality, noise-resistant time–frequency
fastlib / fCWT
Code
Issues 22
Pull requests 4
Discussions
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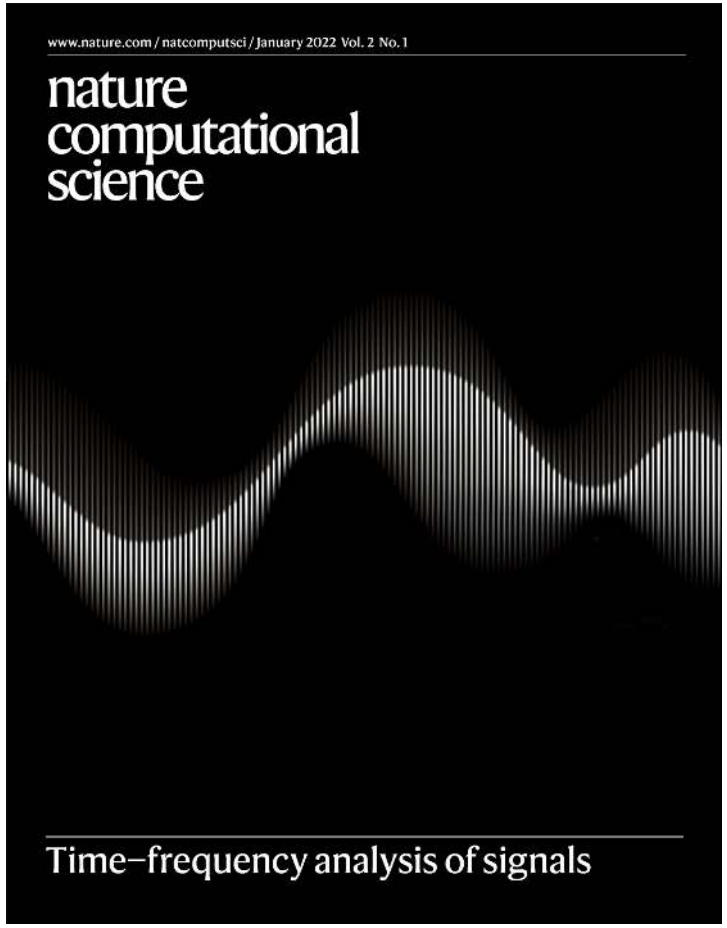
Projects
fCWT Public
Pin
Unwatch 9
Fork 35
Star 172
main
Go to file
Add file
Code
About
The fast Continuous Wavelet Transform (fCWT) is a library for fast calculation of CWT.
c
fast
cpp
optimization
signal-processing
matlab
wavelet-transform
cwt
time-frequency-analysis
Branches
Tags
fastlib Fix Linux building
on Mar 23
91
MATLAB
Matlab fix
10 months ago
img
Readme update
10 months ago
libs
Fixed small bugs in Python and...
10 months ago


www.nature.com / natcomputsci / January 2022 Vol. 2 No. 1
nature computational science
Time–frequency analysis of signals

L3 Cache pre-allocation

Single point precission

256-bit SIMD

fCWT is **FAST**…

… but also highly hardware **SPECIFIC**

AVX 2.0

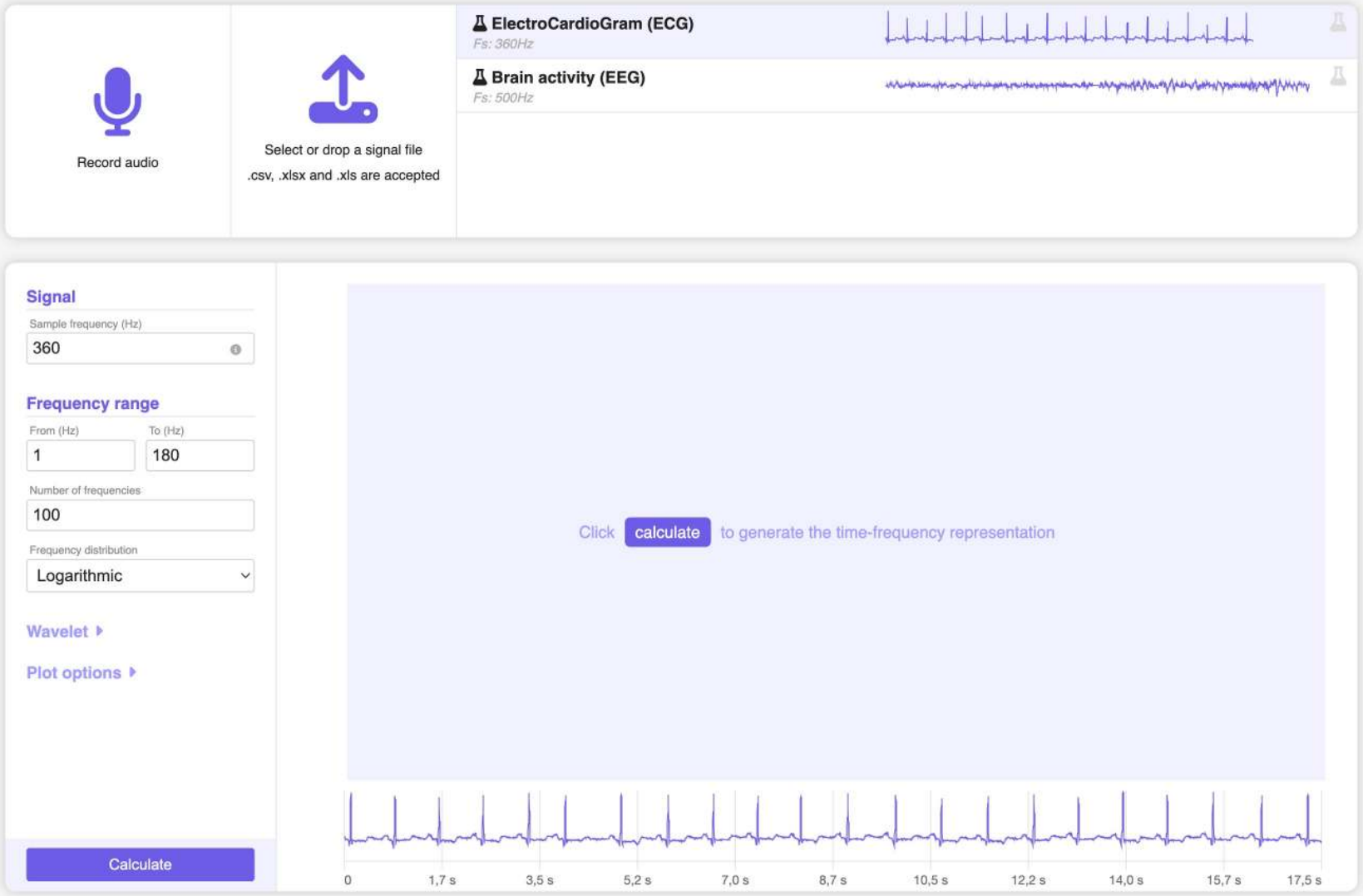
Multi-threading

Intel Intrinsics

FFTW

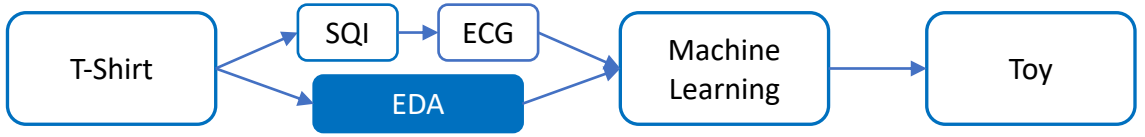
WebfCWT

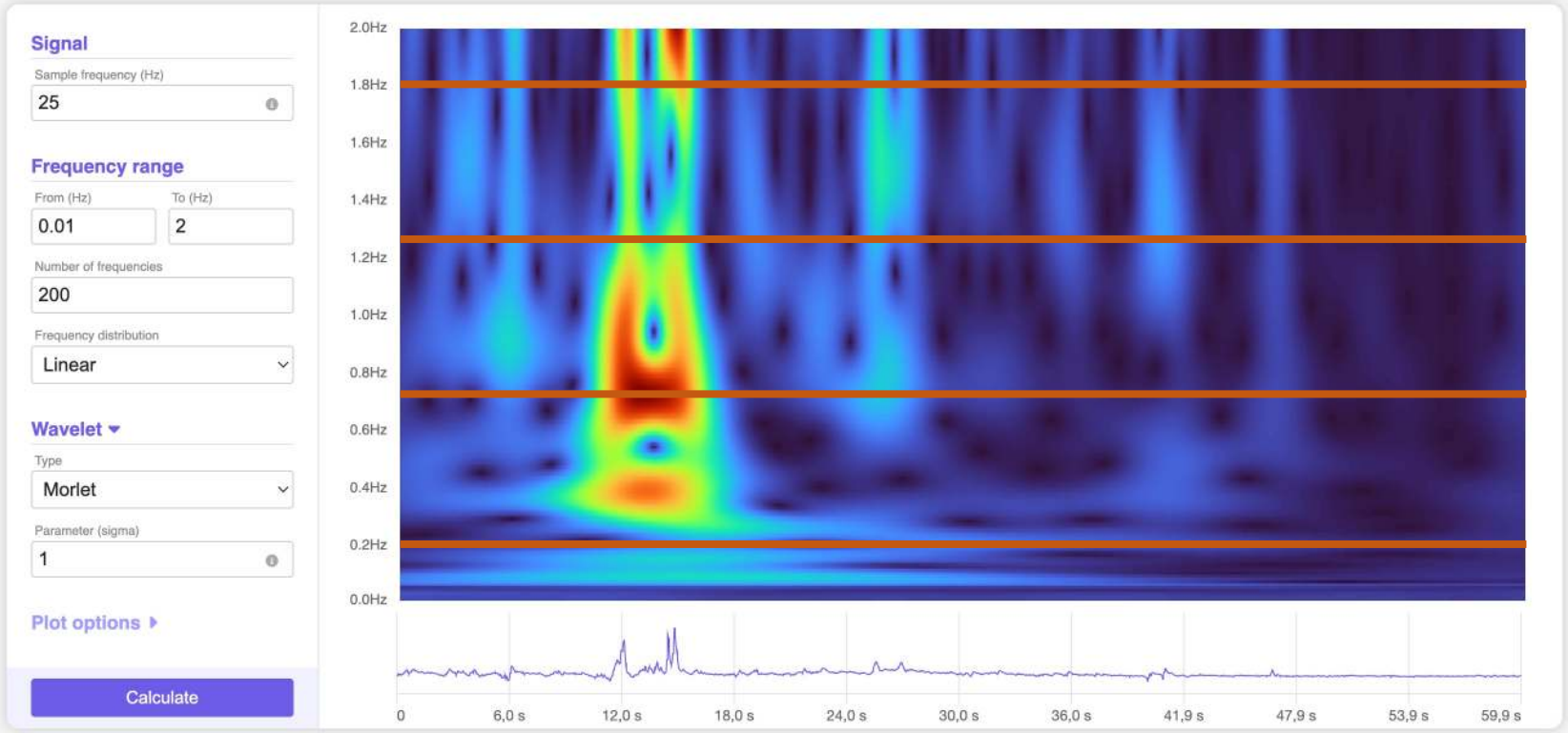
WEBASSEMBLY


Record audio
Select or drop a signal file
.csv, .xlsx and .xls are accepted
ElectroCardioGram (ECG)
Fs: 360Hz
Brain activity (EEG)
Fs: 500Hz
Signal
Sample frequency (Hz)
360
Frequency range
From (Hz)
To (Hz)
1
180
Number of frequencies
100
Frequency distribution
Logarithmic
Wavelet
Plot options
Calculate
Click calculate to generate the time-frequency representation
0
1,7 s
3,5 s
5,2 s
7,0 s
8,7 s
10,5 s
12,2 s
14,0 s
15,7 s
17,5 s

www.fcwt.app

EDA Signal


T-Shirt
SQI
ECG
EDA
Machine Learning
Toy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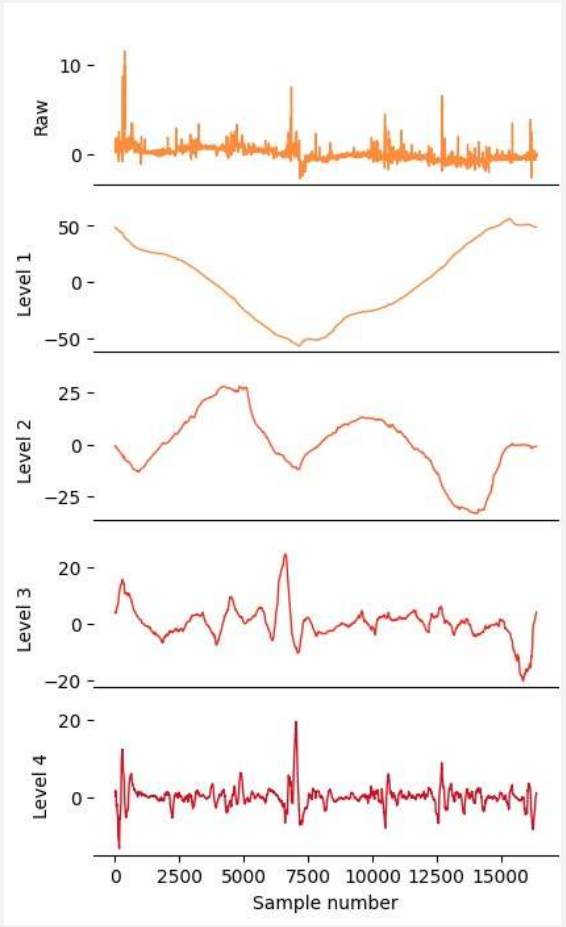
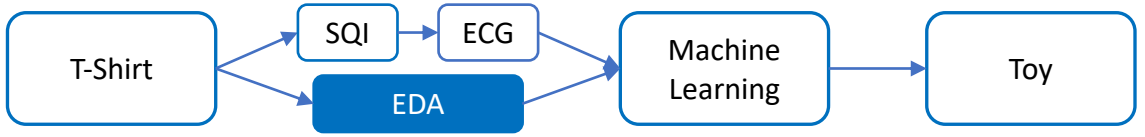
Sample frequency (Hz)
25
Frequency range
From (Hz)
0.01
To (Hz)
2
Number of frequencies
200
Frequency distribution
Linear
Wavelet
Type
Morlet
Parameter (sigma)
1
Plot options
Calculate
2.0Hz
1.8Hz
1.6Hz
1.4Hz
1.2Hz
1.0Hz
0.8Hz
0.6Hz
0.4Hz
0.2Hz
0.0Hz
0
6,0 s
12,0 s
18,0 s
24,0 s
30,0 s
36,0 s
41,9 s
47,9 s
53,9 s
59,9 s


Raw
10
0
Level 1
50
0
−50
Level 2
25
0
−25
Level 3
20
0
−20
Level 4
20
0
0
2500
5000
7500
10000
12500
15000
Sample number

EDA Signal


T-Shirt
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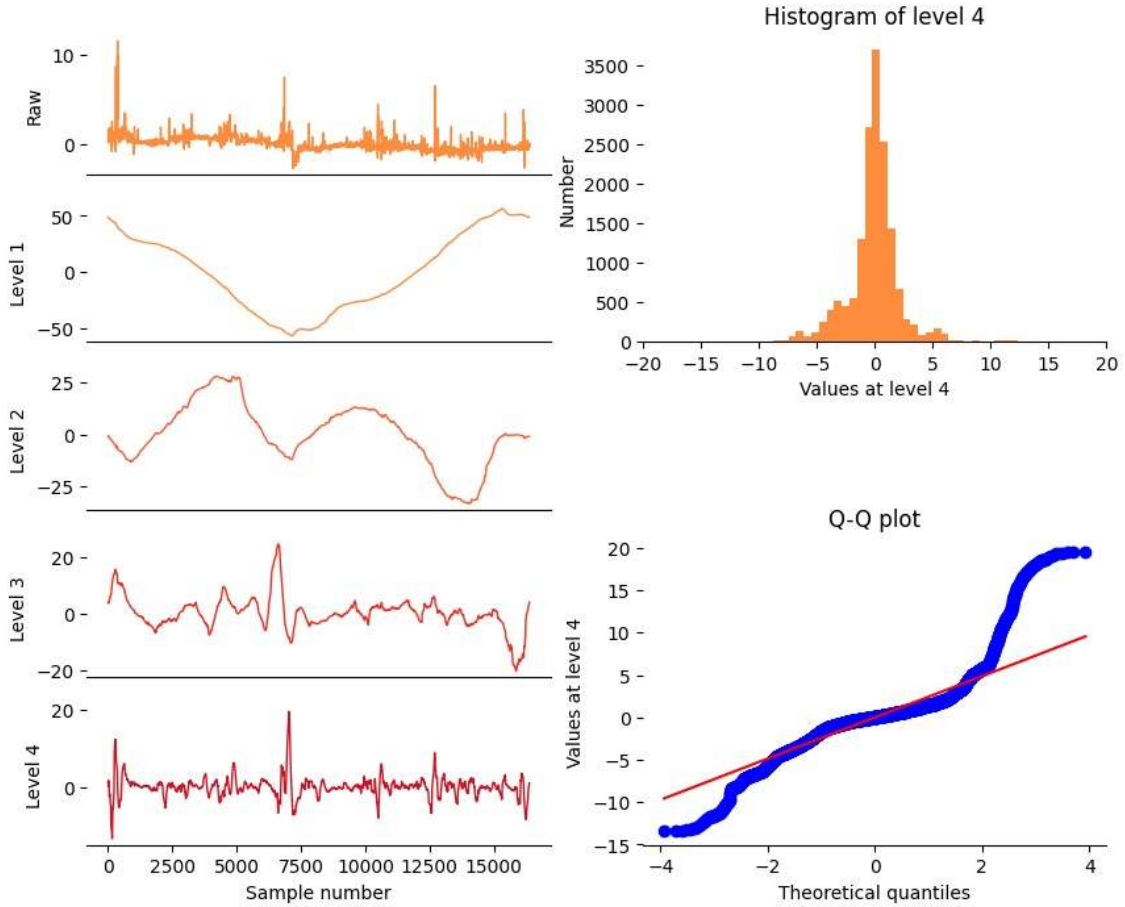
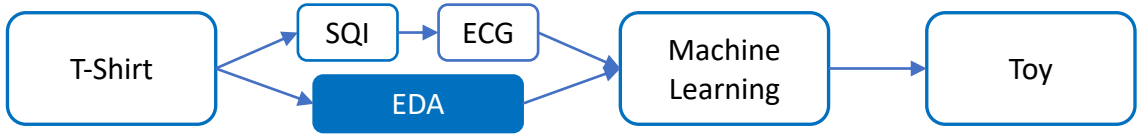
Toy


Raw
Level 1
Level 2
Level 3
Level 4
Sample number
Histogram of level 4
Number
Values at level 4
Q-Q plot
Values at level 4
Theoretical quantiles

EDA Signal


T-Shirt
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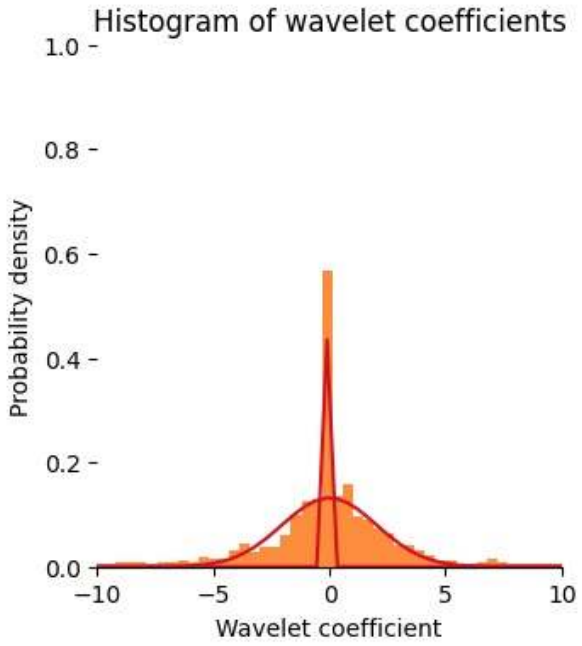
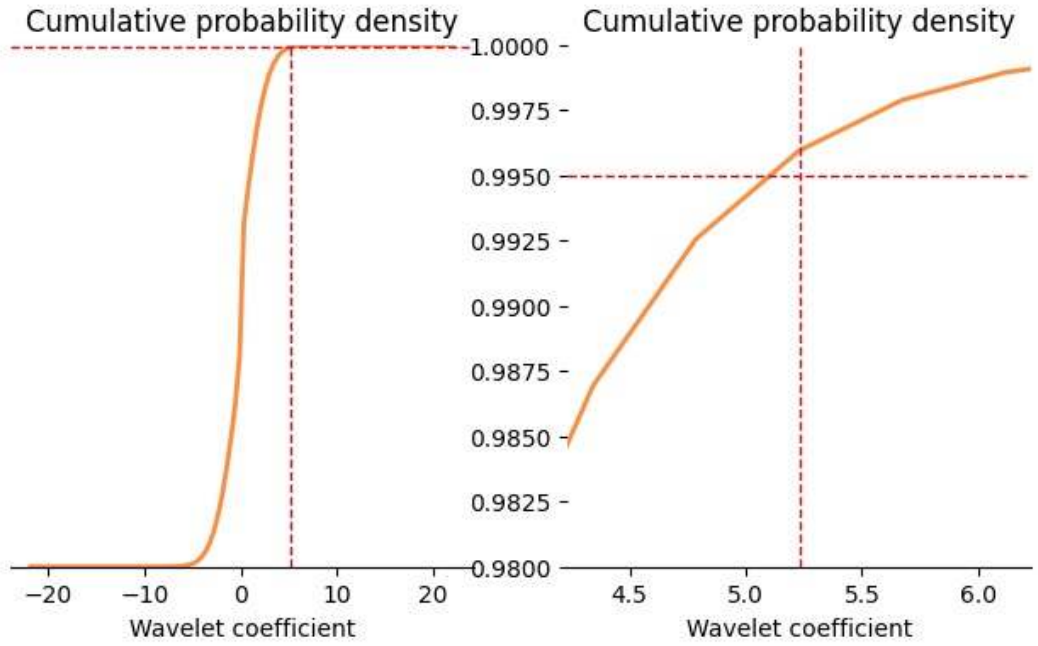
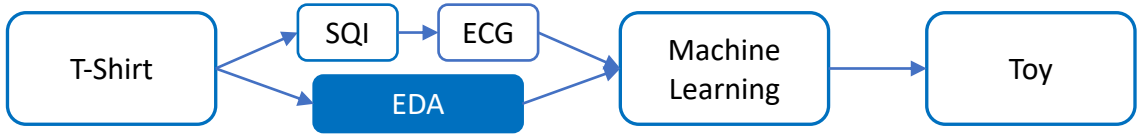
Machine Learning
Toy


Histogram of wavelet coefficients
Probability density
1.0
0.8
0.6
0.4
0.2
0.0
−10
−5
0
5
10
Wavelet coefficient


Cumulative probability density
1.0000
0.9975
0.9950
0.9925
0.9900
0.9875
0.9850
0.9825
0.9800
−20
−10
0
10
20
Wavelet coefficient
Cumulative probability density
4.5
5.0
5.5
6.0
Wavelet coefficient

EDA Signal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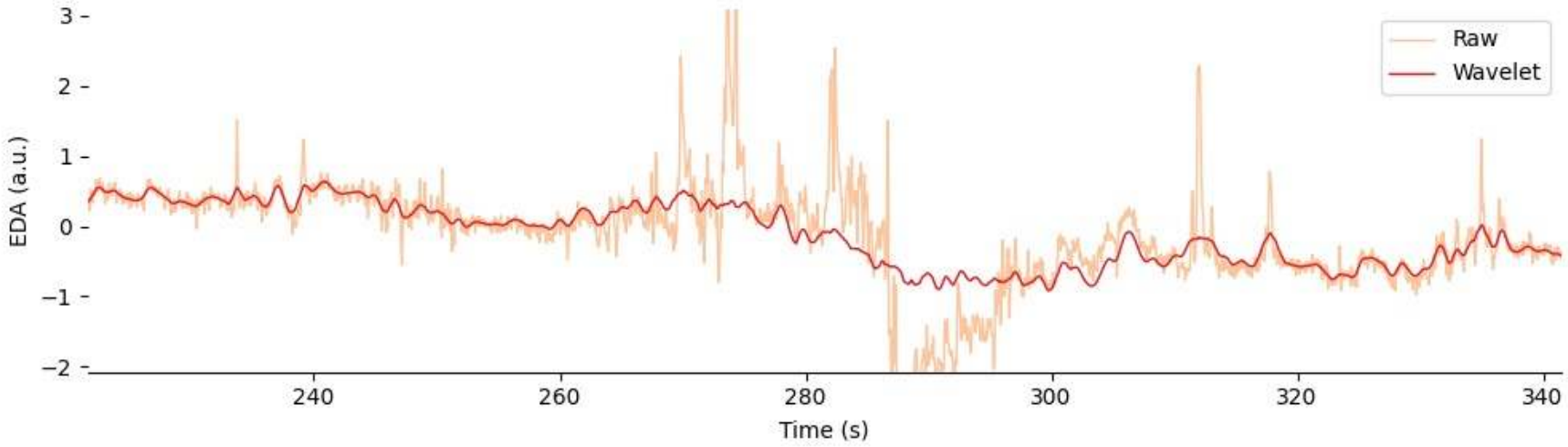
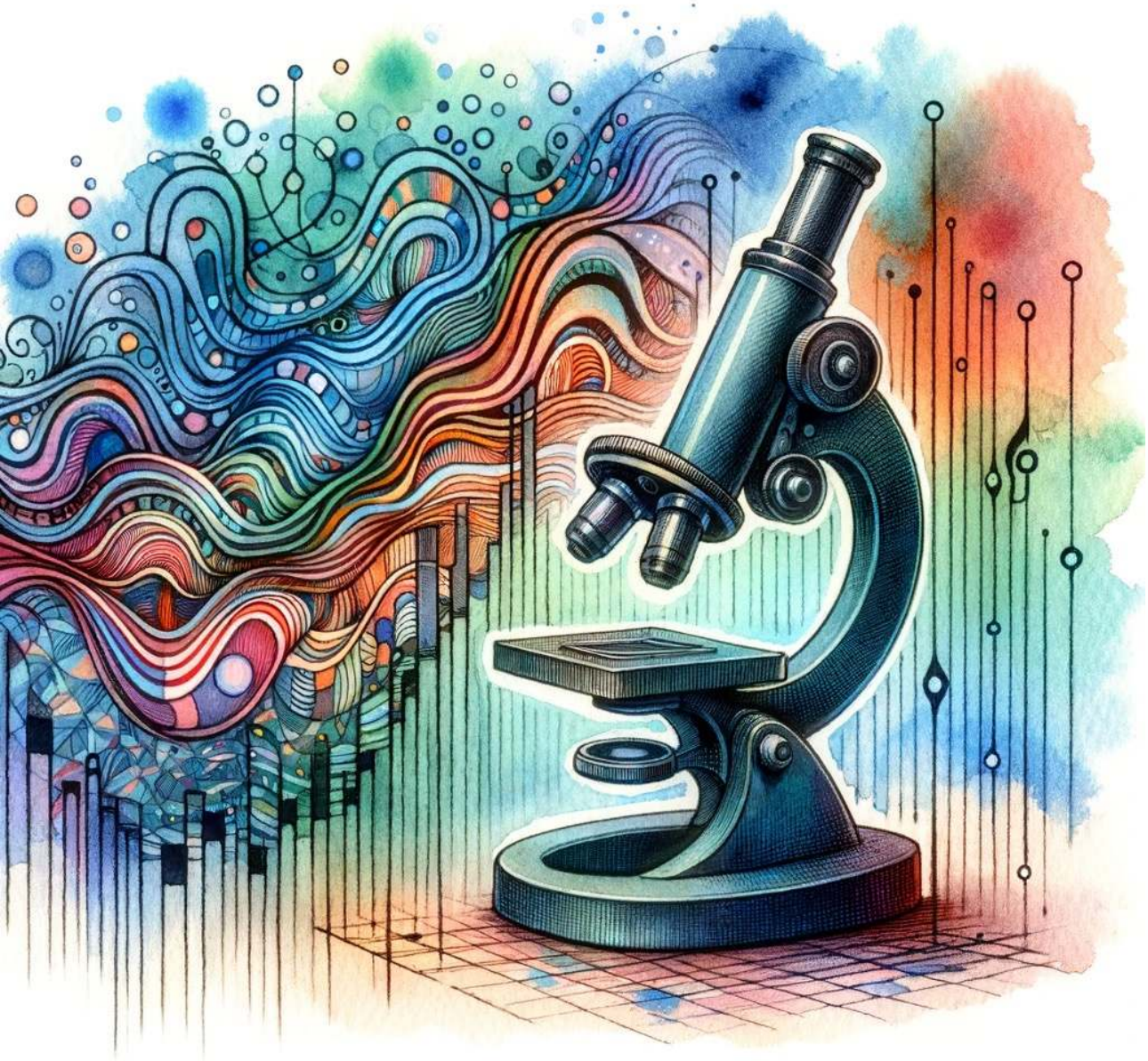
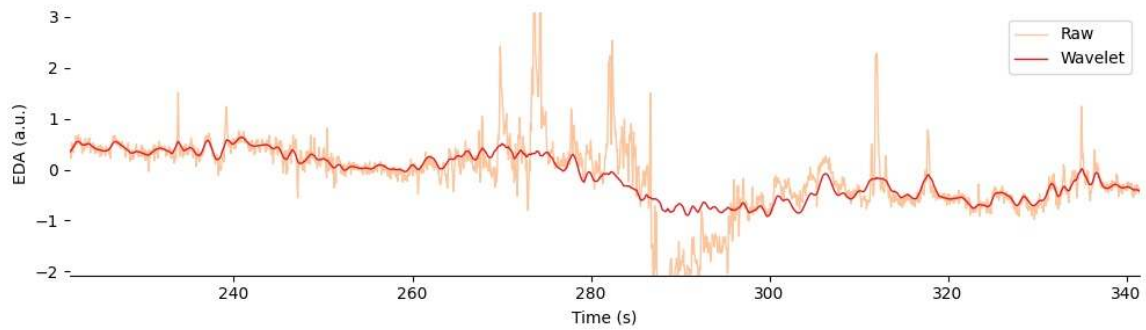
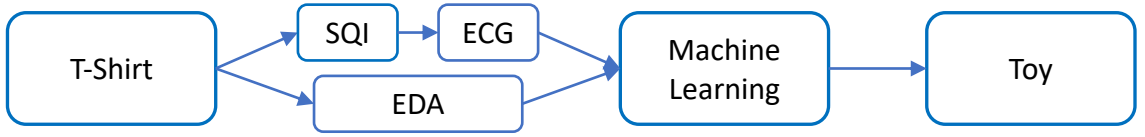
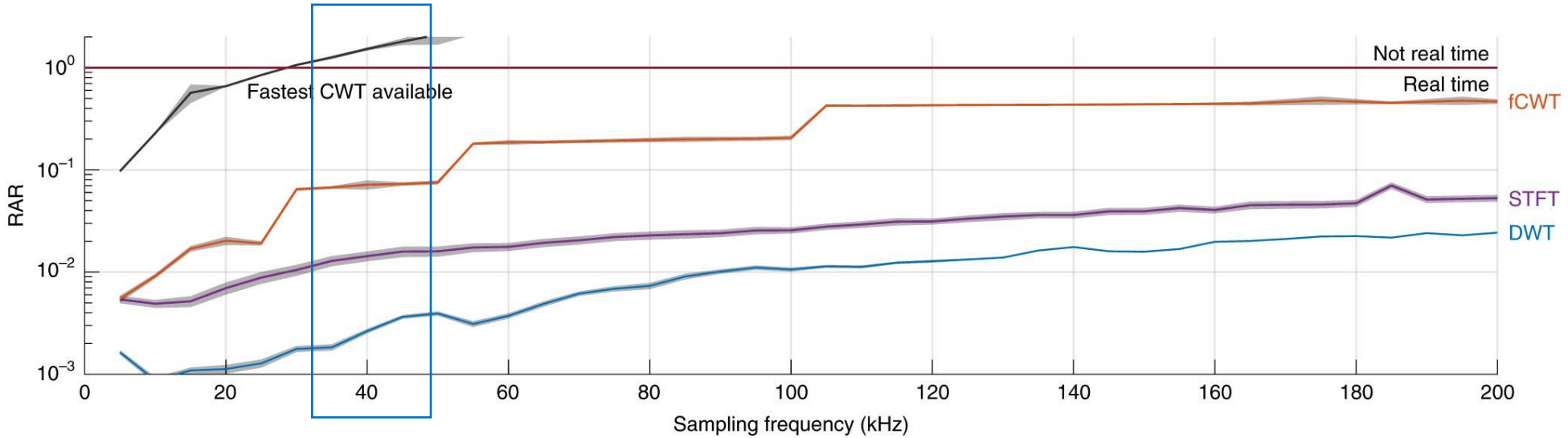
Toy


EDA (a.u.)
3
2
1
0
−1
−2
240
260
280
300
320
340
Time (s)
Raw
Wavelet



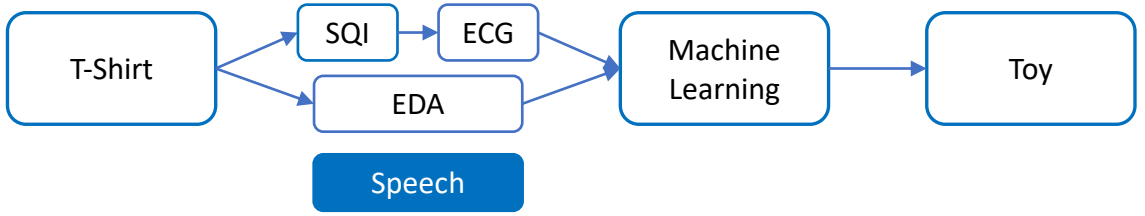

Raw
Wavelet
EDA (a.u.)
3
2
1
0
−1
−2
240
260
280
300
320
340
Time (s)


T-Shirt
SQI
ECG
EDA
Machine Learning
Toy


Not real time
Real time
Fastest CWT available
fCWT
STFT
DWT
RAR
10^{0}
10^{-1}
10^{-2}
10^{-3}
0
20
40
60
80
100
120
140
160
180
200
Sampling frequency (kHz)

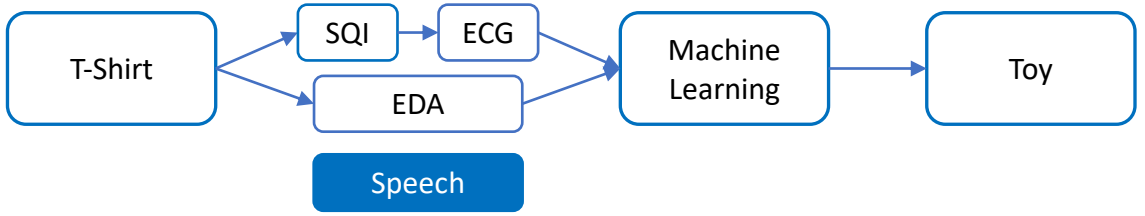
Speech

Speech

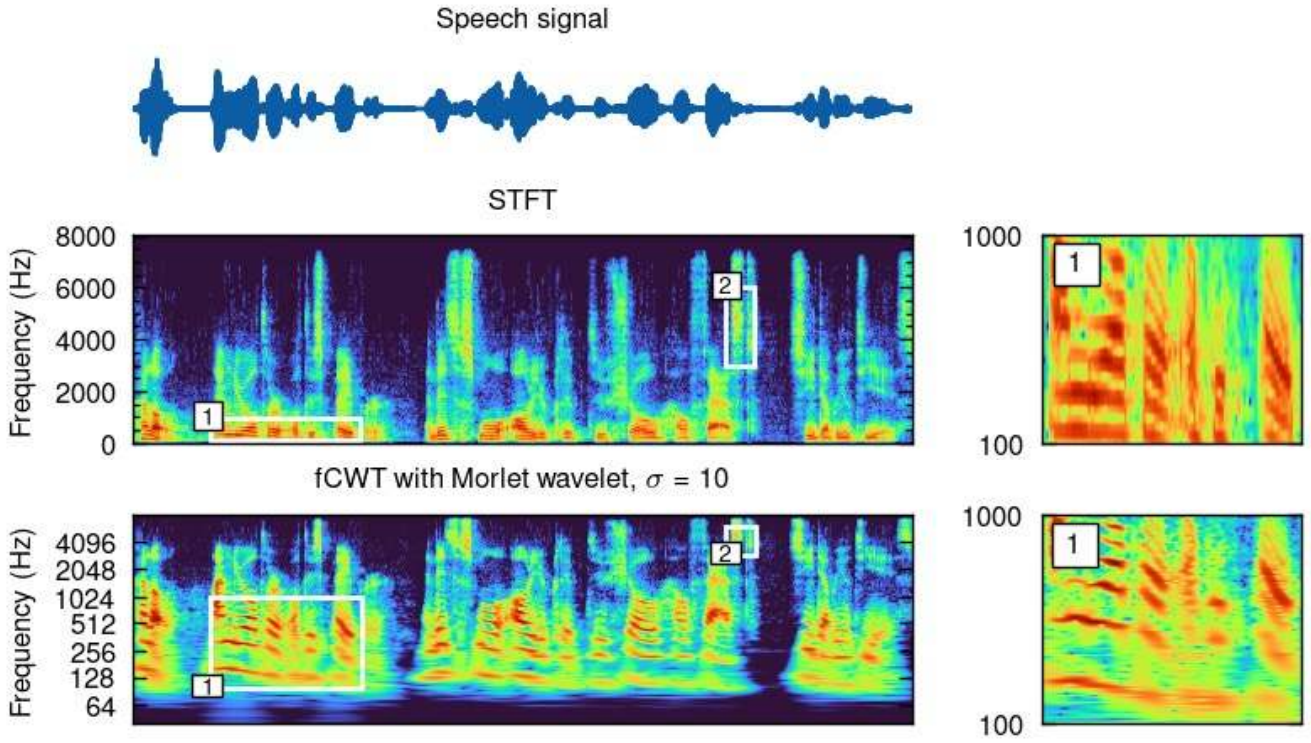


www.fcwt.app

Speech

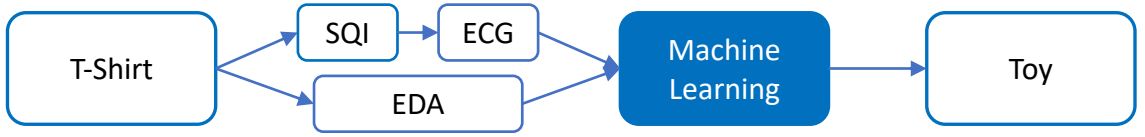


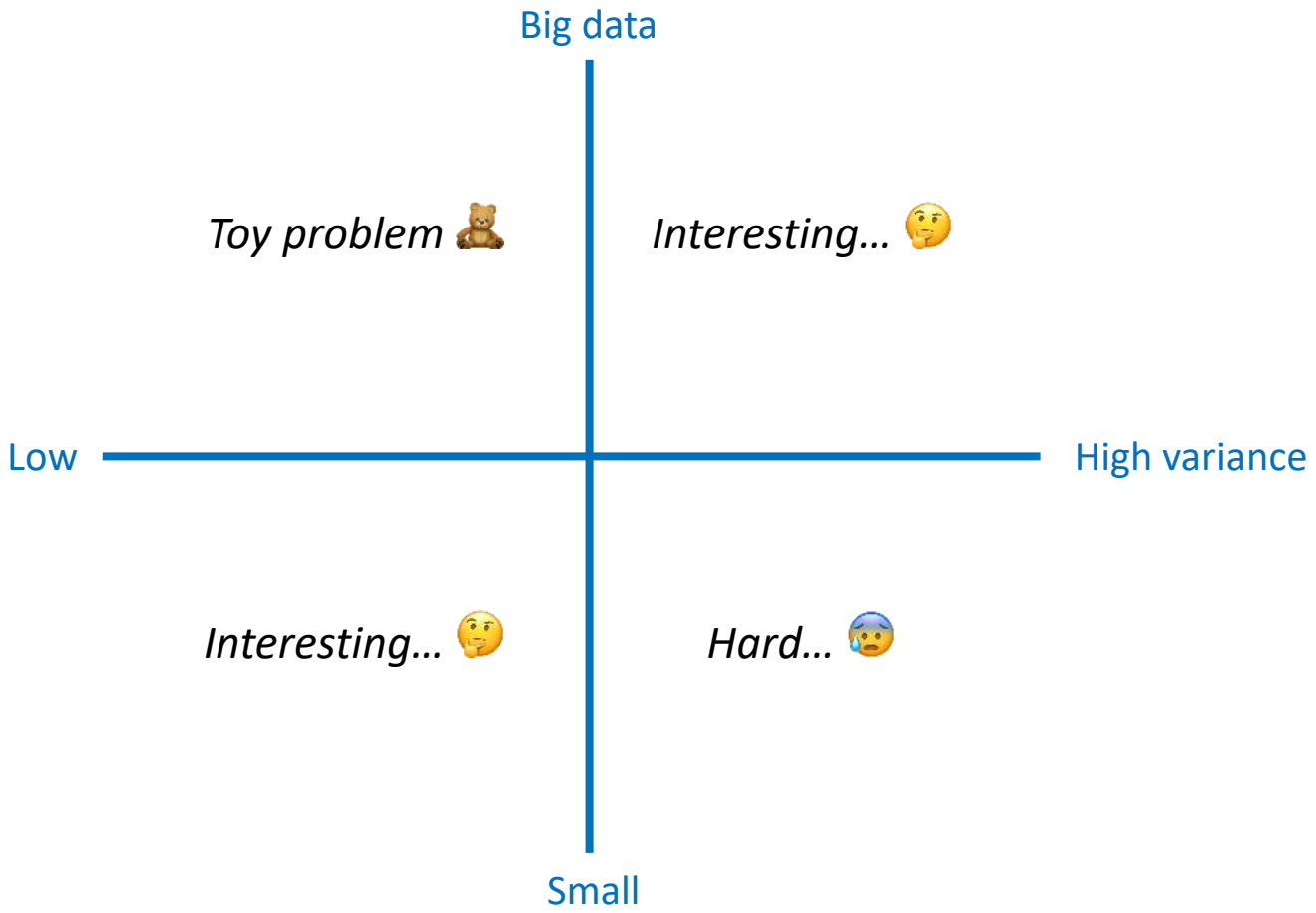
- Compared fCWT to STFT
- EMO-DB and eNTERFACE05
- Deep Convolutional Neural Network (DCNN)
- Promising results



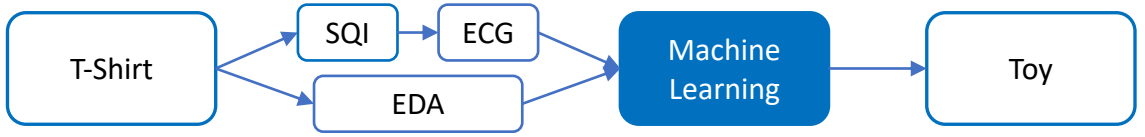
Machine learning

… or maybe not



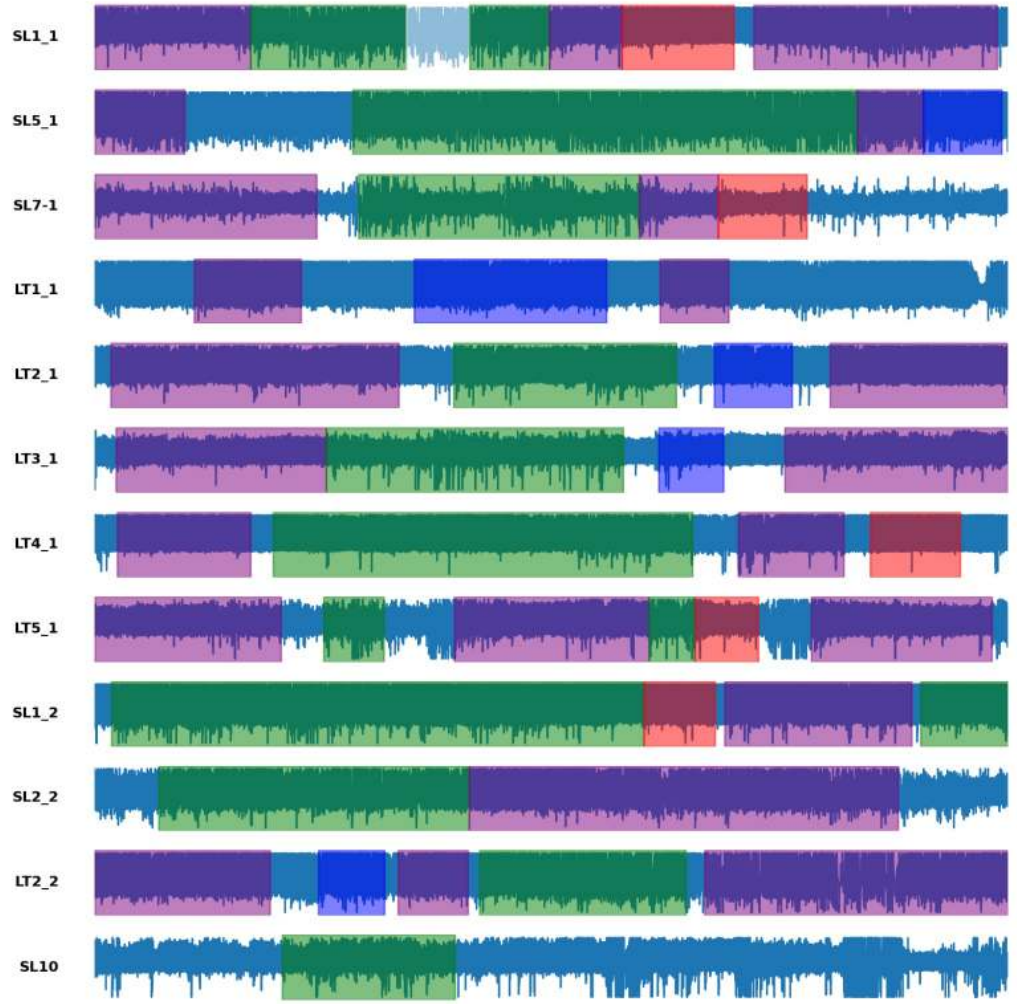


Machine learning



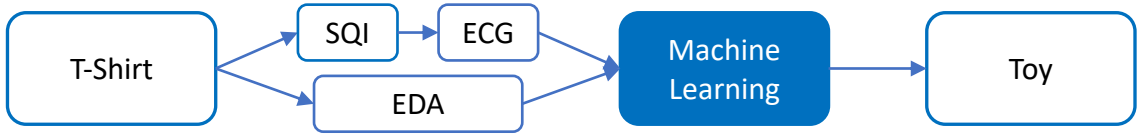
Dataset

- 16 measurements
  - 8 happy (positive, high arousal)
  - 4 angry/frustrated (negative, high arousal)
  - 4 relaxed (neutral, low arousal)



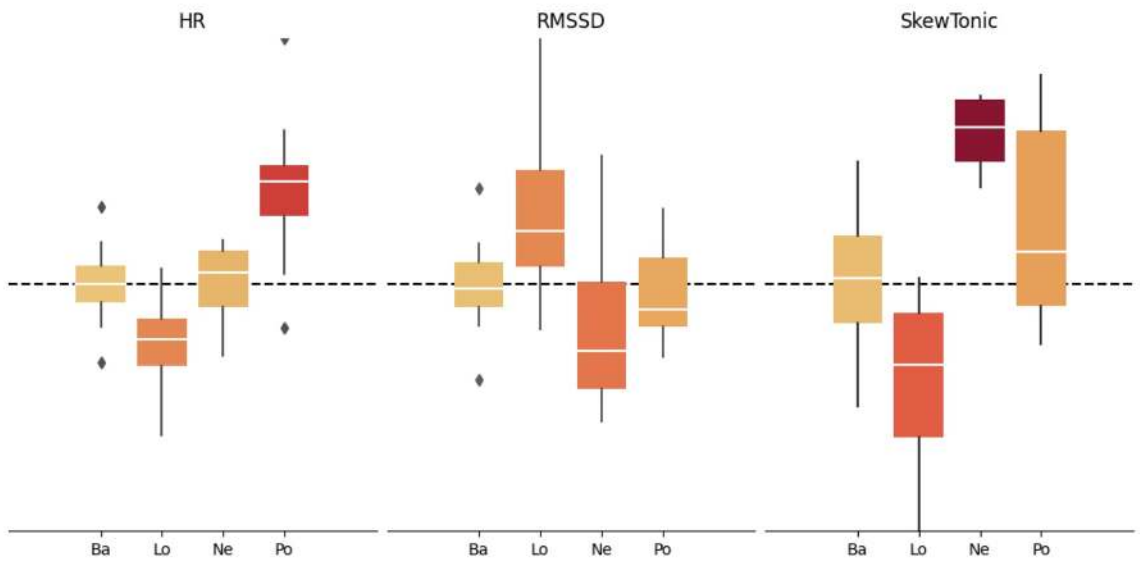
Baseline
Happy
Angry/frustrated
Relaxed

Machine learning



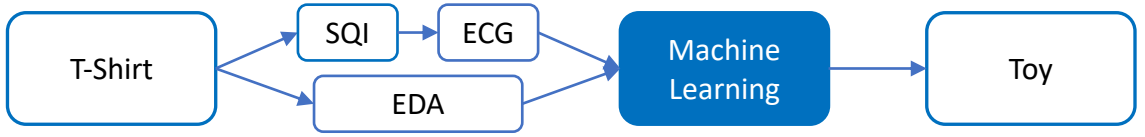
Methods

- Selected 3 knowledge-based features
  - Heart rate (HR)
  - Root Mean Squared of Successive Differences (RMSSD)
  - Skewness of Tonic EDA (SkewTonic)



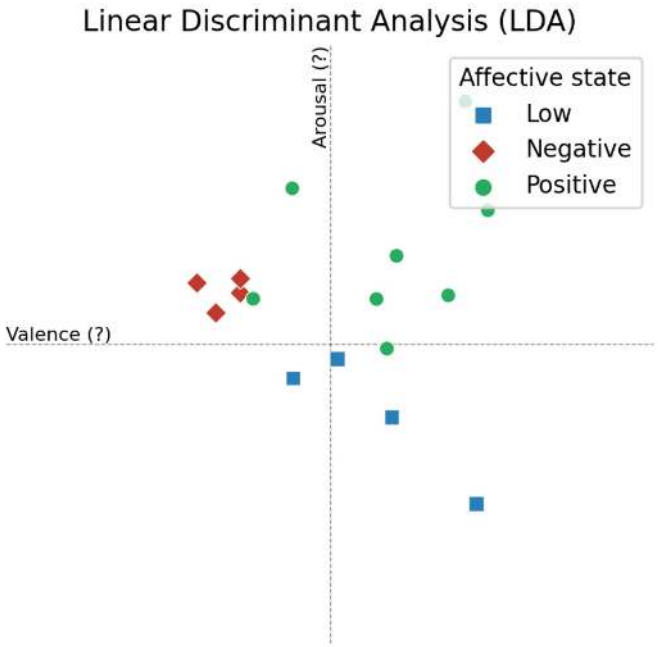
Baseline normalized features

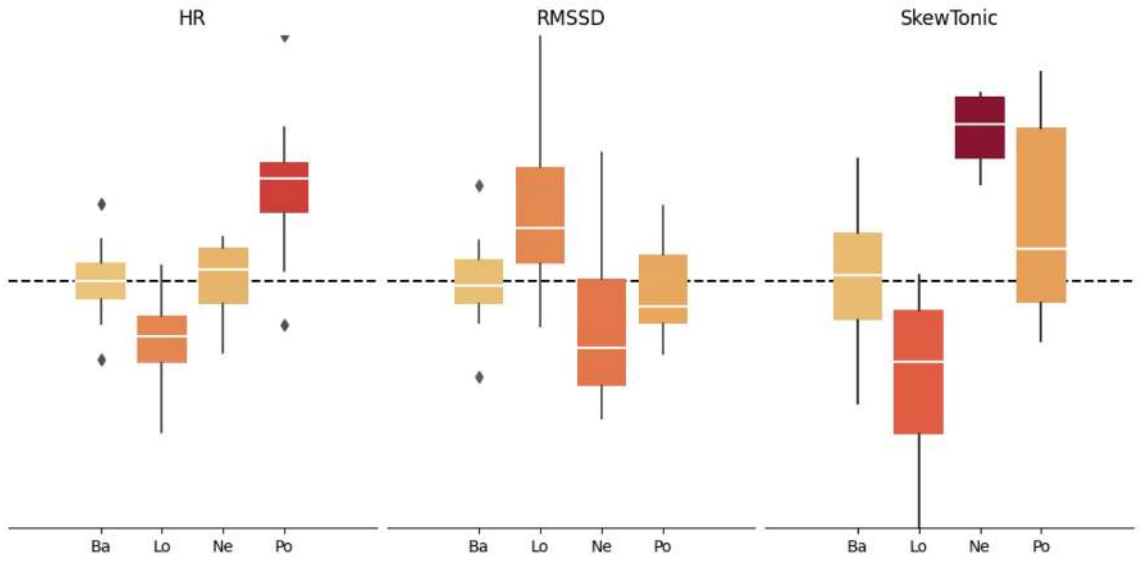
Machine learning



Results

- Significant results using MANOVA statistical test (p=*.006*)

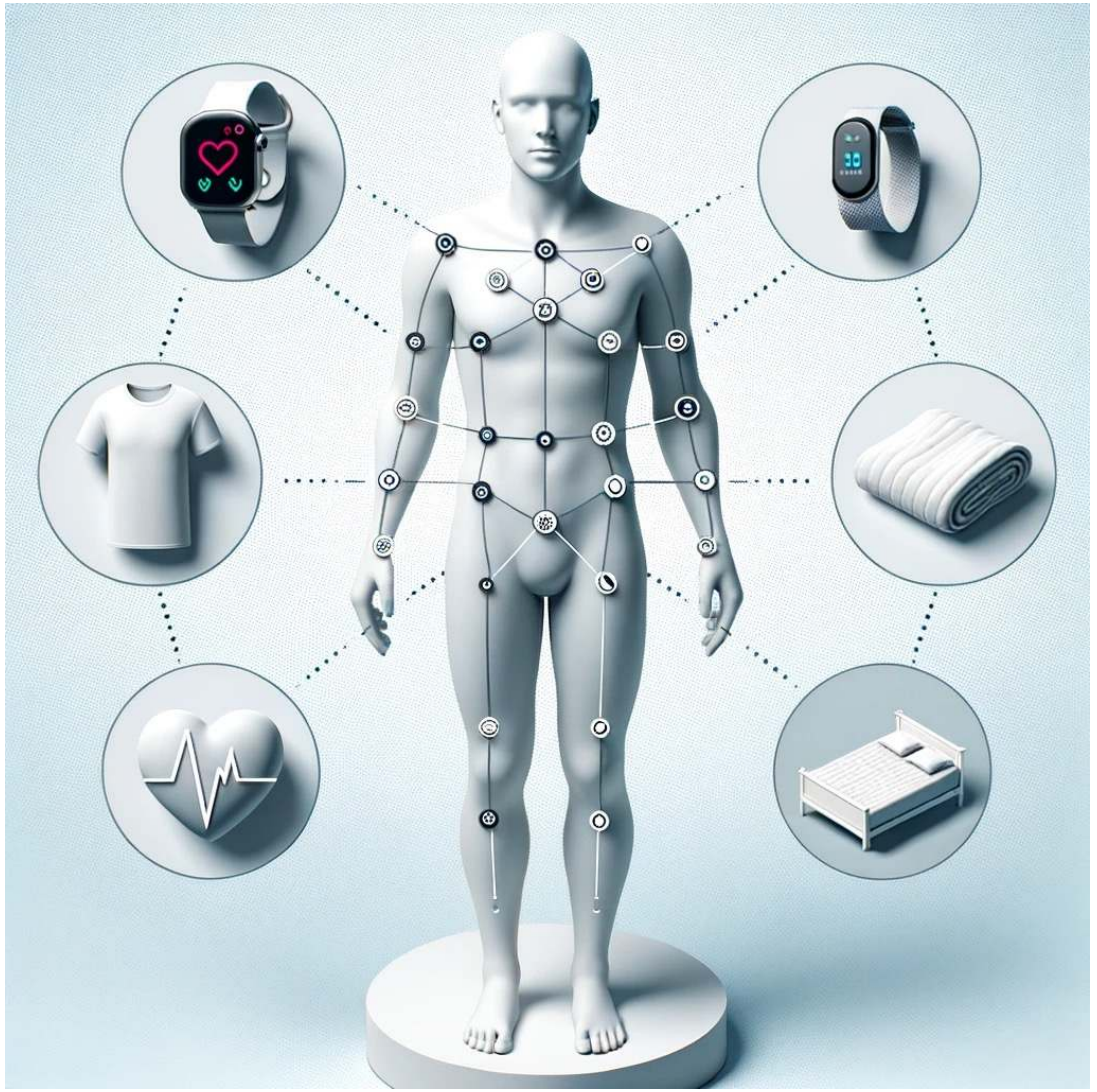




Baseline normalized features

Outlook

- Promising results but more data required
- Translates to remote healthcare solutions
- Smart clothing, smart sheets, etc…
- Cardiac monitoring, early diagnosis
- Improve Human-Robot Interaction
- Closing the loop



Questions?

ANNELOES MEIJER - CONTACT: A.L.MEIJER@UU.NL

AFFECTIVE HUMAN-ROBOT INTERACTION USING BIOSIGNALS

Utrecht University

Honda Research Institute

Electrodermal Activity (EDA)

We performed an evaluation of continuous EDA signals against continuous self-reported arousal. The study is an extension of our earlier work [1]. We present results of lab and wearable devices. With positive correlations between EDA features and self-report, it shows that EDA can be a promising avenue for real-world and real-time stress and arousal detection.

Figure 1. A segment of an idealistic EDA signal.

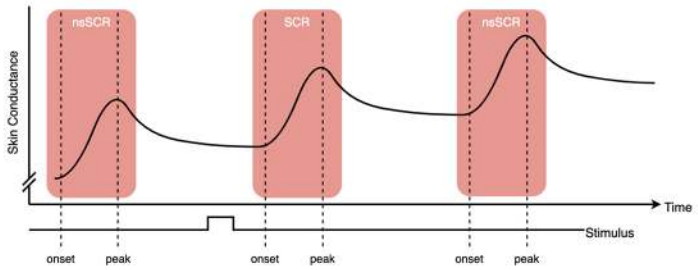


Figure 2. EDA features and their correlation to self-reported arousal.

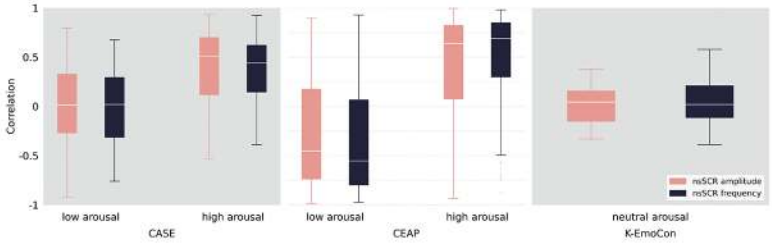


Figure 3a. Example EDA features against self-report; 20 Hz.

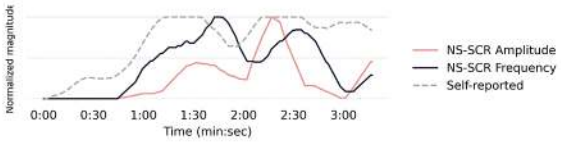


Figure 3b. Example EDA features against self-report; 4 Hz.

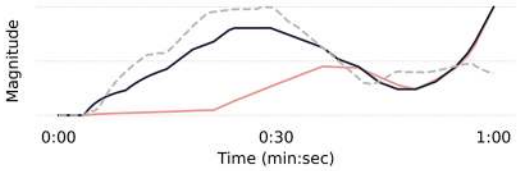
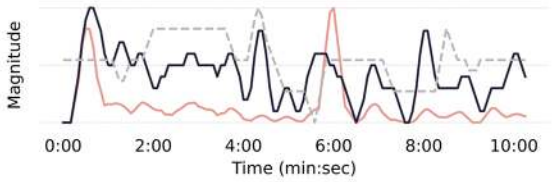


Figure 3c. Example EDA features against self-report; 0.2 Hz.



Empatica E4 Wristband

Our next project!

Let's connect Empatica to Haru!

The wristband measures:

- Electrodermal Activity
- Blood Volume Pulse
- Skin Temperature
- Accelerometer

Try the Empatica E4 yourself!

[1] A.L. Meijer, L.P. Arts, R. Gomez and E.L. van den Broek (2023) Towards Continuous Monitoring of Well-Being., in: Workshop Proceedings of the 19th International Conference on Intelligent Environments, pp. 196–205.
[2] A.L. Meijer, L.P. Arts, R. Gomez and E.L. van den Broek (Under Review) Electrodermal Activity: Continuous Monitor of Well-Being, in: Journal of Smart Cities and Society.

nature computational science

The fast Continuous Wavelet Transform (fCWT)

Real-time, high-quality, noise-resistant time-frequency analysis

Lukas P. A. Arts ✉ & Egon L. van den Broek ✉
Departement of Computing Science
Utrecht University

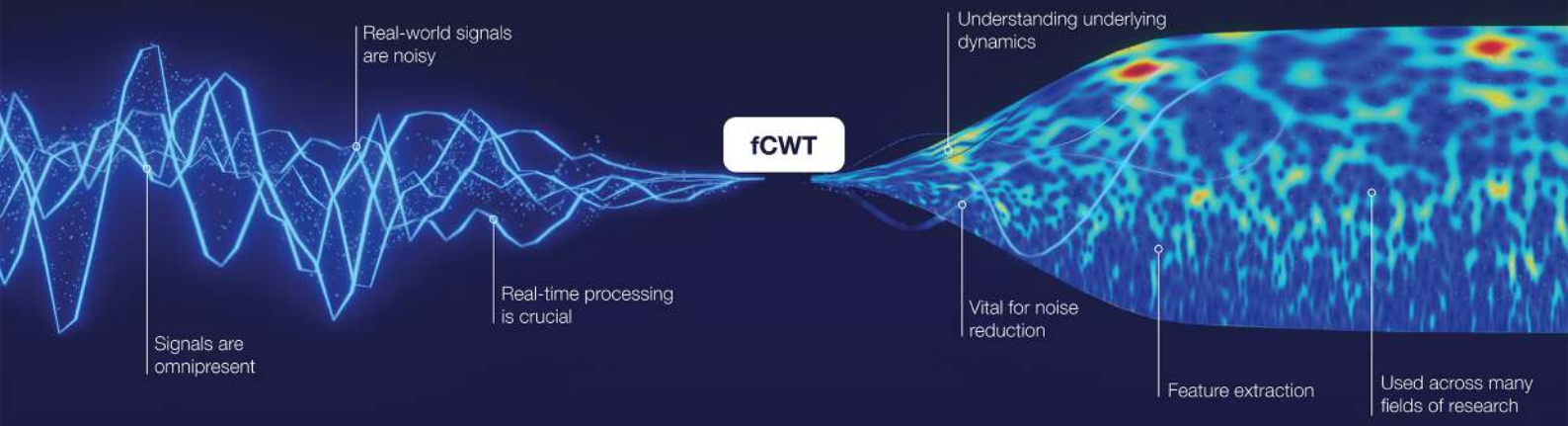
Signals are everywhere. They allow communication between a sender and a receiver (listener). Unfortunately, real-world signals are often noisy. For example, following a conversation during a loud party. Frequency analysis makes processing easier as it dissects a signal into distinct frequencies which can be analysed separately.

A Fourier Transformation is often the first method used. This is perfect for static signals. However, when a signal's frequency changes over time, FT cannot be used anymore. Then a Continuous Wavelet Transformation is needed. Unfortunately, its dynamic tracking ability also makes CWT very slow limiting its use in real-time, low-hardware contexts. As a solution, we developed fCWT, a highly optimised C++ implementation of the CWT.

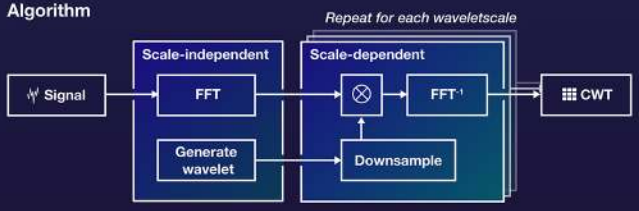
How does CWT work?
Wavelets stretch and shrink to measure different frequencies and move to measure the position of these frequencies using convolution.

Time-Amplitude

Time-Frequency spectrum



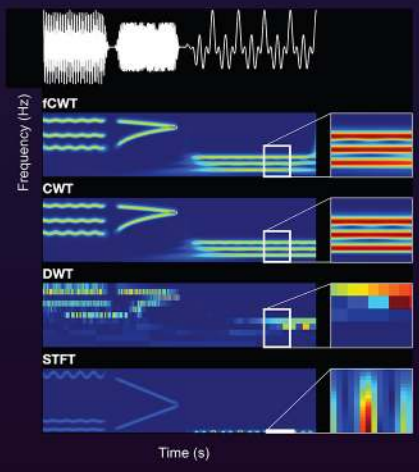
Algorithm



Benchmark against other CWT implementations

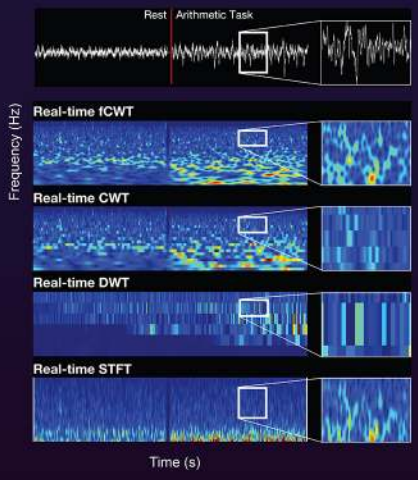
Synthetic data

Superb and equal accuracy when compared to CWT and other methods.



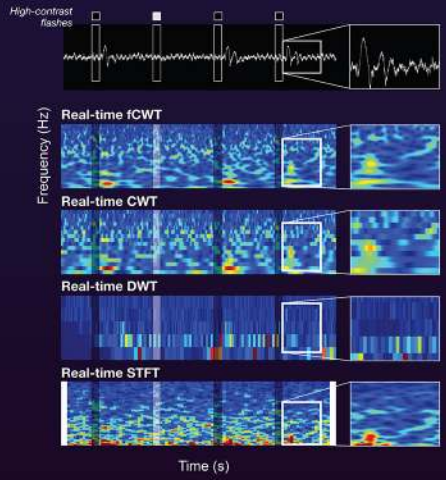
ElectroEncephaloGraphy (EEG)

Real-time, high-resolution analysis of noisy and non-stationary EEG



High-density in vivo analysis

Real-time, simultaneous analysis of electrodes in the visual cortex



Discussion

fCWT is 34-121x faster than its competitors while featuring an exact calculation of the CWT instead of approximations. Performance is wavelet- and signal-type independent making fCWT suitable for a broad range of signals.

As CWT underlies many other time-frequency methods, its speed can be translated to other techniques as well. Limitations are inherited from CWT as the implementation is mathematically the same.

Conclusion

fCWT allows acceleration in science, engineering, industry and health. It brings offline research to real-time practice by providing an open-source repository and framework in three languages (Python, Matlab, and C++)

im twin
Funded by European Union's Horizon 2020 research and innovation program under grant agreement no. 952095, from Intrinsic Motivations to Transitional Wearable INtelligent companions for autism spectrum disorder (IM-TWIN)

Universiteit Utrecht

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