

**Théophile Mohr Durdez**

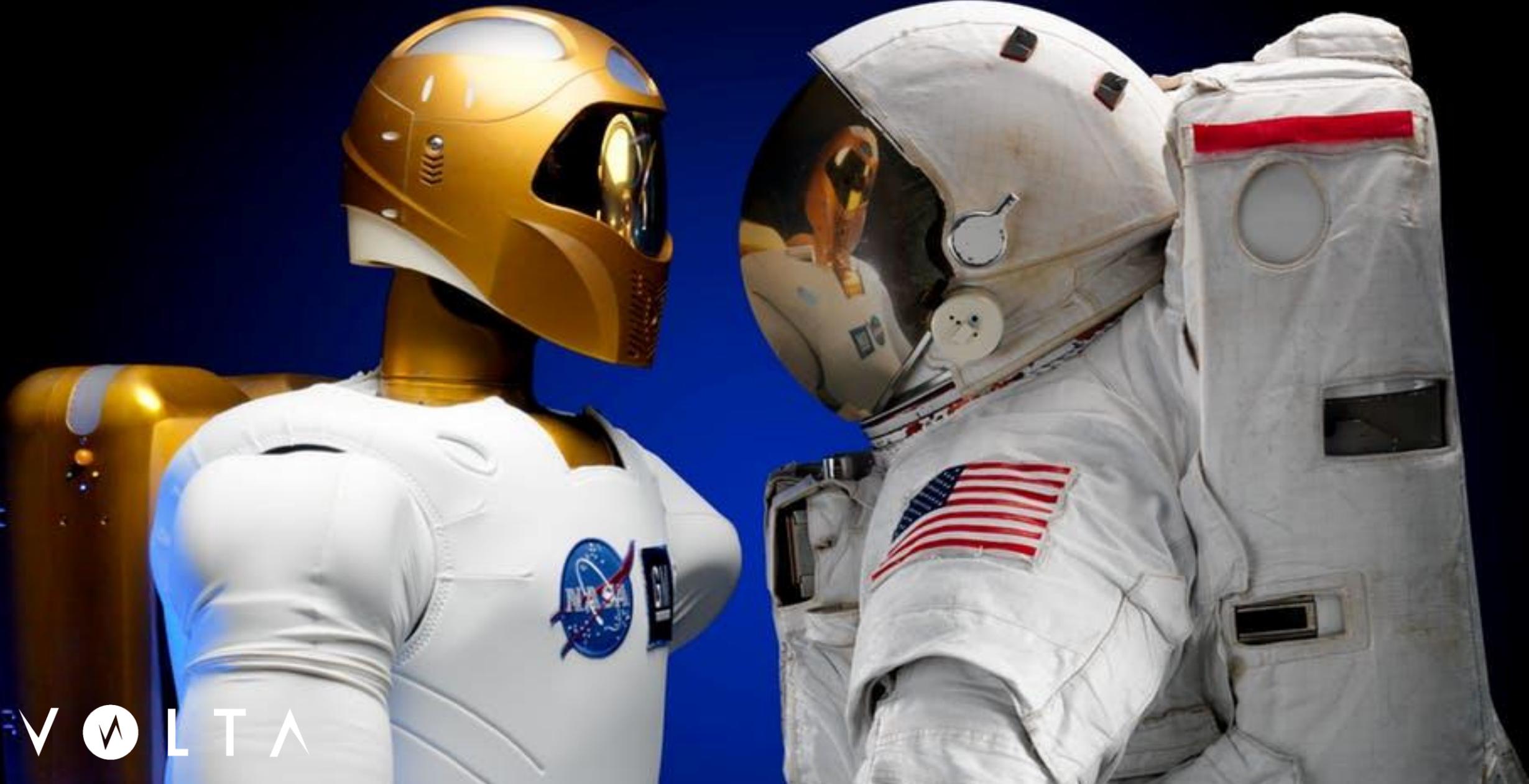
CEO, Volta Medical

Intelligence artificielle et  
Cardiologie: des algorithmes  
à l'application médicale

*JAT – Nice 2020*

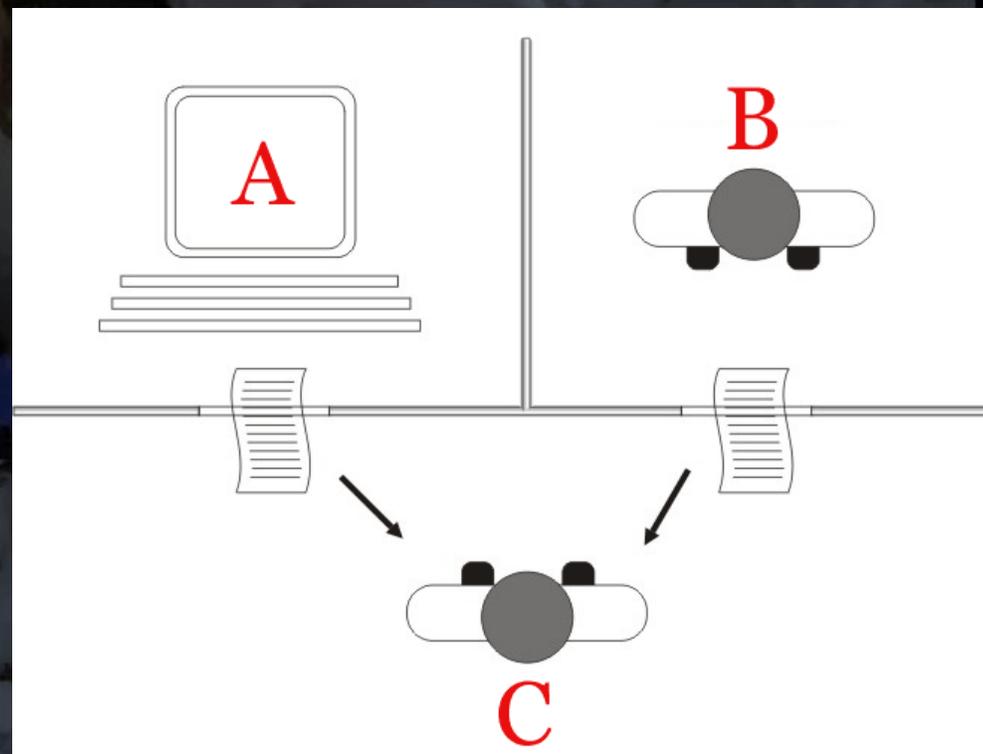
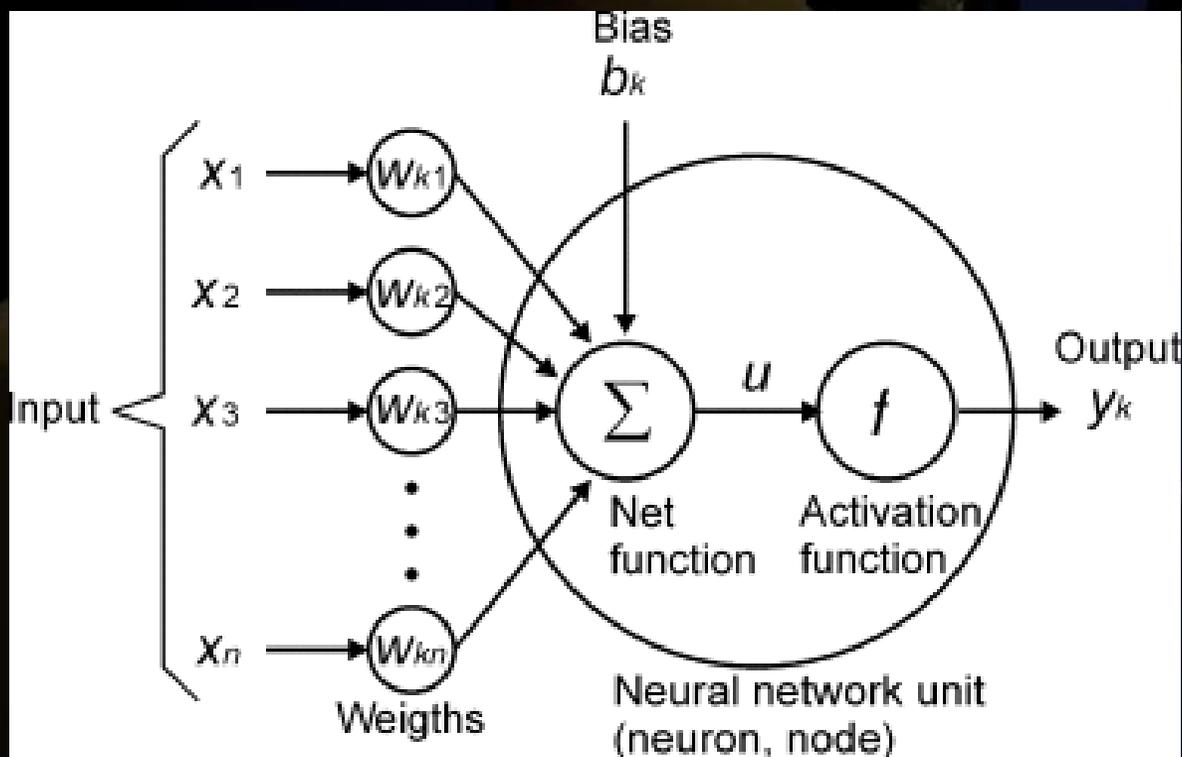
*12/SEP/2020*

# L'avènement de l'Intelligence Artificielle?



# Une vieille histoire

Premier article sur le potentiel des réseaux de neurones artificiels



# Go

## 2016

### AlphaGo gagne face à Lee Sedol



# Poker

2017

Libratus gagne face à champions du monde



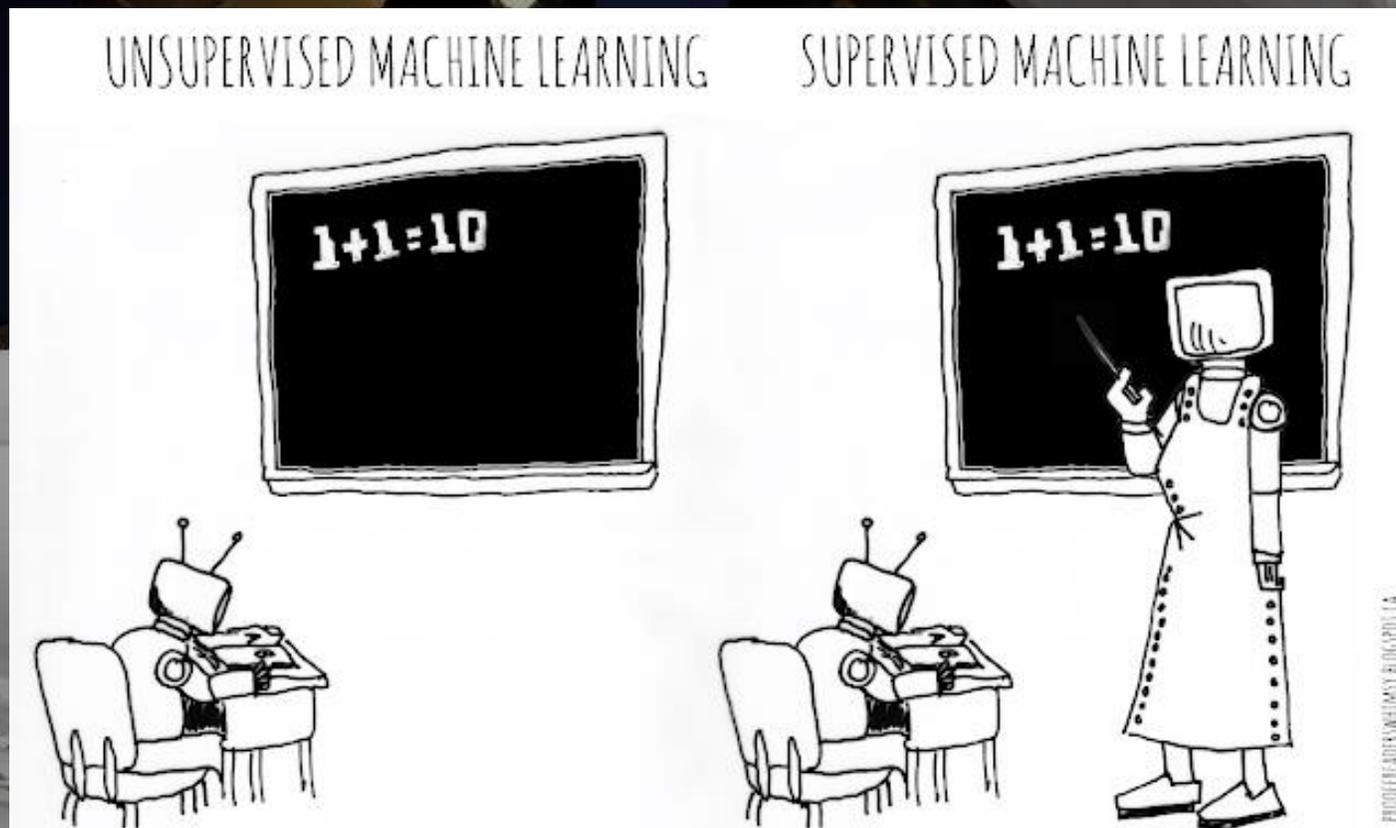


**Qu'est-ce que l'IA?**

The image shows two astronauts in space suits. The astronaut on the left is wearing a gold helmet and a white suit with a NASA logo on the chest. The astronaut on the right is wearing a white helmet and a white suit with an American flag patch on the chest. The background is a dark blue gradient.

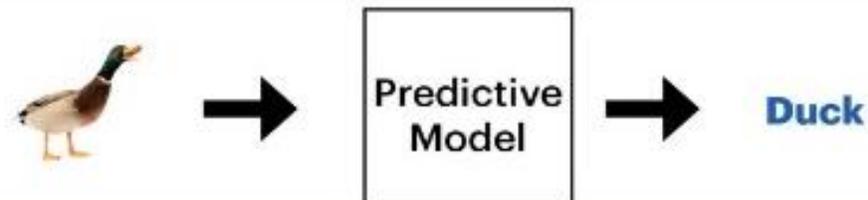
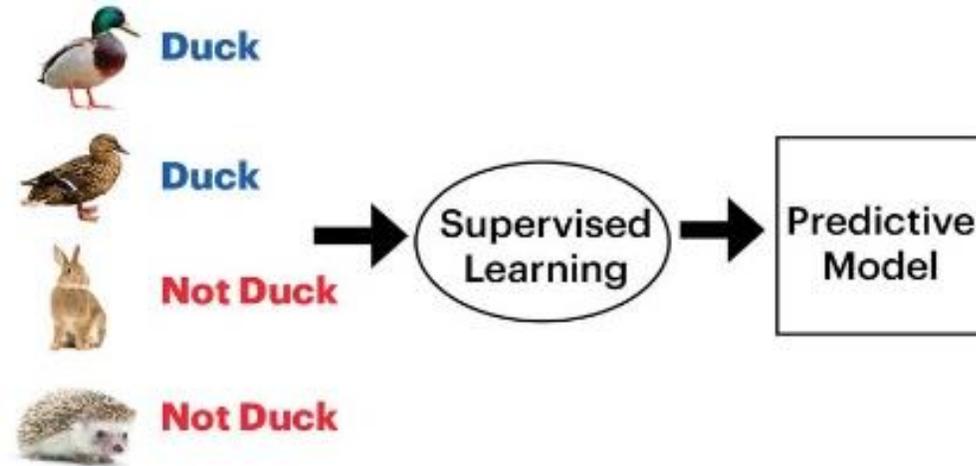
# 1. Apprentissage

# 1. Deux types d'apprentissage



# A. Apprentissage Supervisé

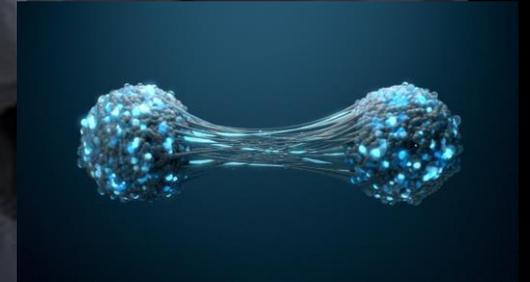
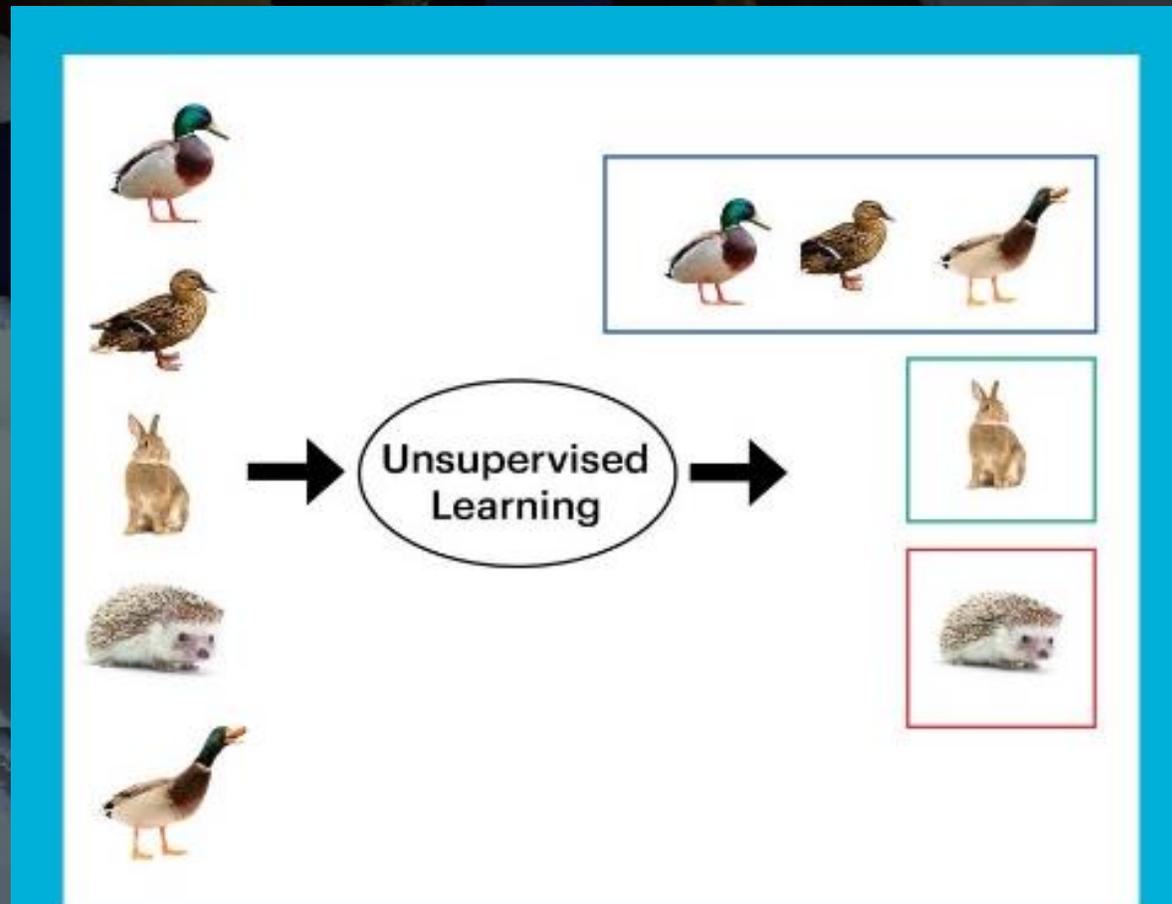
Utilisation d'information humaine pour "aider" lors de l'apprentissage

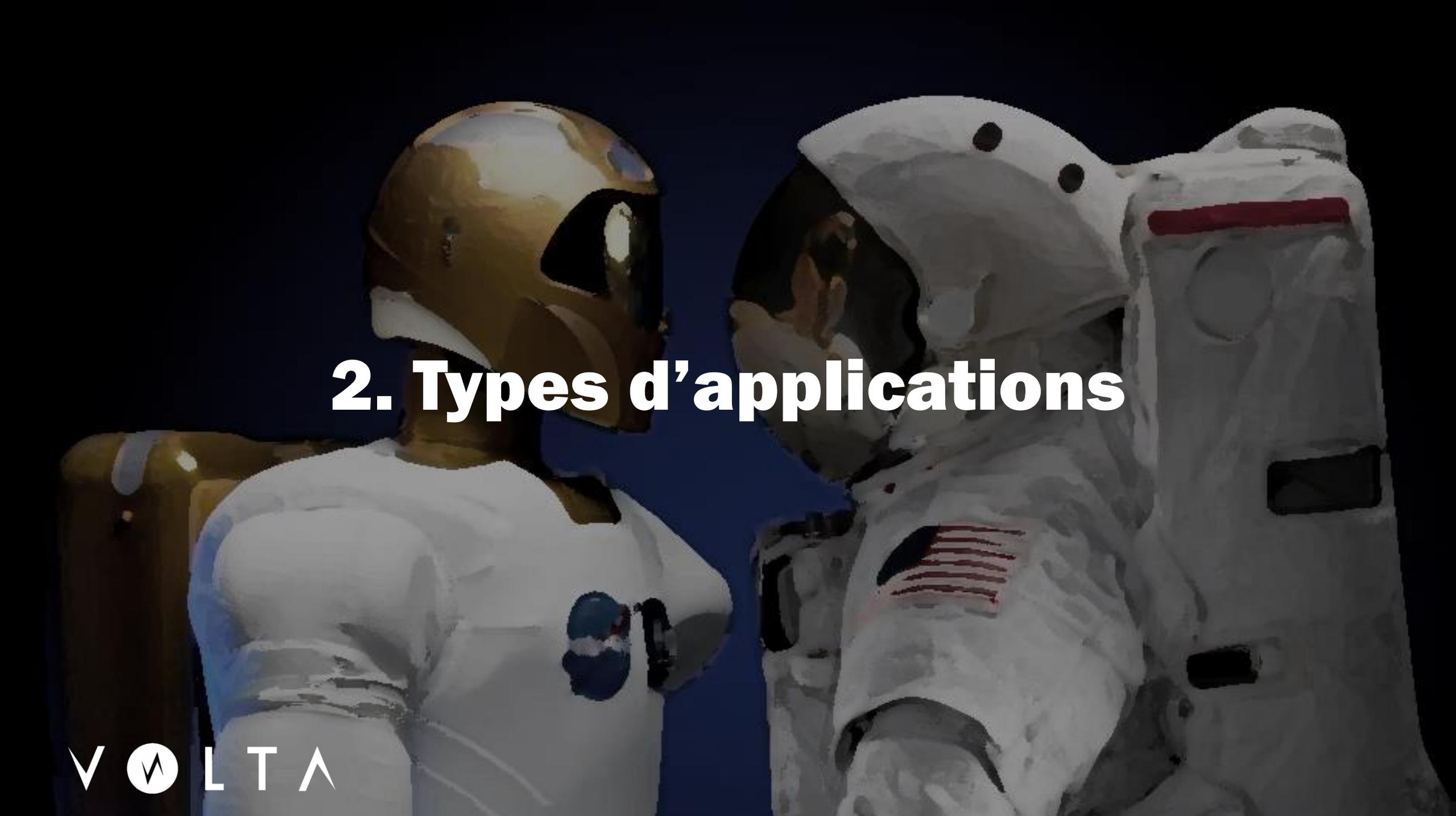


# B. Apprentissage Non-supervisé

Aucune information humaine pour "aider" lors de l'apprentissage

NETFLIX

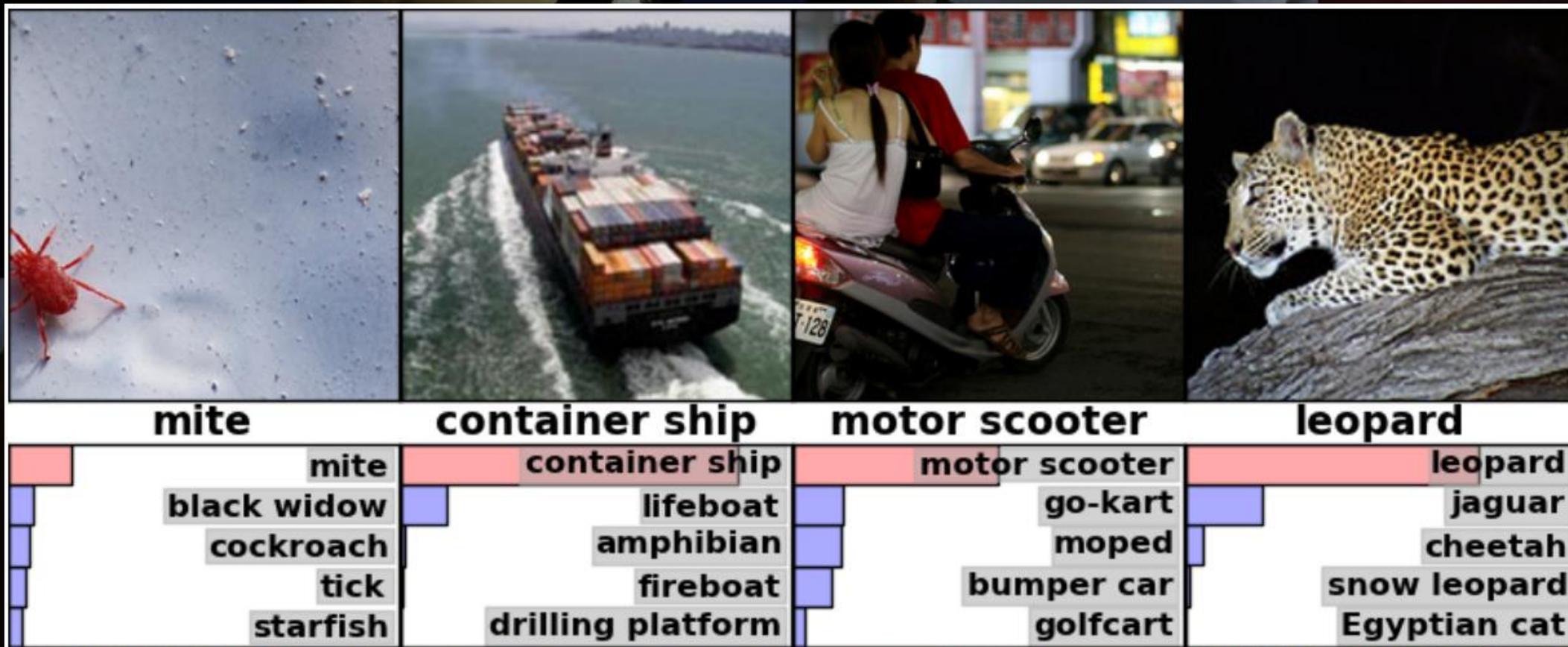


The image shows two astronauts in white space suits against a dark blue background. The astronaut on the left is wearing a gold helmet and has a NASA logo on their chest. The astronaut on the right is wearing a white helmet and has an American flag patch on their chest. The text "2. Types d'applications" is overlaid in the center in white.

## 2. Types d'applications

# A. Classification

Identifying to which category an object belongs to.

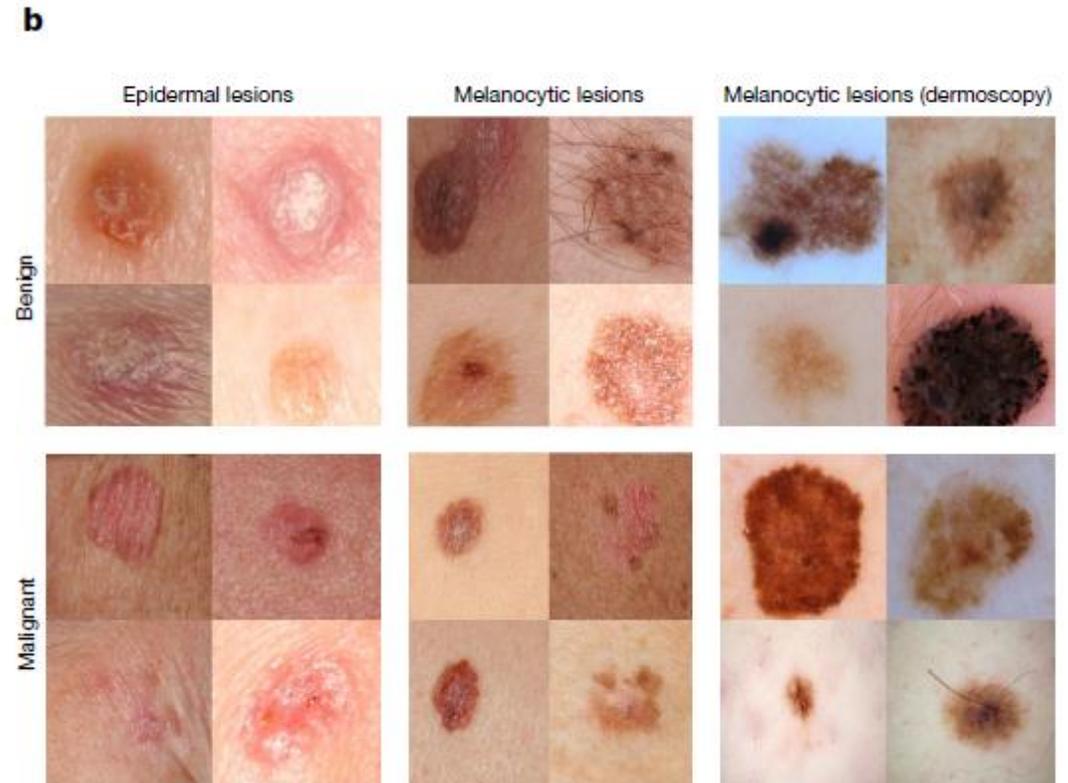
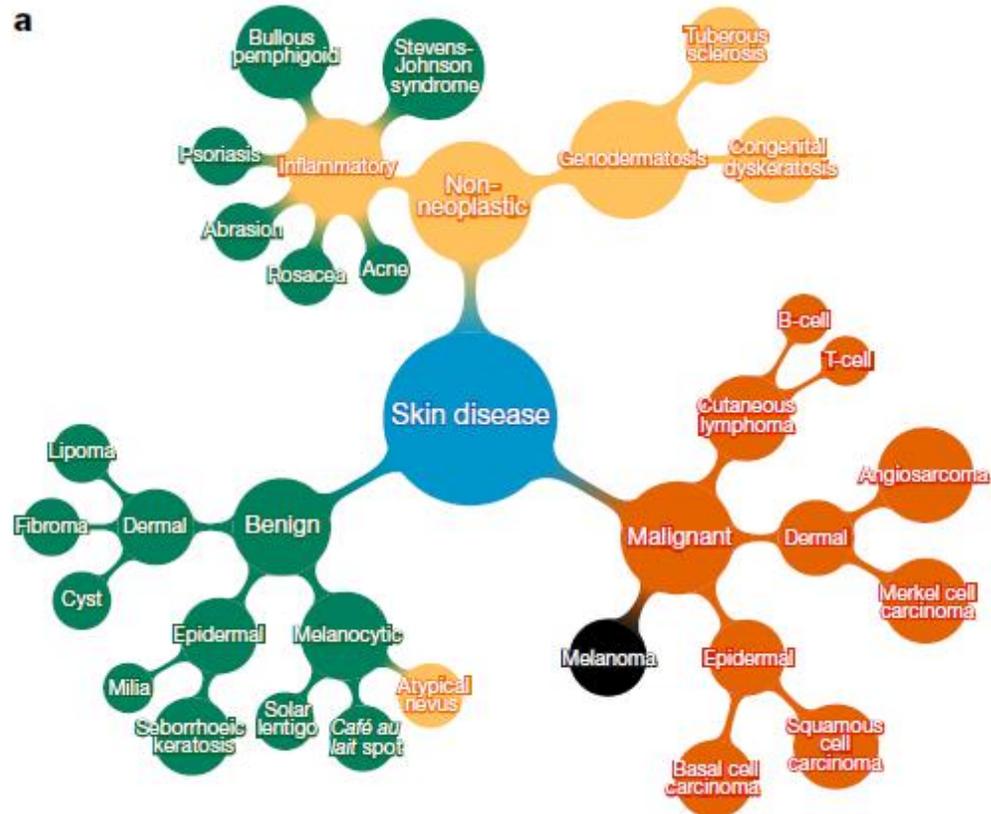


# Dermatology: Diagnostic Images

**nature**  
International journal of science

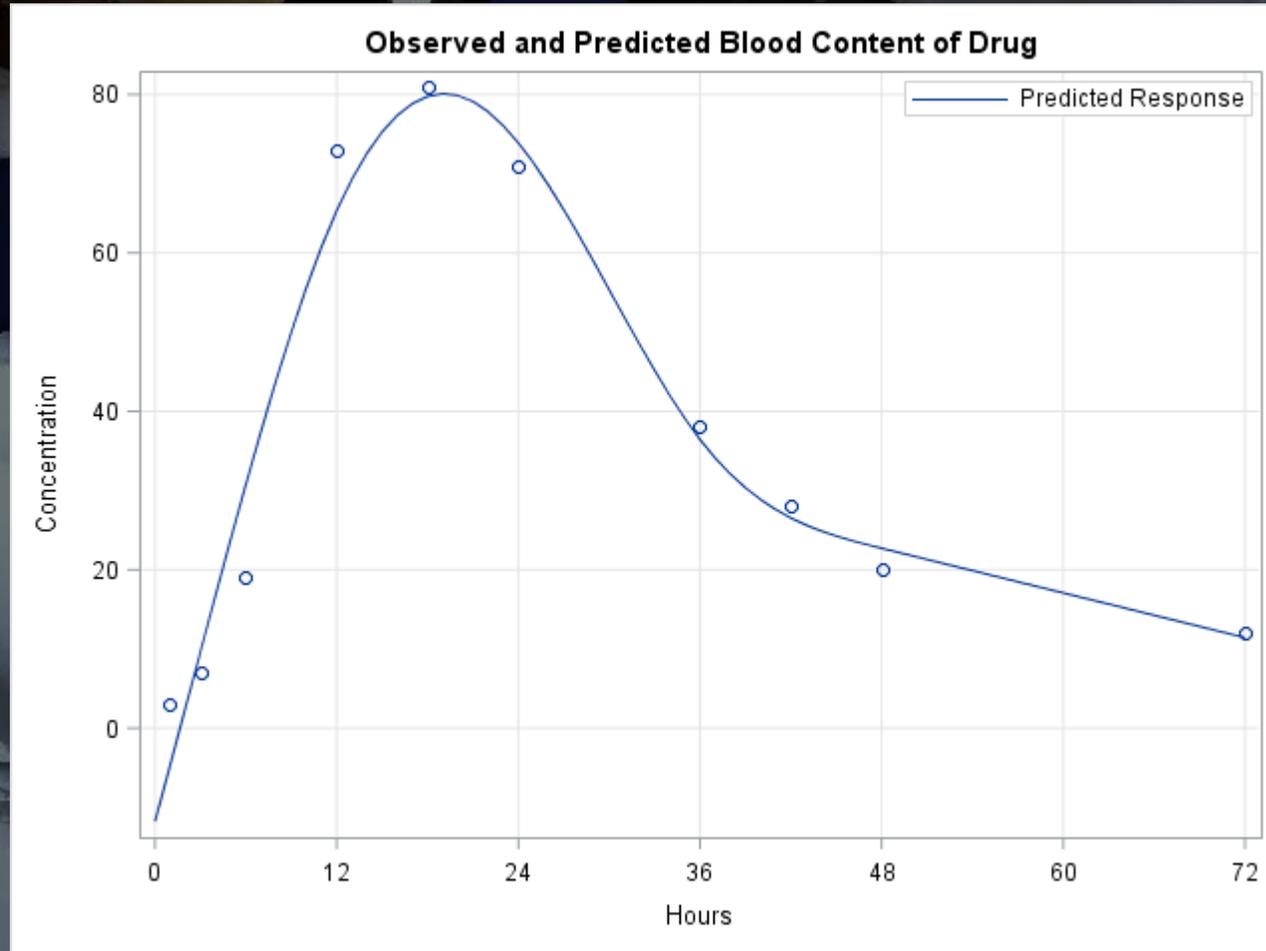
## Dermatologist-level classification of skin cancer with deep neural networks

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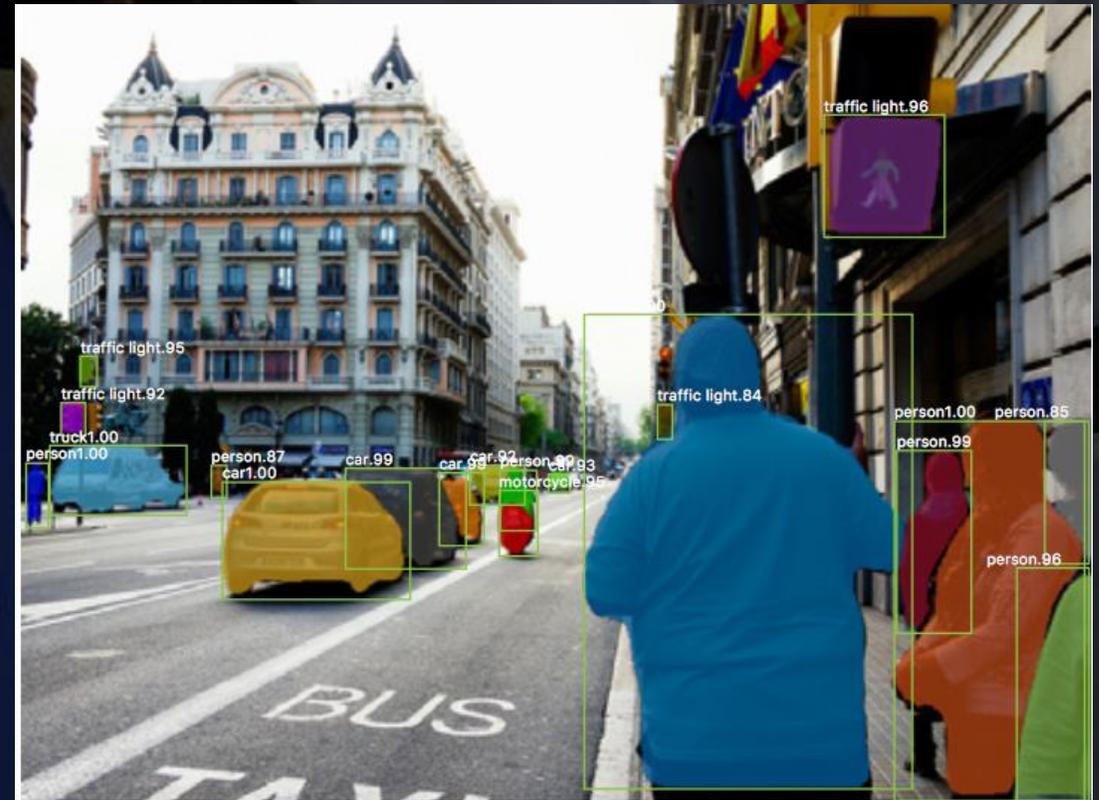
# B. Regression

Predicting a continuous-valued attribute associated with an object.



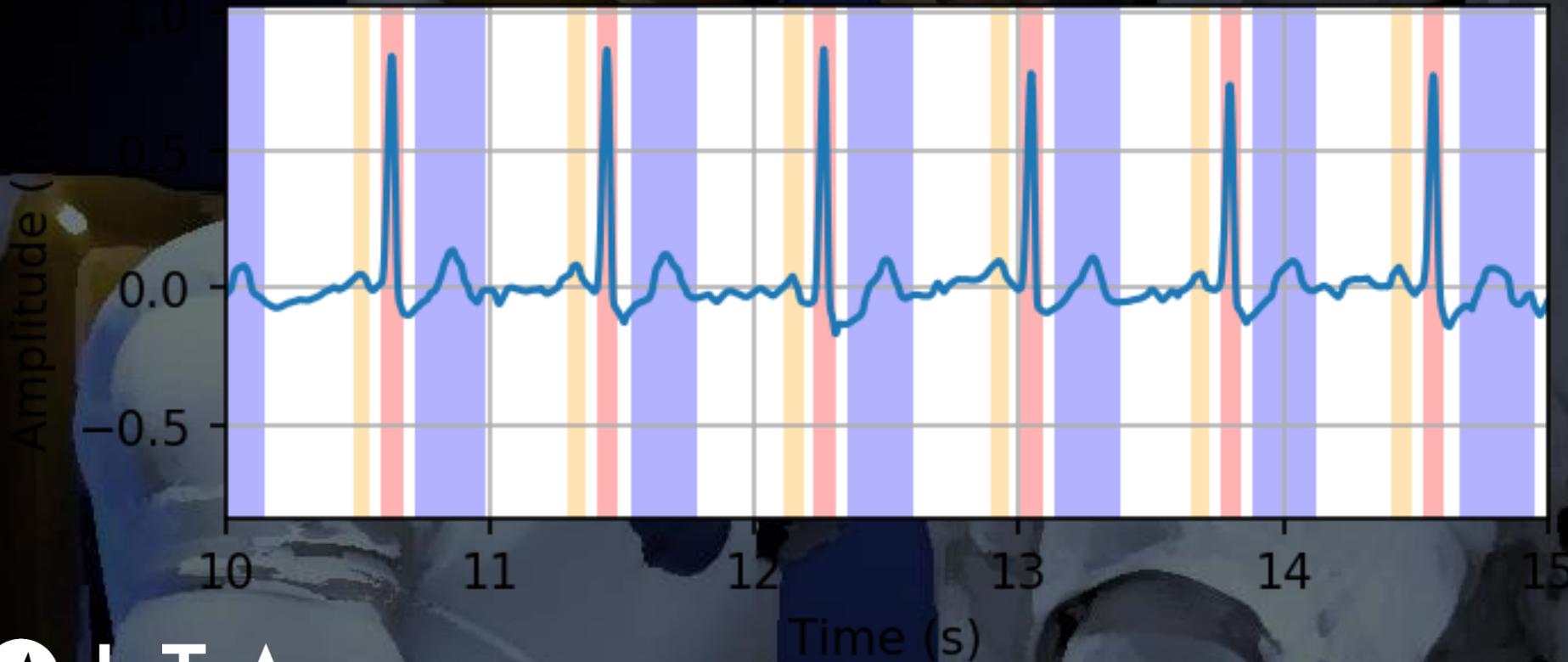
# C. Segmentation

Predicting where an object is located in another object.

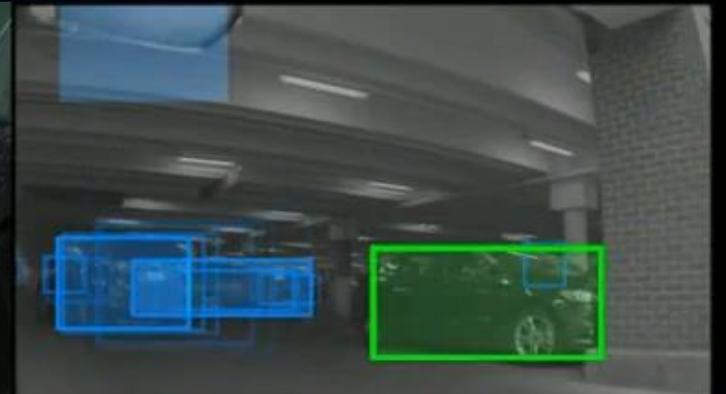


# C. Segmentation

Predicting where an object is located in another object.



# C. Segmentation



LEFT REARWARD VEHICLE CAMERA



MEDIUM RANGE VEHICLE CAMERA



# D. Natural Language Processing

Understanding Human Language

*Segmentation / Classification*

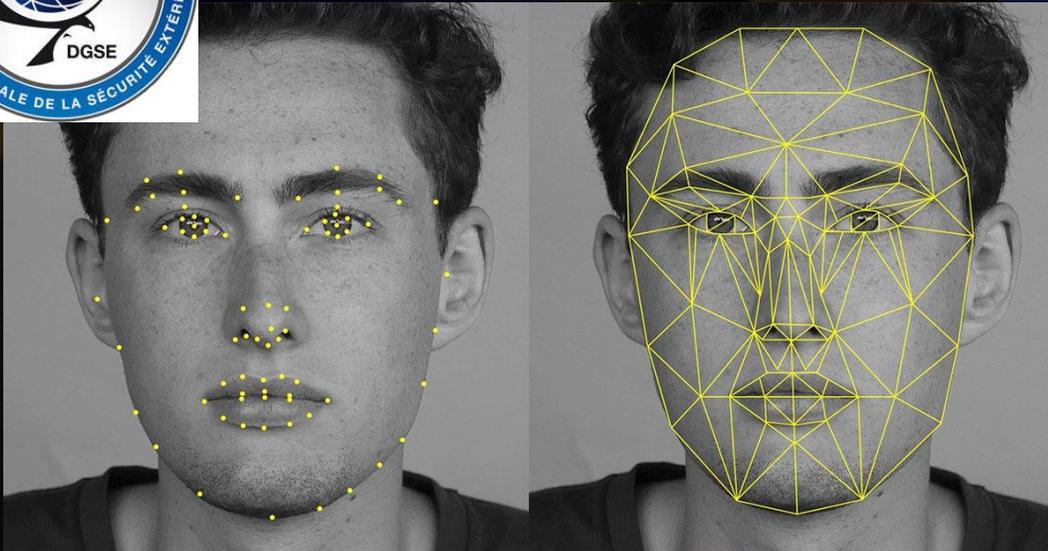
Translation

Speech Recognition



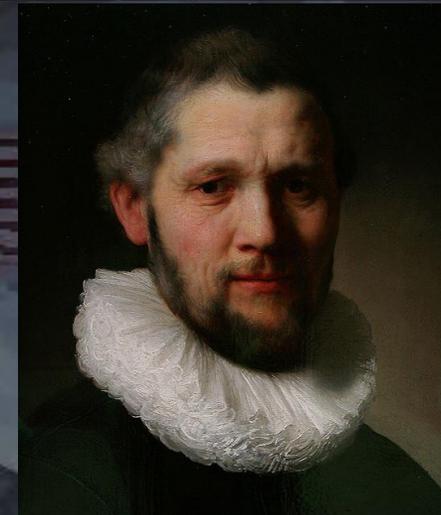
# E. Face Recognition

Understanding Human Language  
*Segmentation / Classification*



# F. Content Generation

Creating « plausible » content with an algorithm



# F. Content Generation

Creating « plausible » content with an algorithm



# Méthodes

Deux Approches:

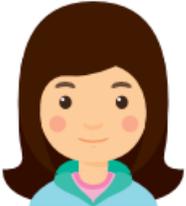
- Feature Engineering



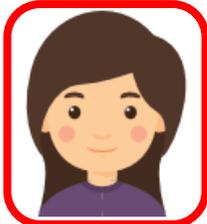
- Apprentissage profond



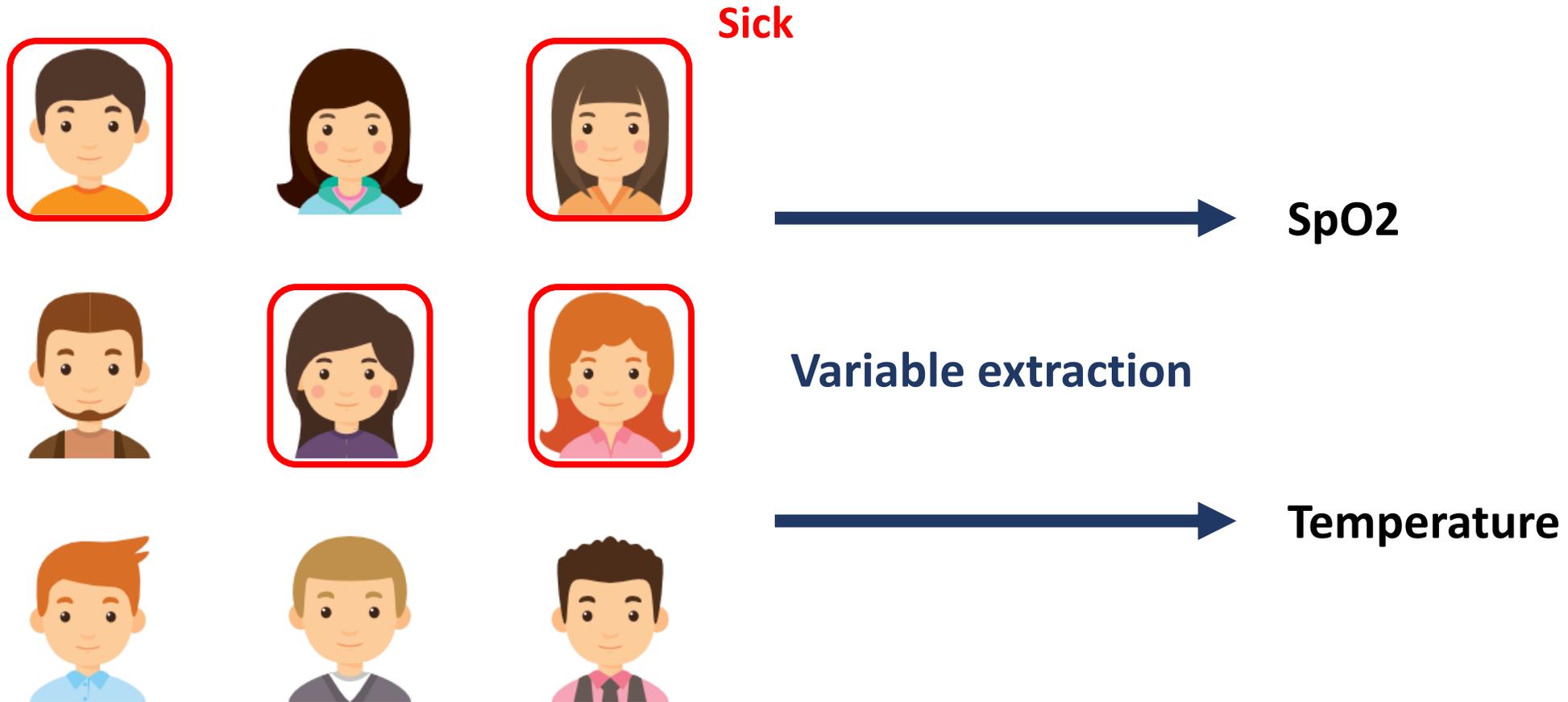
# Apprentissage machine



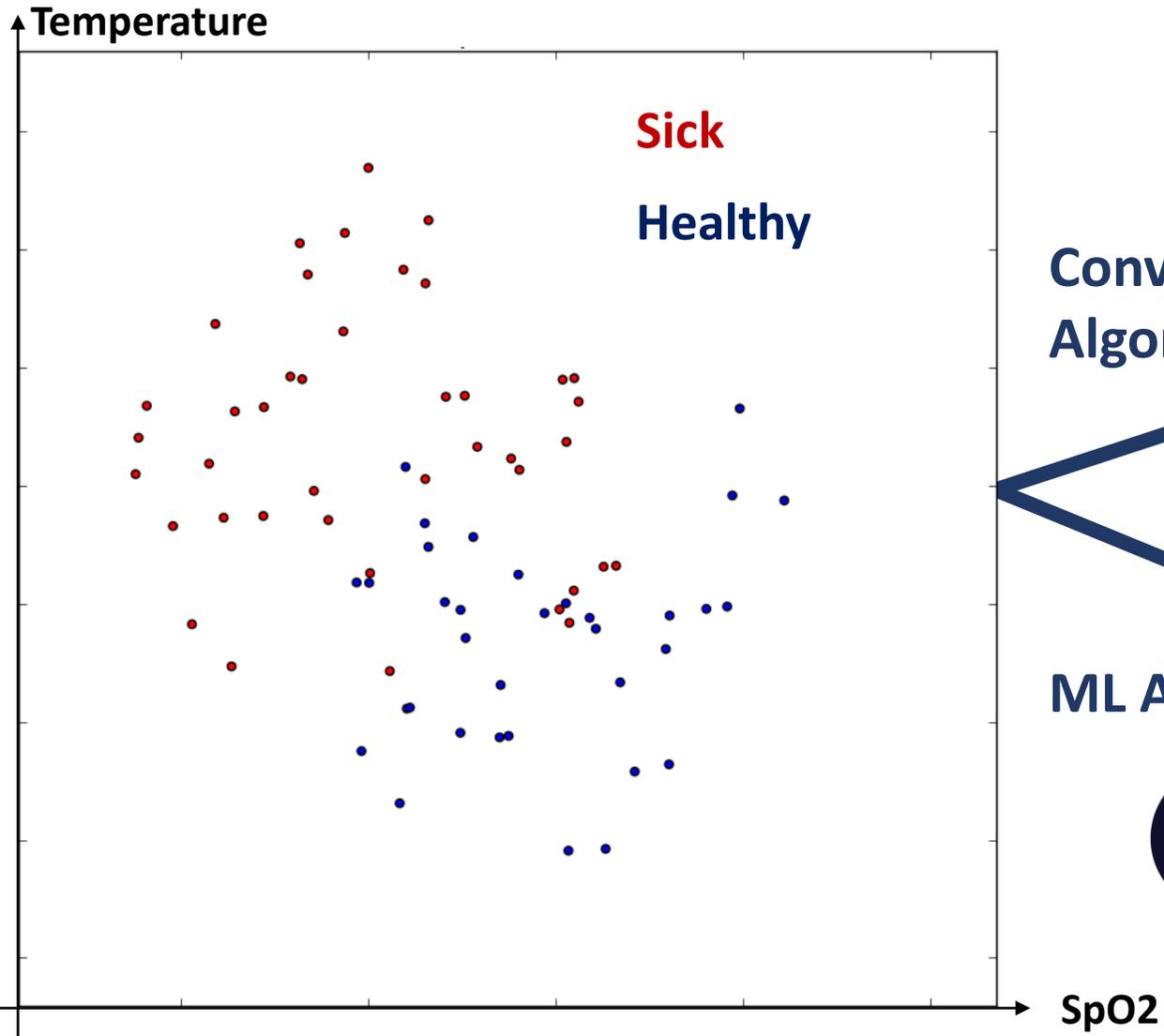
Sick



# Apprentissage machine

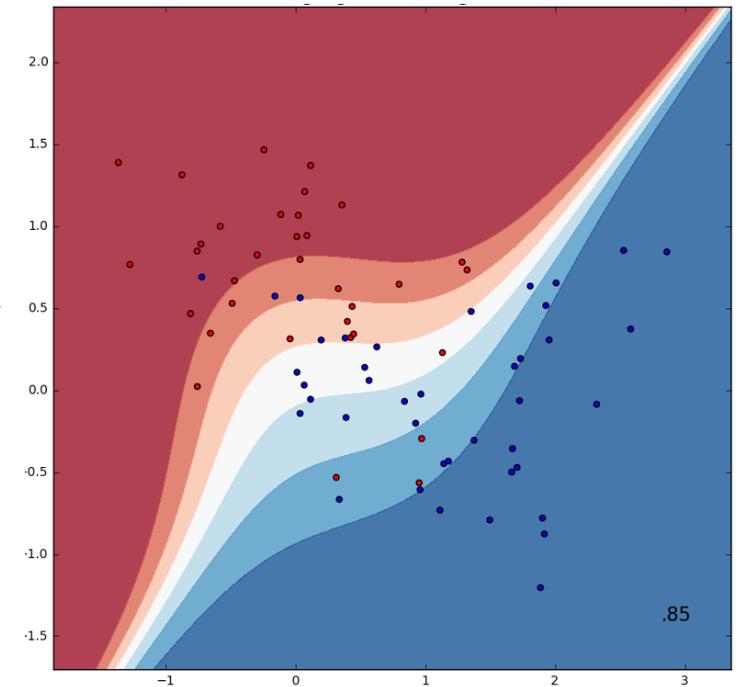
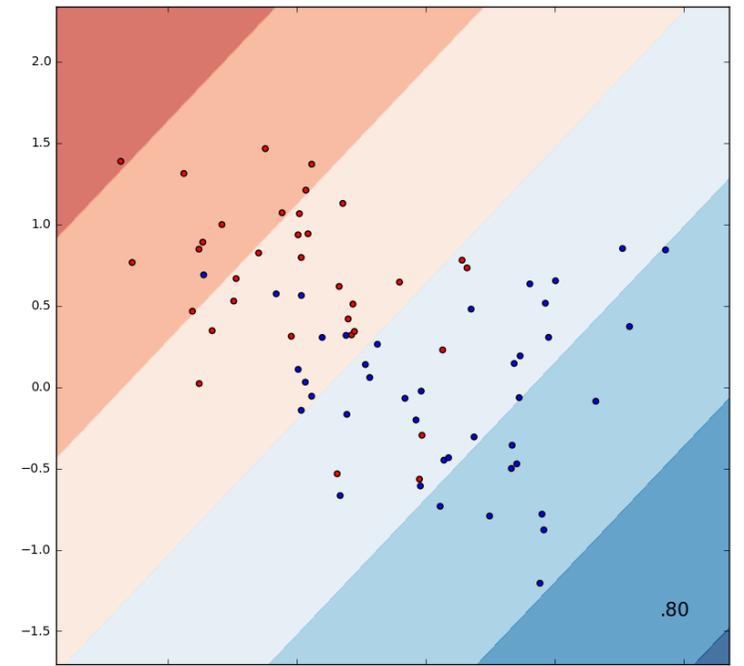


# Machine learning

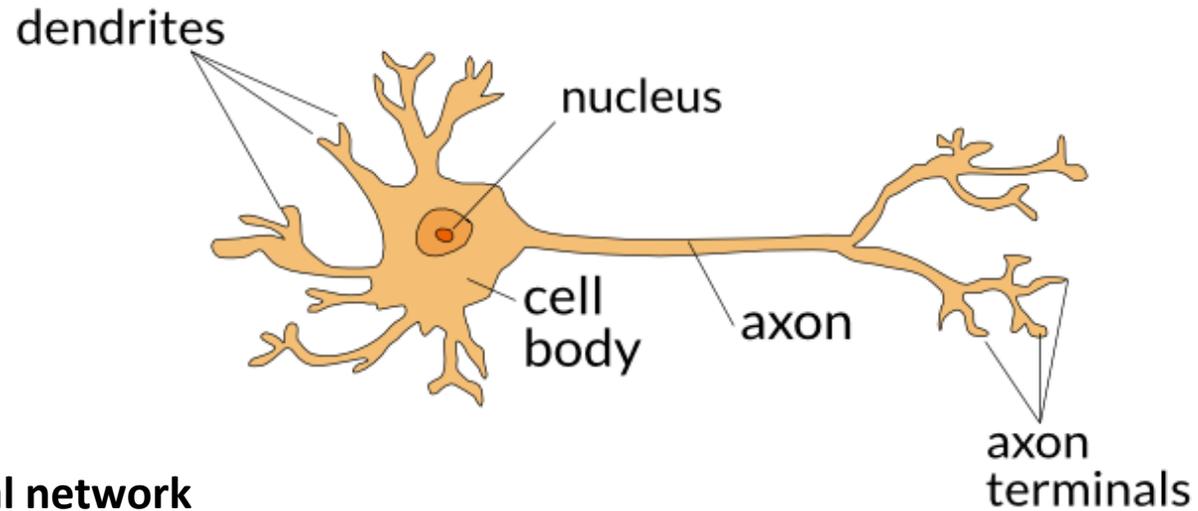


Conventional  
Algorithm

ML Algorithm

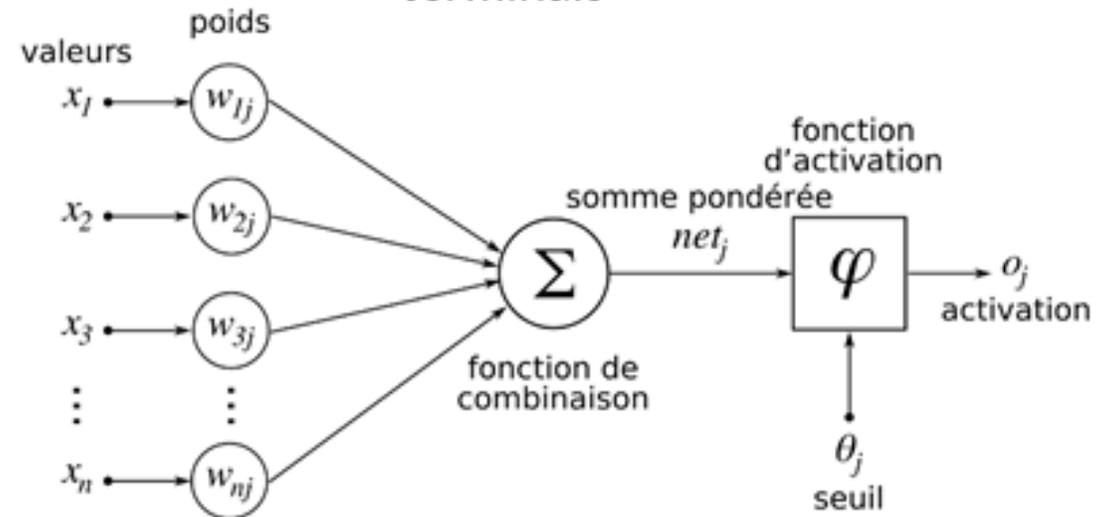
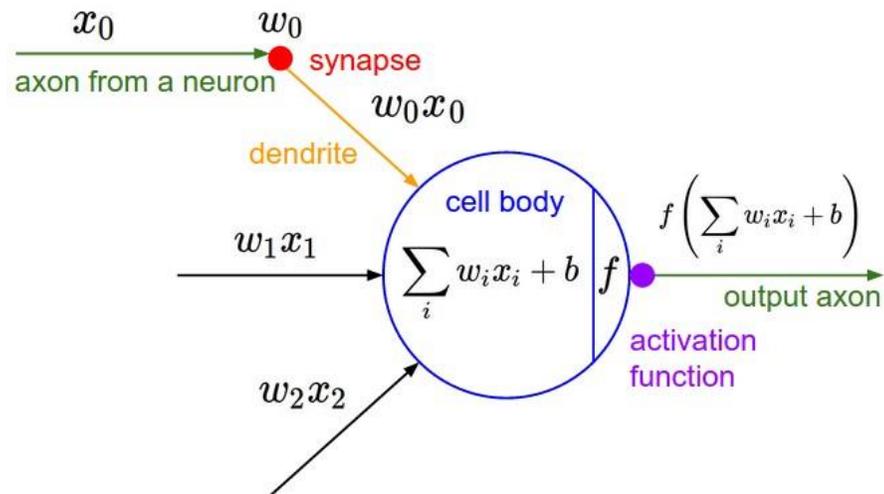


# Apprentissage profond

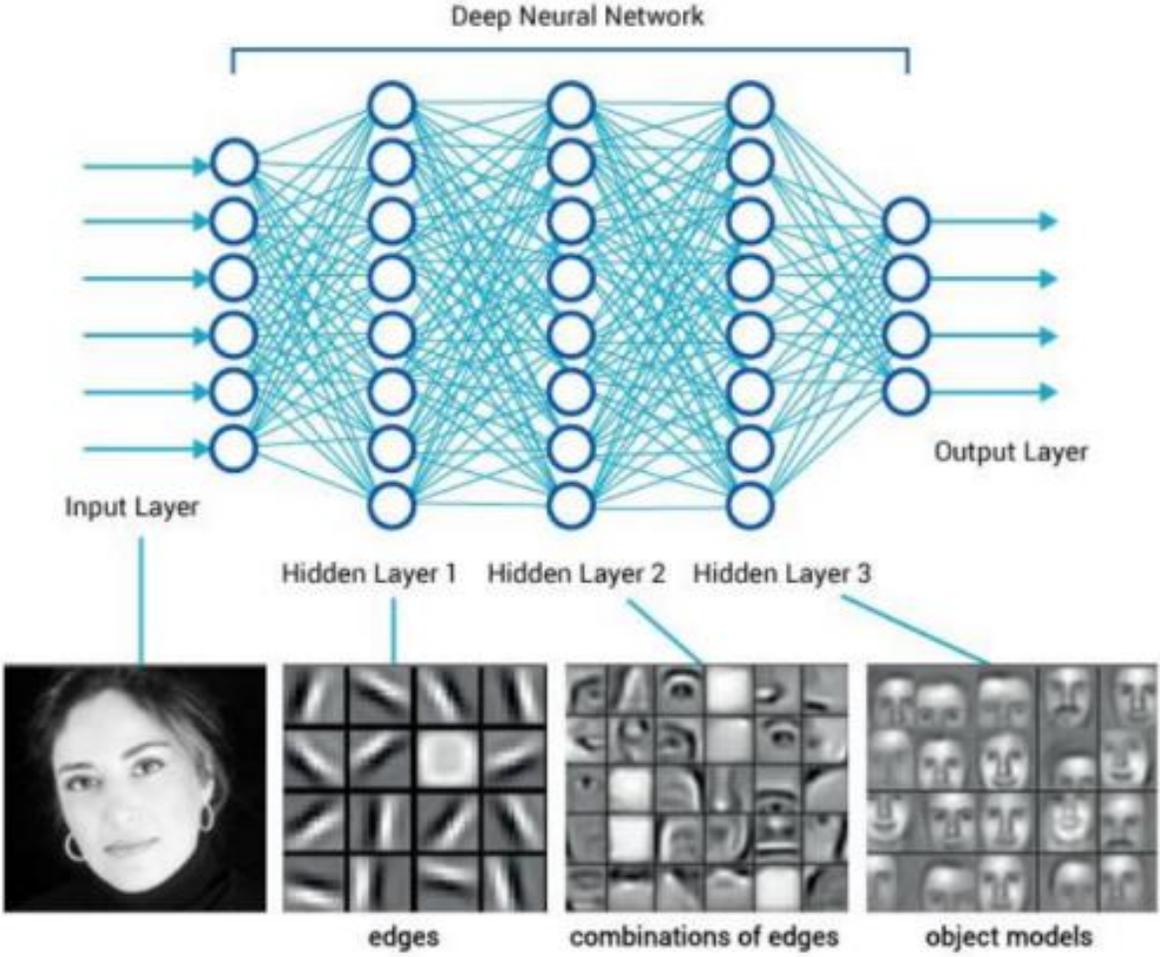


## Perceptron

Elementary unit of artificial neural network



# Apprentissage profond



# Apprentissage profond

## *Convolution*

1 <sub>x1</sub>	1 <sub>x0</sub>	1 <sub>x1</sub>	0	0
0 <sub>x0</sub>	1 <sub>x1</sub>	1 <sub>x0</sub>	1	0
0 <sub>x1</sub>	0 <sub>x0</sub>	1 <sub>x1</sub>	1	1
0	0	1	1	0
0	1	1	0	0

Image

4		

Convolved  
Feature



\*

1	0	-1
2	0	-2
1	0	-1



# Pourquoi l'IA?

- Moins de biais humains
- Permet de prendre en compte plus de paramètres analytiques
- Détecte des motifs complexes
- Permet une analyse plus rapide



**Est-ce Magique?**



**NON !**

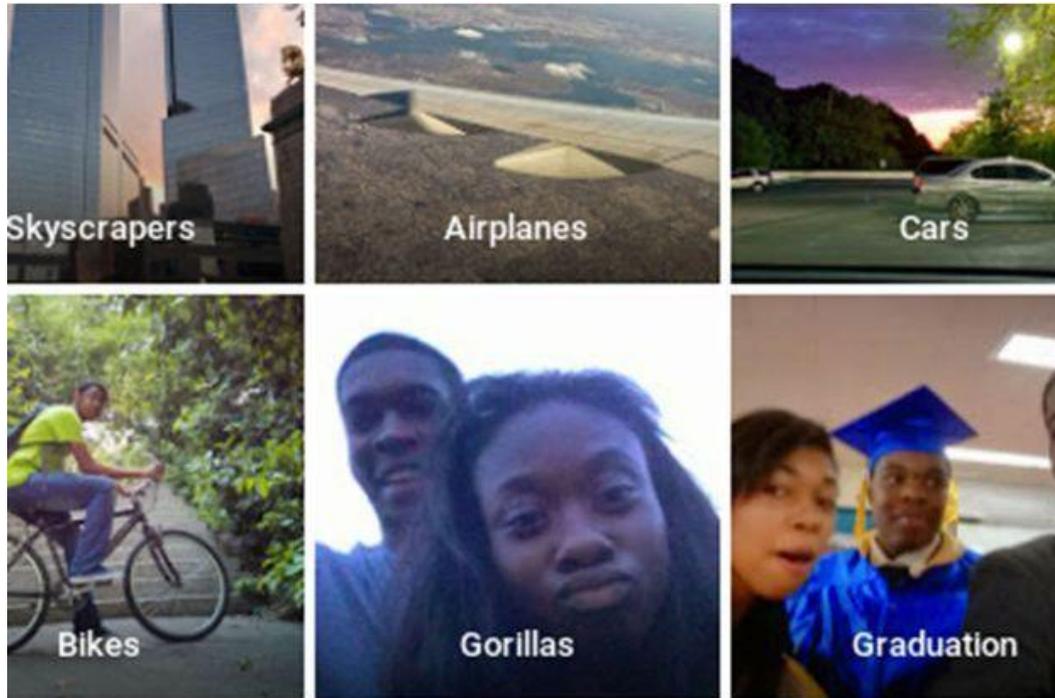
# Principales Limites

Influence de l'ingénieur et de la base de données:

1. Représentativité de la base de données pour l'entraînement.
2. Conception de l'algorithme

# Principales limites

- Biais présents dans la base de donnée d'entraînement
- Phénomène de renforcement des biais
- Attention à la représentativité des données



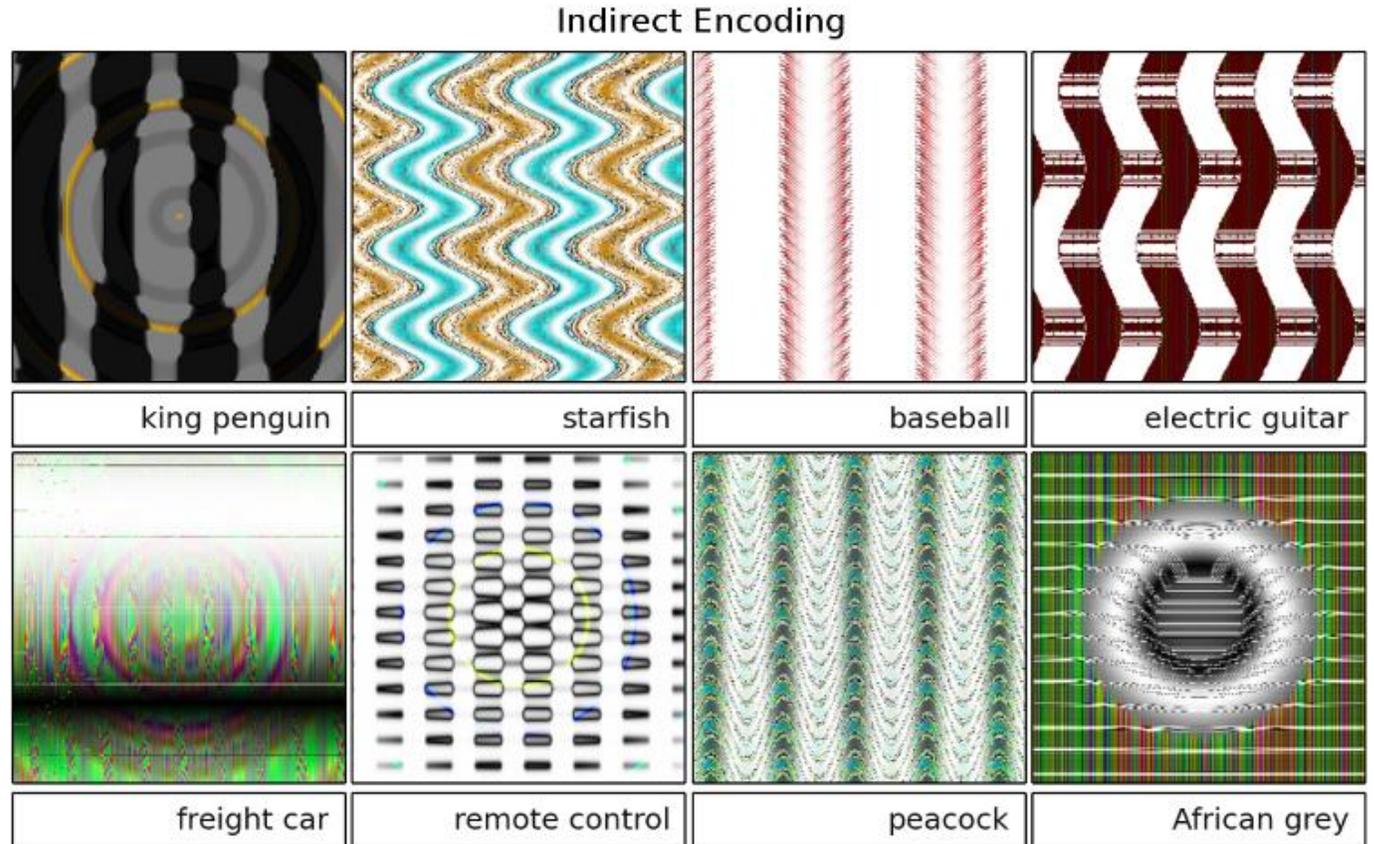
November 2018

## Machine Learning and Health Care Disparities in Dermatology

Adewole S. Adamson, MD, MPP<sup>1,2</sup>; Avery Smith, MS<sup>3</sup>

# Principales limites

- Phénomène « black box »
- Possibilité de corrompre un algorithme
- > Influence de l'ingénieur / data scientist
- En médecine utiliser autant que possible des critères de performances cliniques et non pas historiques (cf jeu de Go)



# Principales limites

- Question de la responsabilité (ex. véhicule autonome)
- Question de la propriété et de la maîtrise des technologies: agrandissement des fossés sociaux (Laurent Alexandre)
- Question éthiques

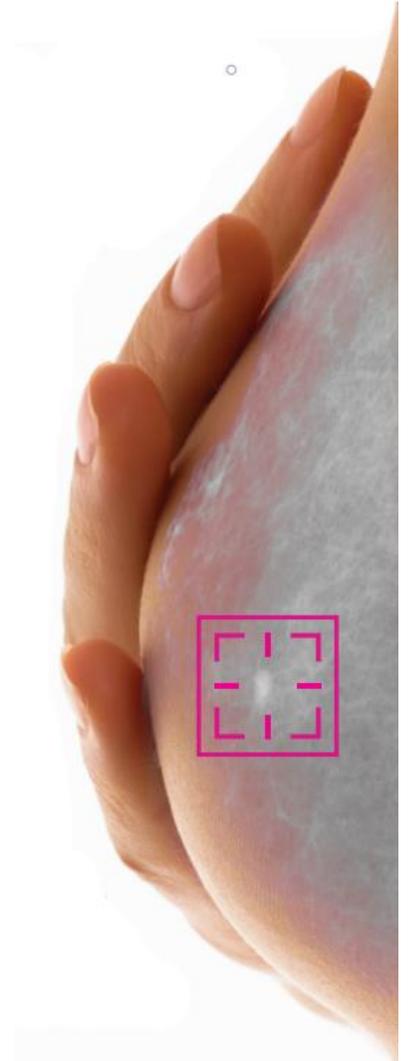
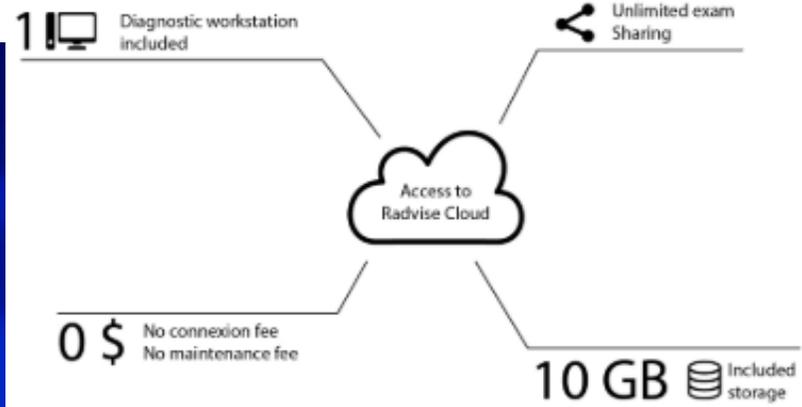




# Applications médicales

# Oncology: Therapixel

*Inria*  
inventeurs du monde numérique

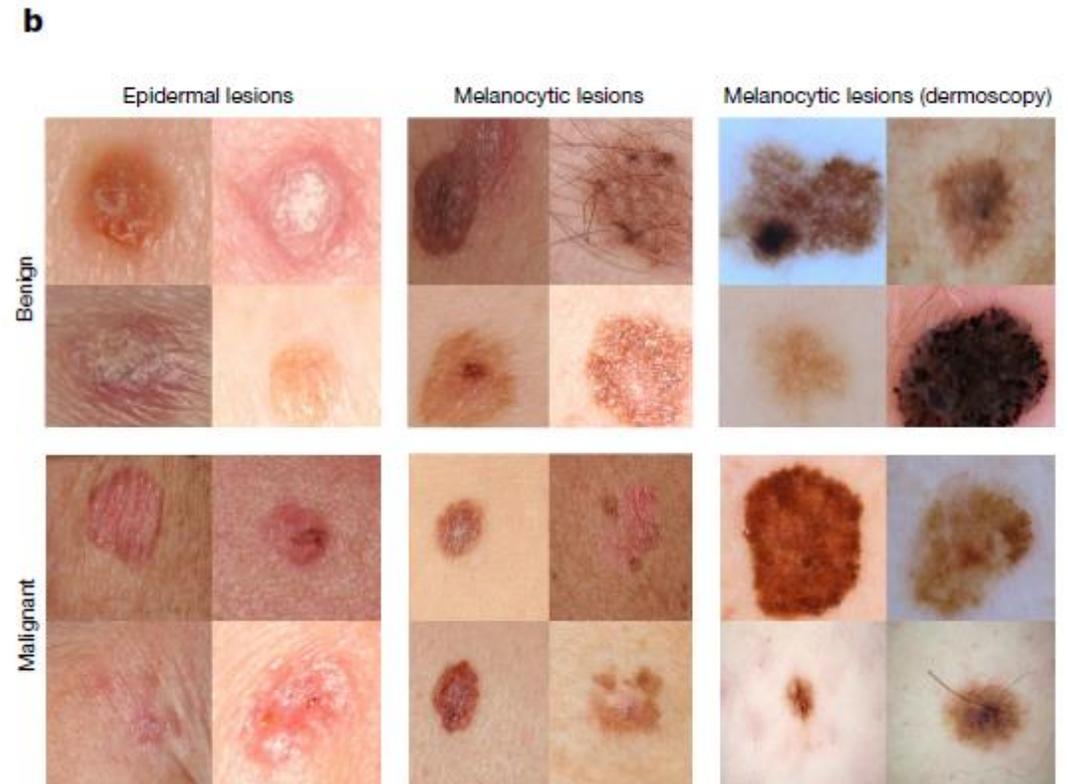
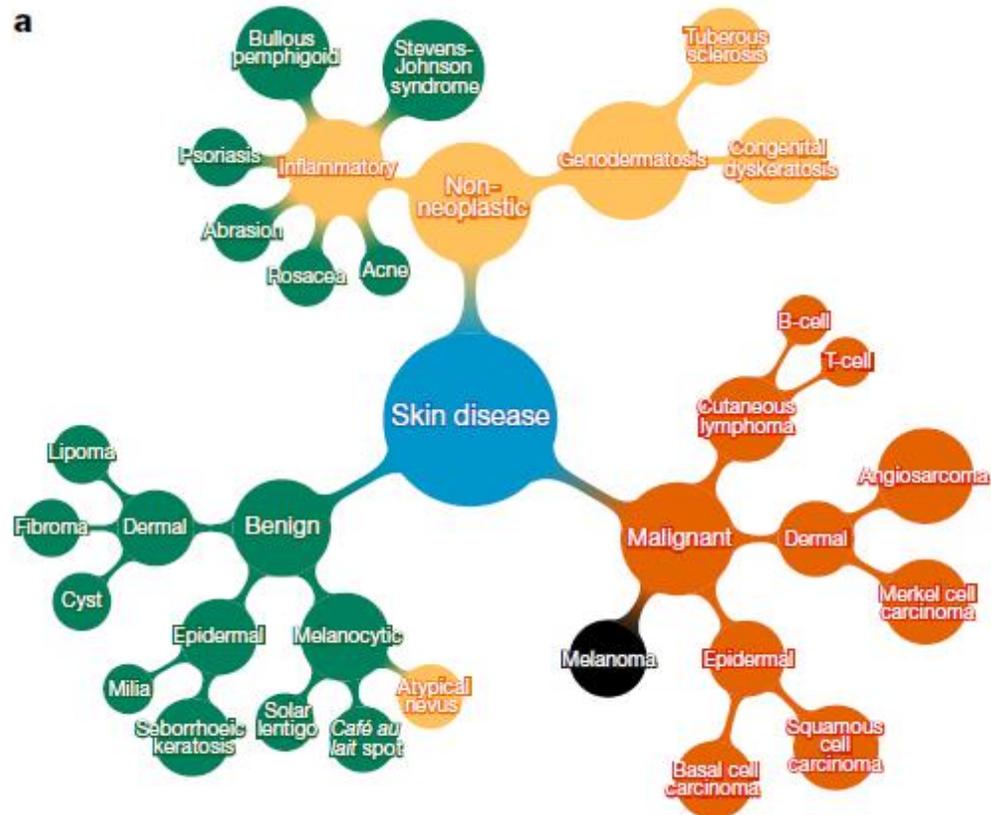


# Dermatology: Diagnostic Images

**nature**  
International journal of science

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# Dermatology: Diagnostic Images



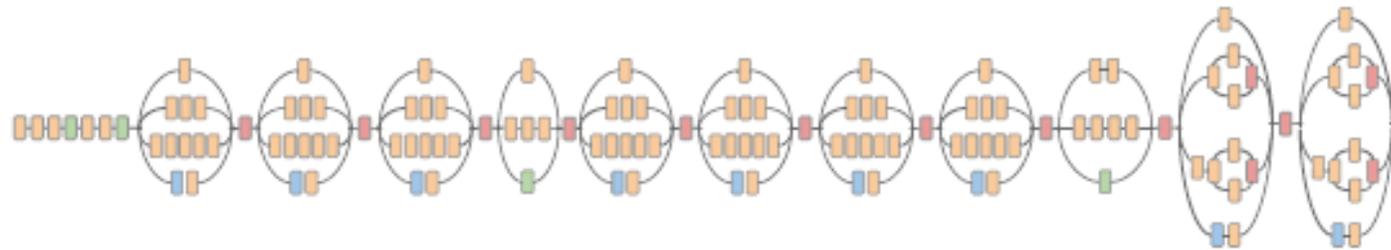
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Skin lesion image



Deep convolutional neural network (Inception v3)



- Convolution
- AvgPool
- MaxPool
- Concat
- Dropout
- Fully connected
- Softmax

Training classes (757)

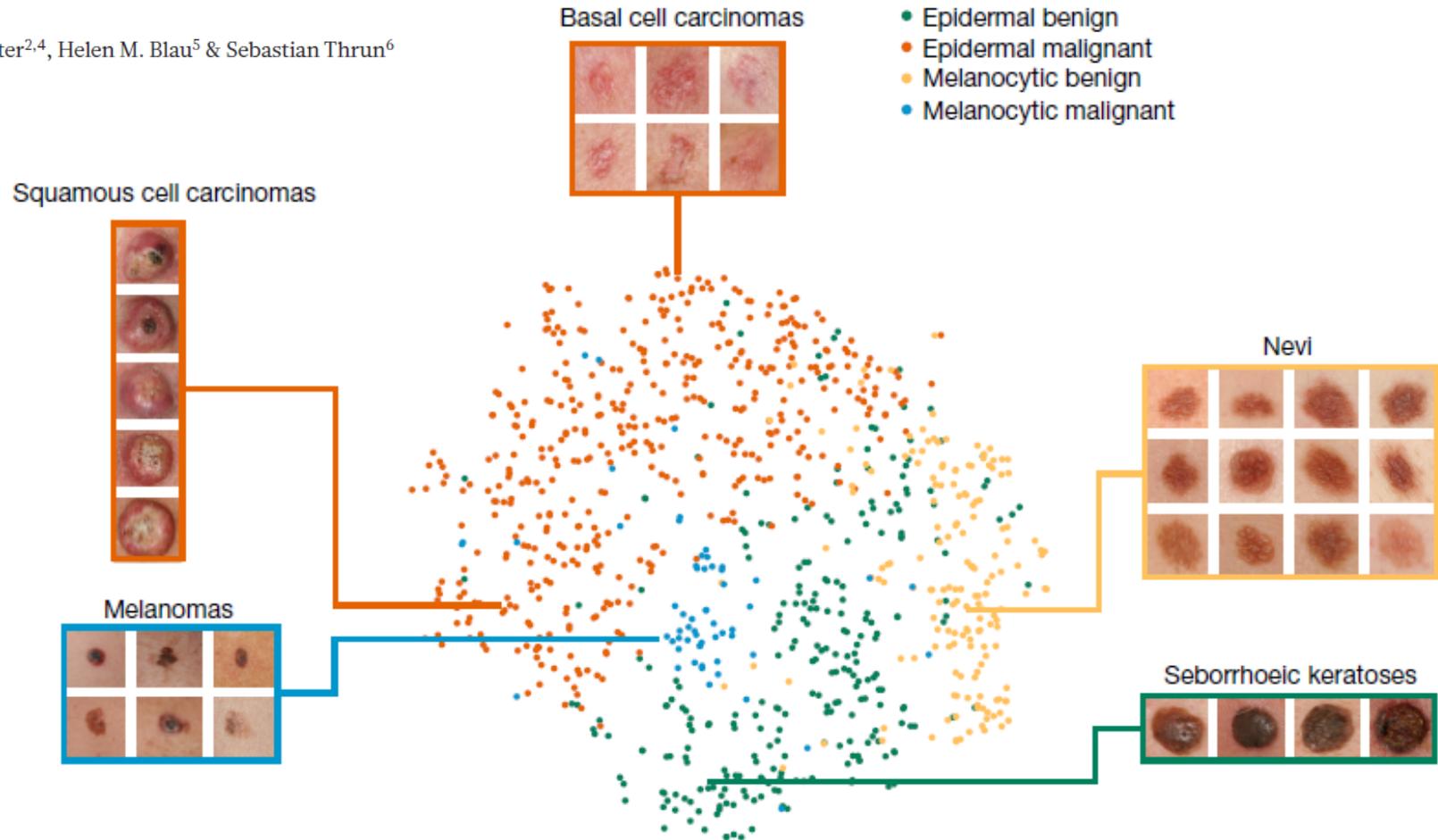
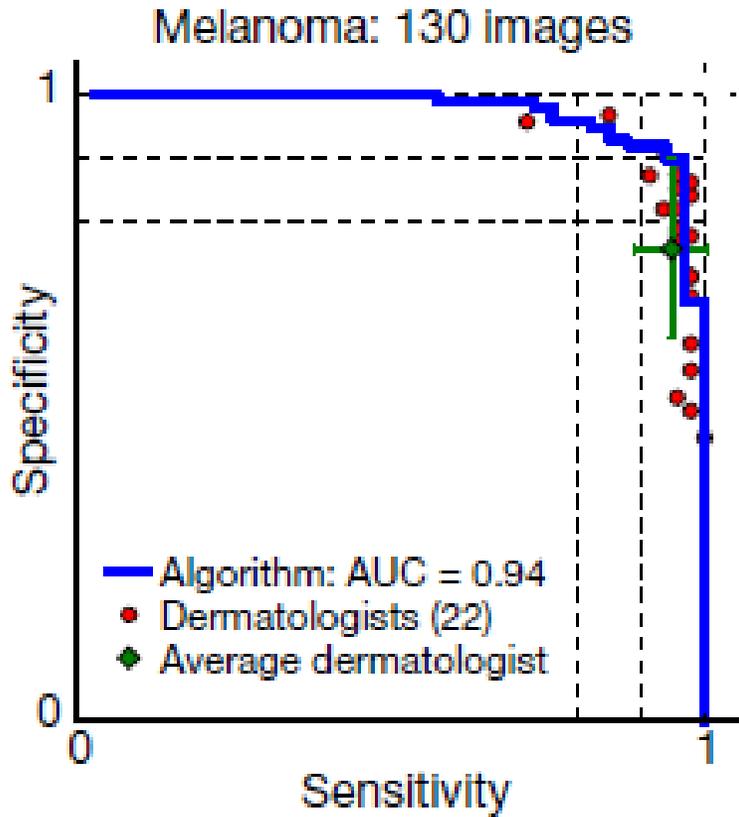
- Acral-lentiginous melanoma
- Amelanotic melanoma
- Lentigo melanoma
- ...
- Blue nevus
- Halo nevus
- Mongolian spot
- ...

# Dermatology: Diagnostic Images



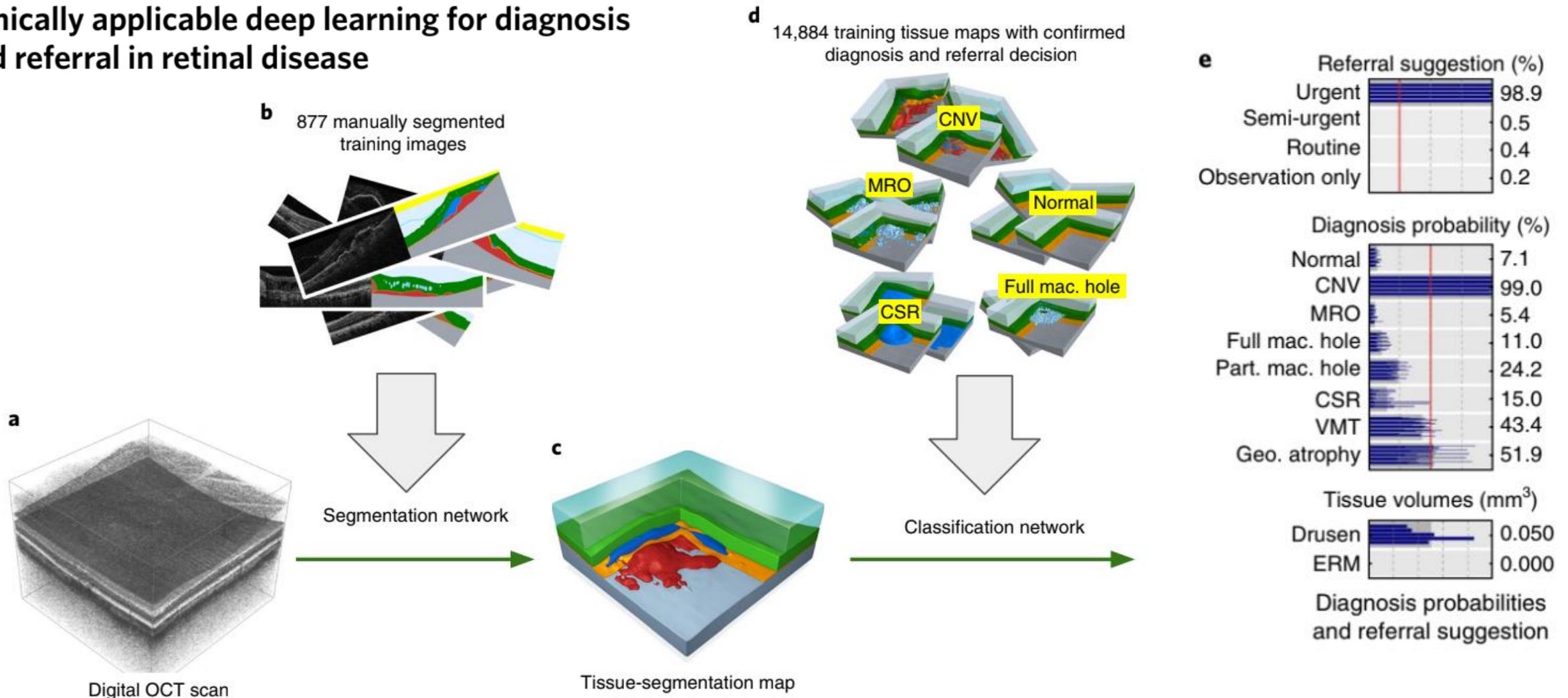
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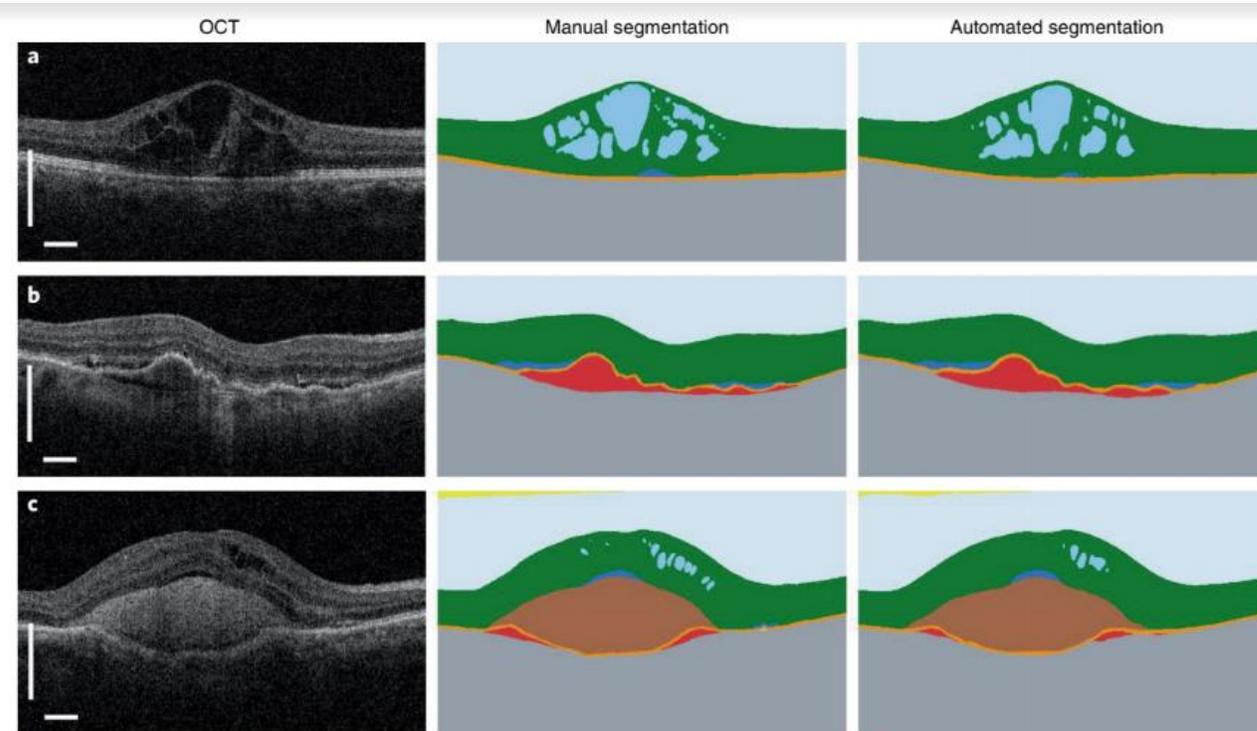
# Ophthalmology: 3D OCT Diagnostic Scans

## Clinically applicable deep learning for diagnosis and referral in retinal disease

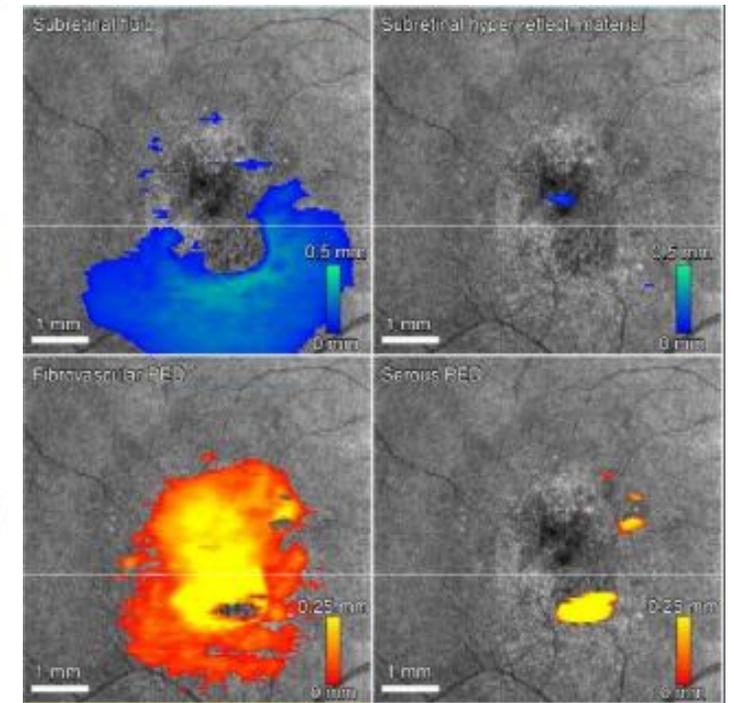
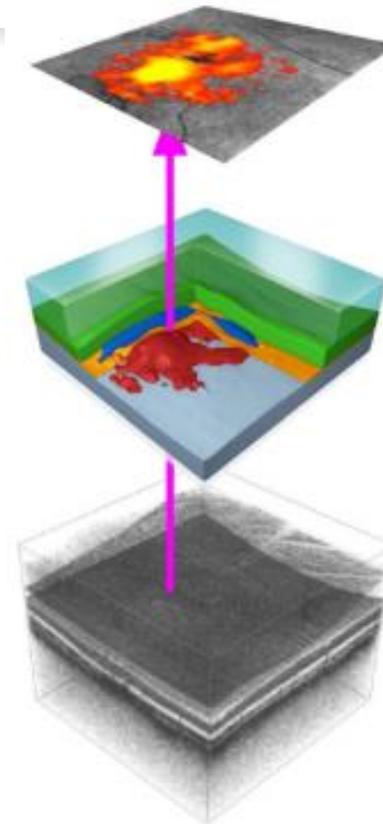


# Ophthalmology: 3D OCT Diagnostic Scans

## Clinically applicable deep learning for diagnosis and referral in retinal disease



- |                              |                                |                          |
|------------------------------|--------------------------------|--------------------------|
| Vitreous or subhyaloid space | Subretinal fluid               | Fibrovascular PED        |
| Posterior hyaloid            | Subretinal hyper reflect. mat. | Choroid and outer layers |
| Epiretinal membrane          | Retinal pigment epithelium     | Padding artefact         |
| Neurosensory retina          | Drusenoid PED                  | Blink artefact           |
| Intraretinal fluid           | Serous PED                     | Foldover artefact        |



# Cardiology: ECG Analysis

## Cardiologist-Level Arrhythmia Detection with Convolutional Neural Networks

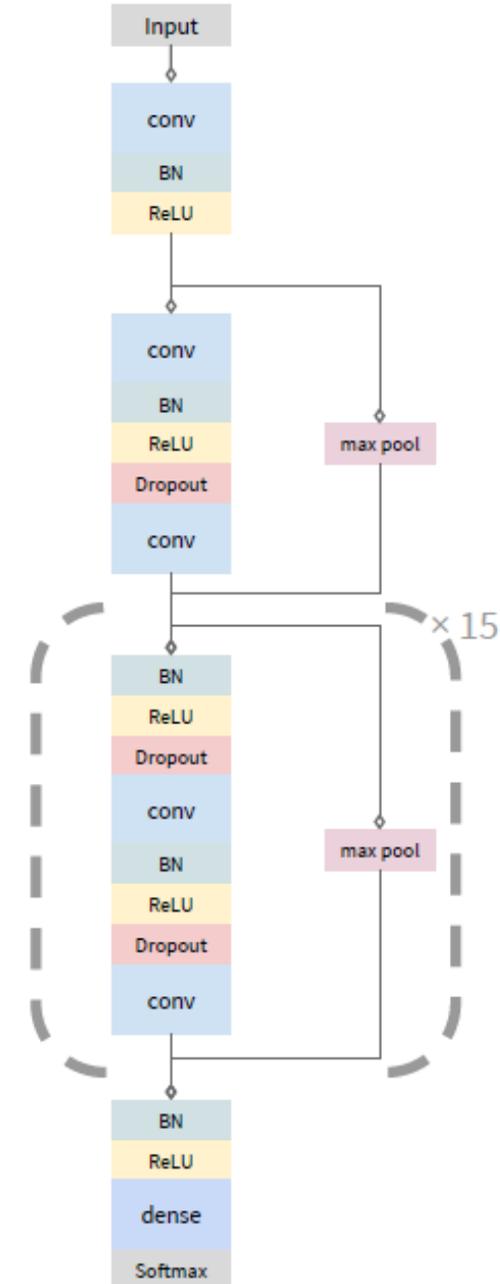
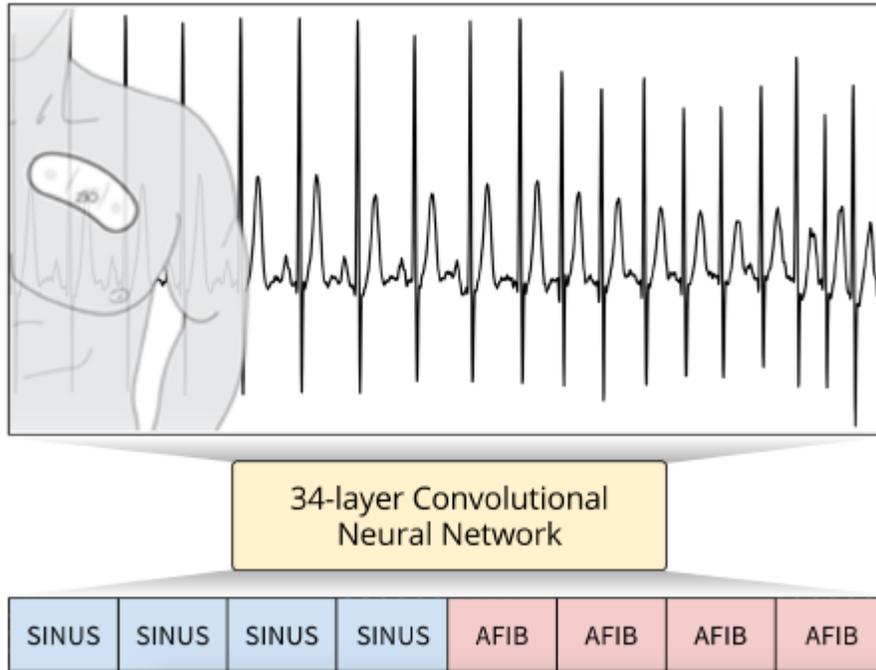
Pranav Rajpurkar\*

Awni Y. Hannun\*

Masoumeh Haghpanahi

Codie Bourn

Andrew Y. Ng



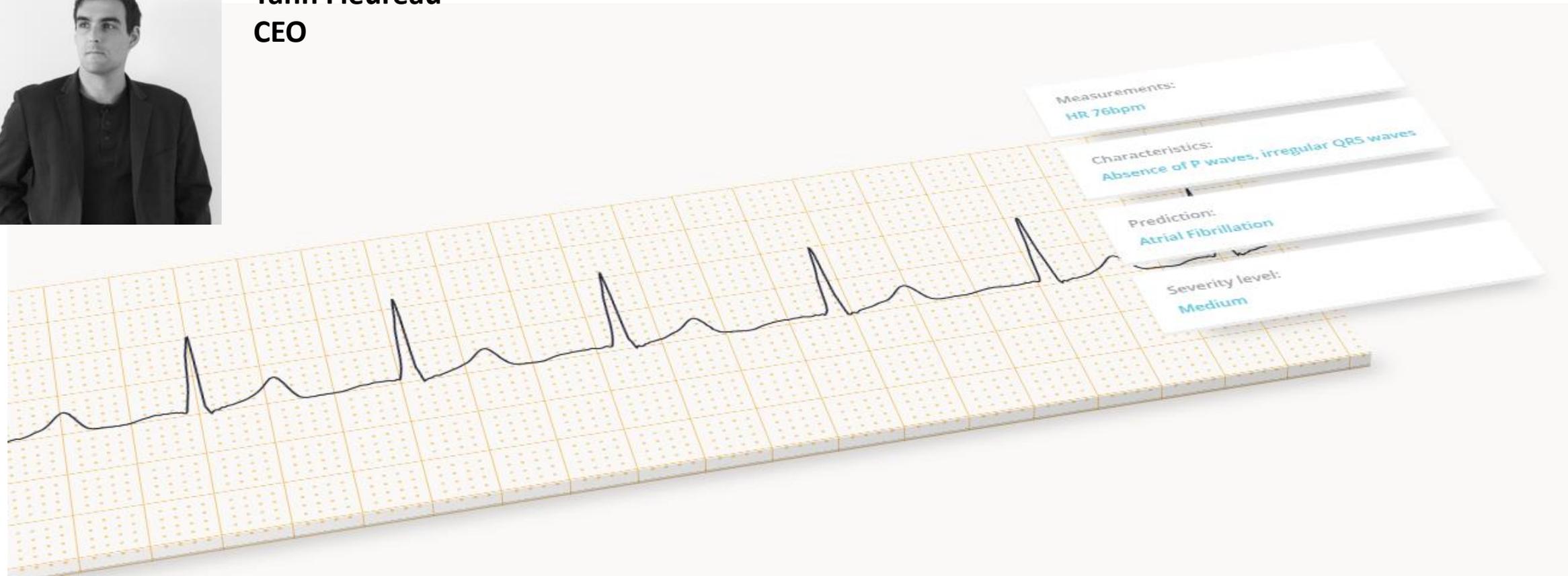


# Cardiologs

The first ECG analysis solution powered by Artificial Intelligence.



**Yann Fleureau**  
CEO



# Et le médecin dans tout ça?

- Une importance renforcée
- Propositions de *OpenHealth Company*:  
La nécessité d'un rapprochement entre concepteurs de technologies et médecins.

-> Prendre l'initiative des projets entrepreneuriaux ou académiques de demain



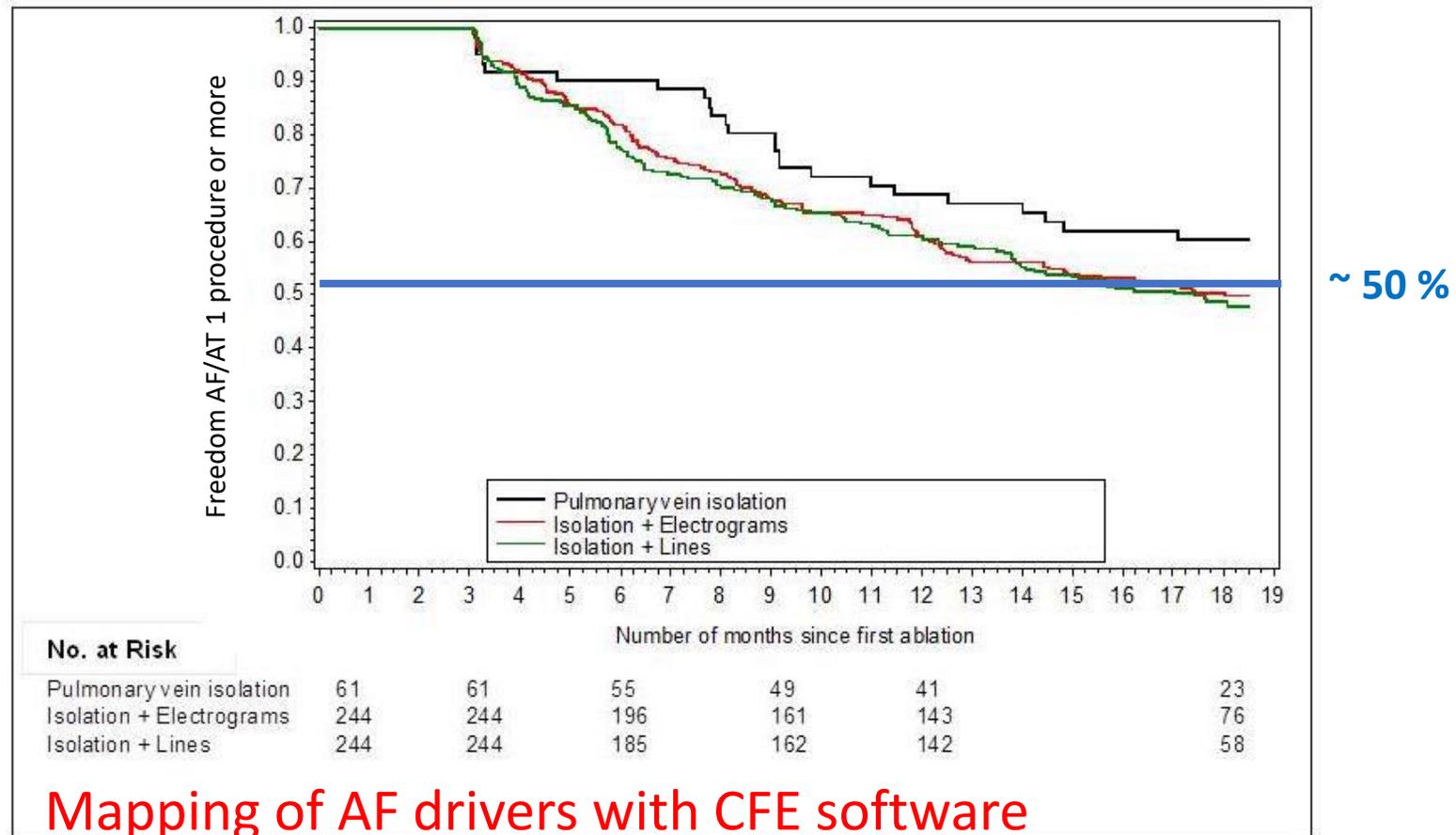
**Open Health**  
COMPANY

Qu'en est-il de l'électrophysiologie  
cardiaque?

# PVI for persistent & LS-persistent AF:

~ 50% Freedom from AF/AT after multiple procedures with or without AA drugs

Averaged results (589 patients, no statistical difference between techniques):

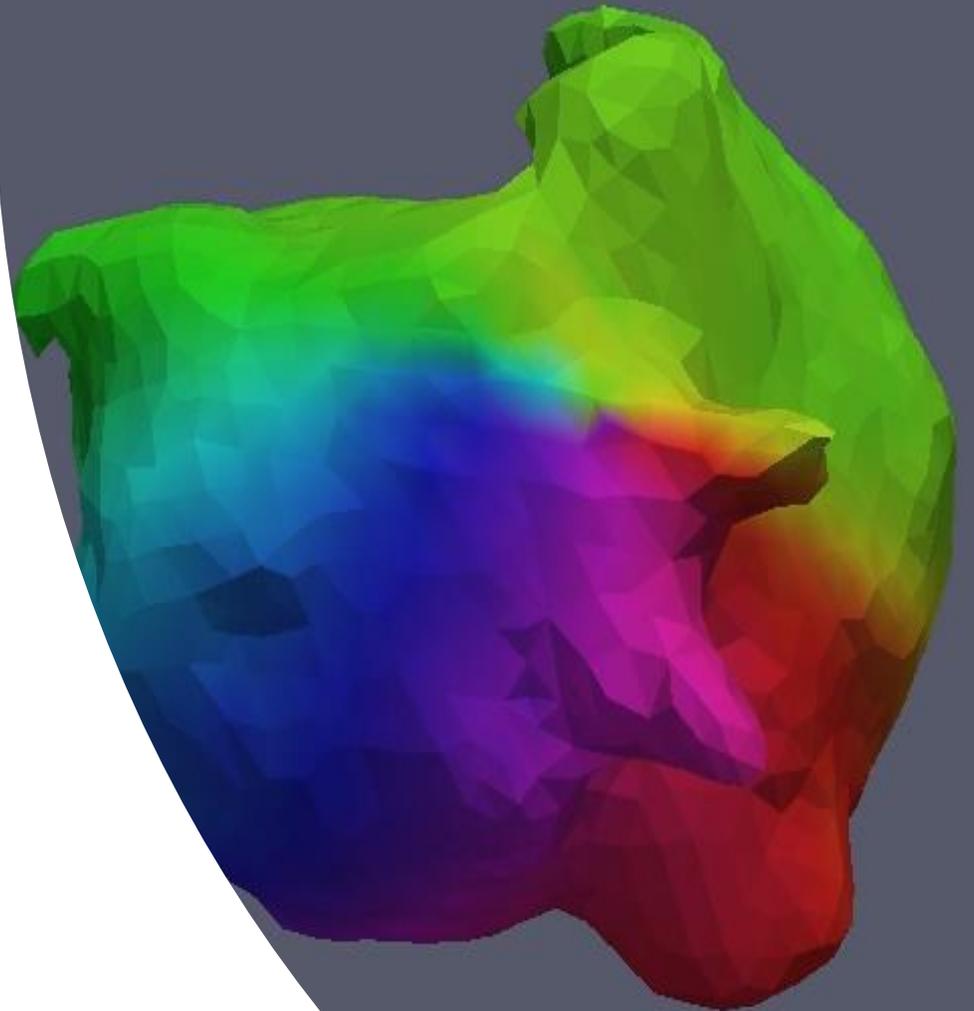


# Comment mieux faire?

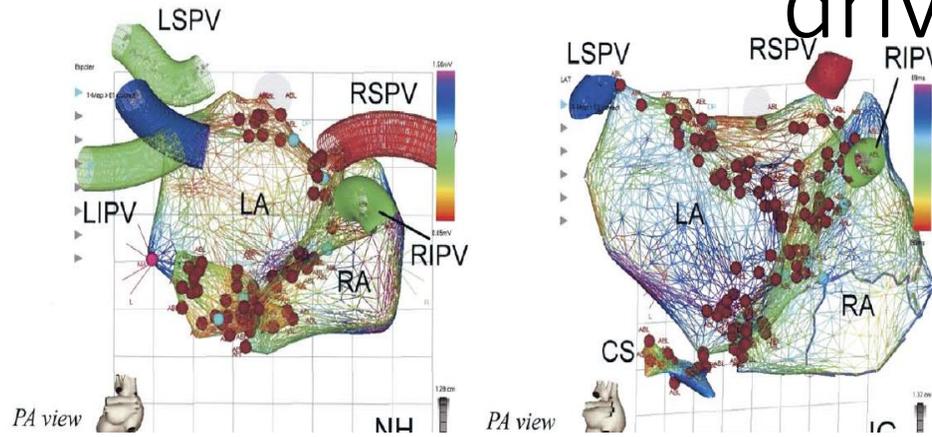
- Visualisation des drivers avec un software sophistiqué
- Analyse visuelle des électrogrammes intracardiaques

# Approches panoramiques

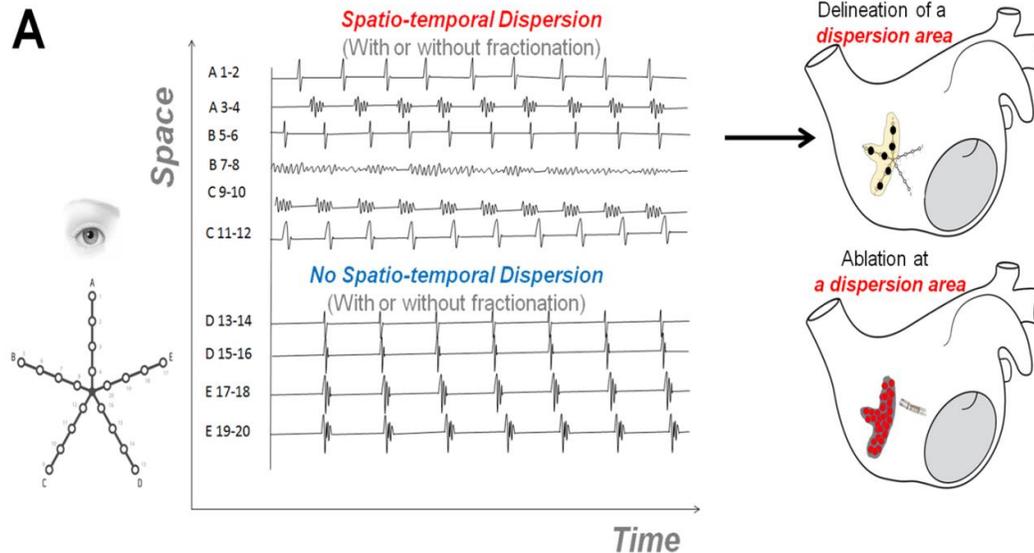
- Reposent sur **des modèles de propagation des ondes**: Ces modèles sont-ils proches de la réalité?
- Tentent de reproduire la propagation des ondes dans **une géométrie hétérogène et complexe**
- Produisent des **cartes complexes difficiles à analyser**
- Difficultés à **localiser précisément les drivers**



# Visual approaches for the detection of AF drivers



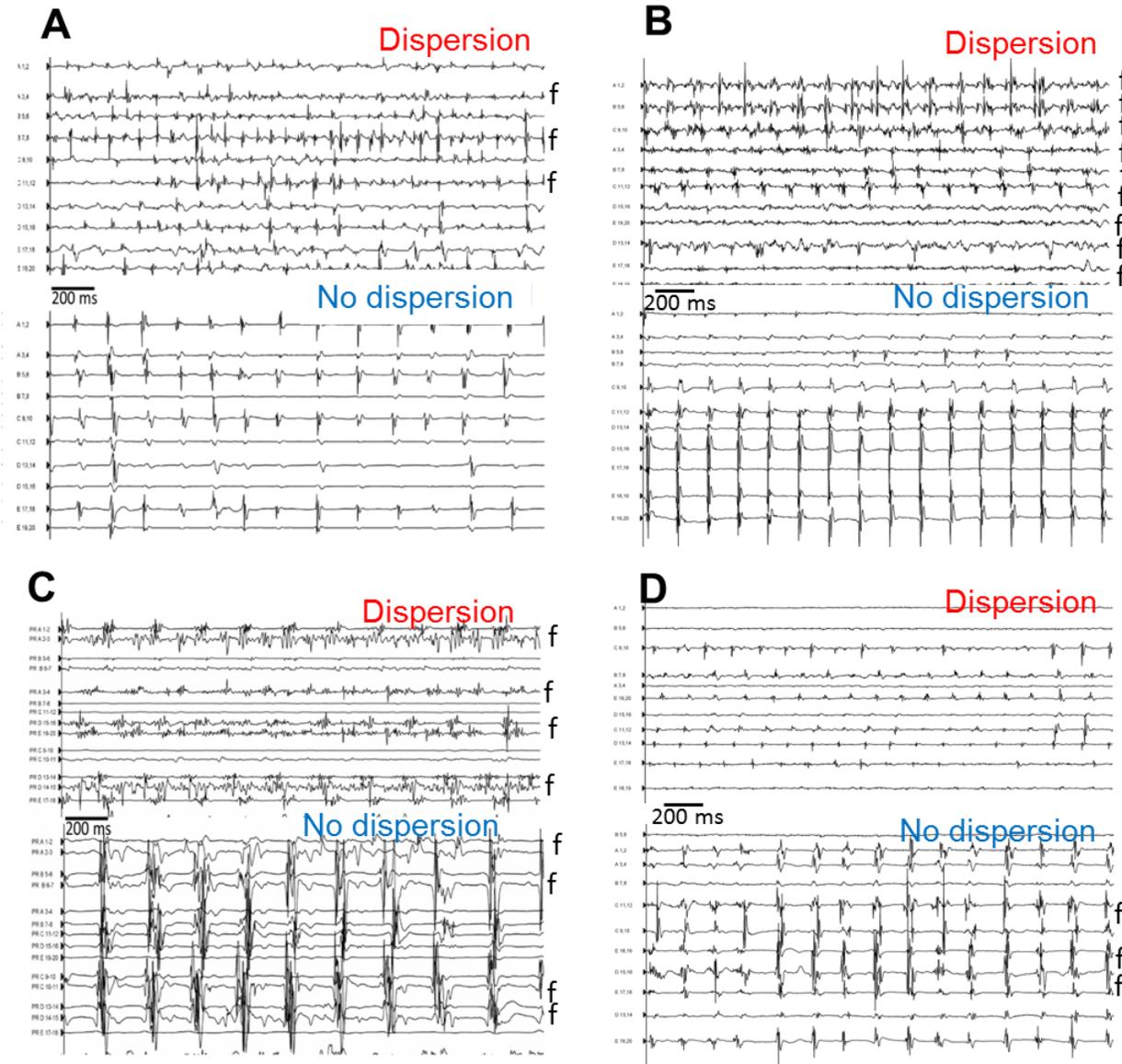
*Electrogram-based ablation  
Complex Fractionated Atrial Electrograms  
Nademanee et al. , JACC 2004*



*Spatio-Temporal Dispersion of Electrograms: Non-simultaneous activation at multiple neighboring electrode locations (with or without fractionation)  
Seitz et al., JACC 2017*

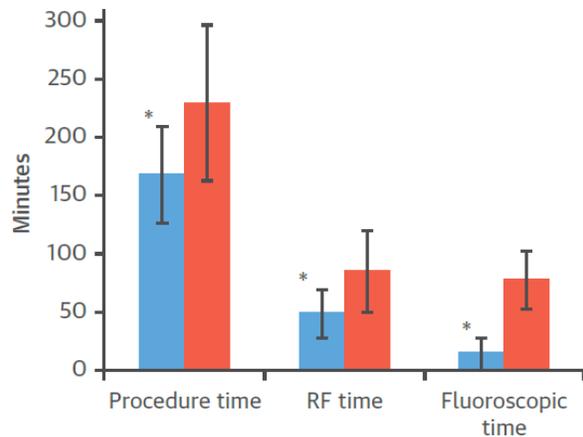
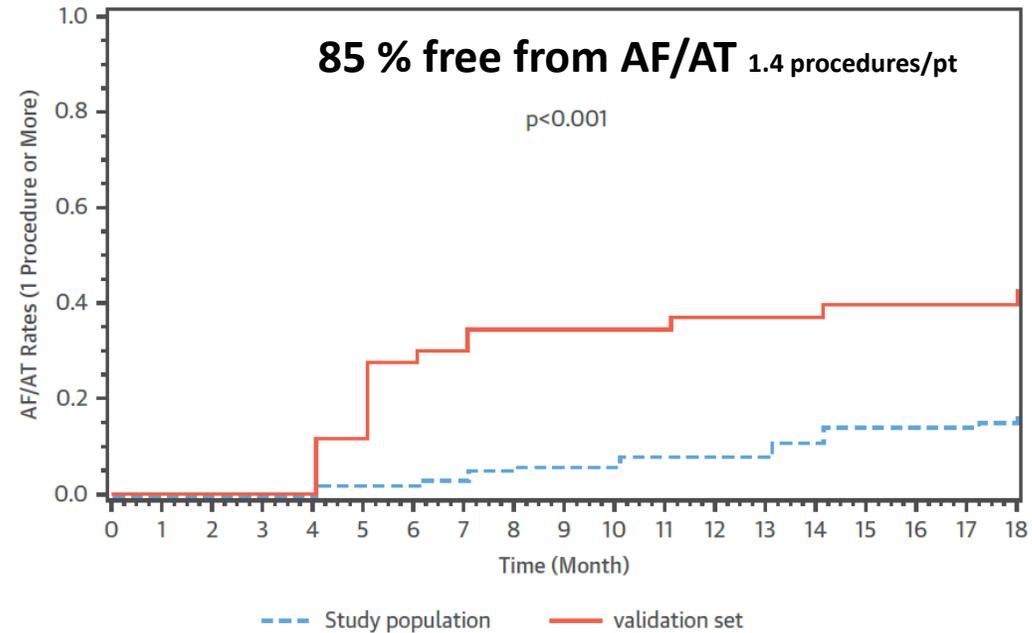
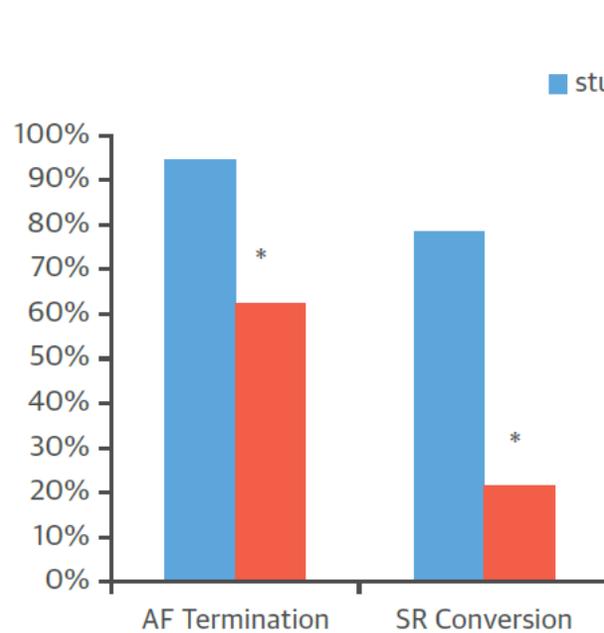
**Two close definitions of AF driver's footprints with good clinical outcomes but limited reproducibility**

# Spatio-Temporal Dispersion of Electrograms: Examples



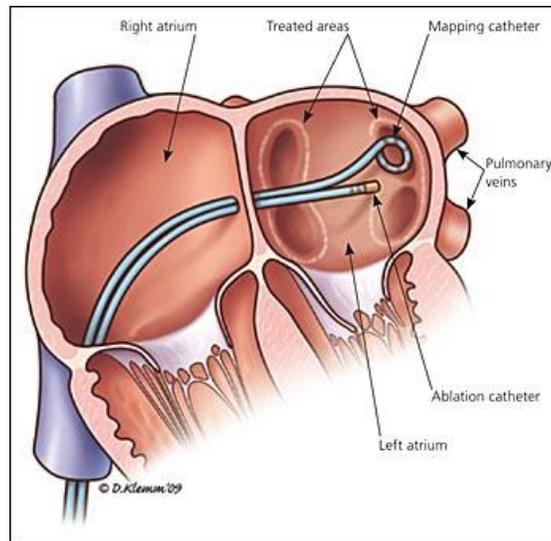
Different patterns of drivers electrograms illustrating the complexity of the visual analysis

# Drivers ablation Vs classical approach: Better efficacy with shorter ablation



**But the detection of drivers was based on EGM visual analysis...**

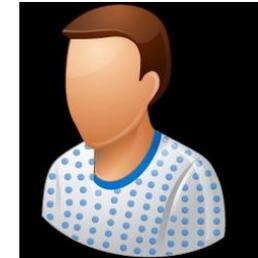
# Les opérateurs sont limités



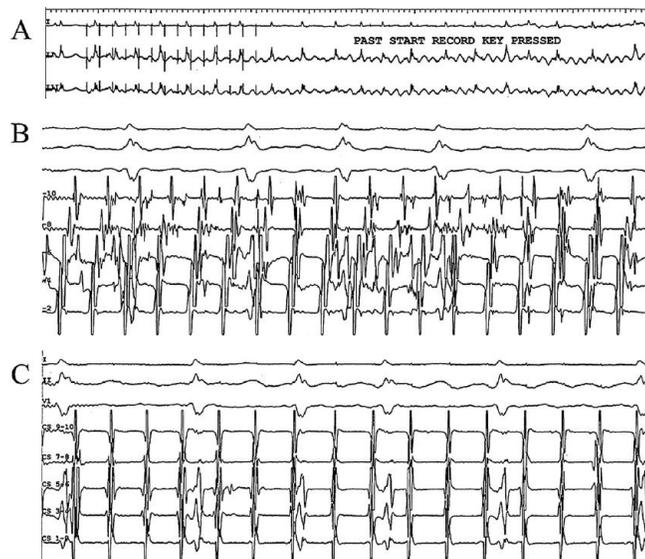
Manipulation



Family  
Patients  
Staff



Signal  
Analysis

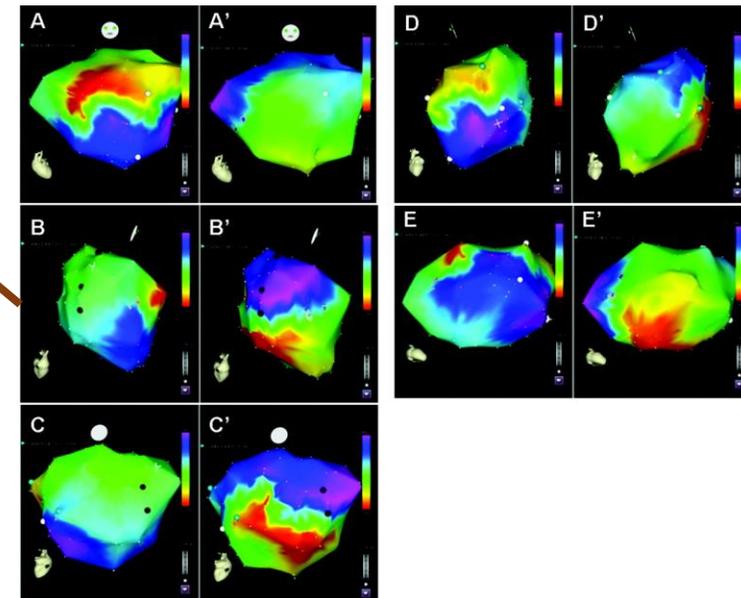


Stress

Fatigue



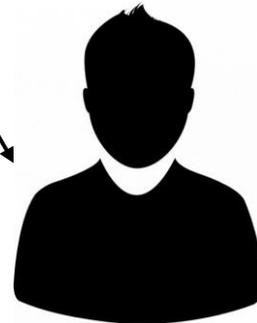
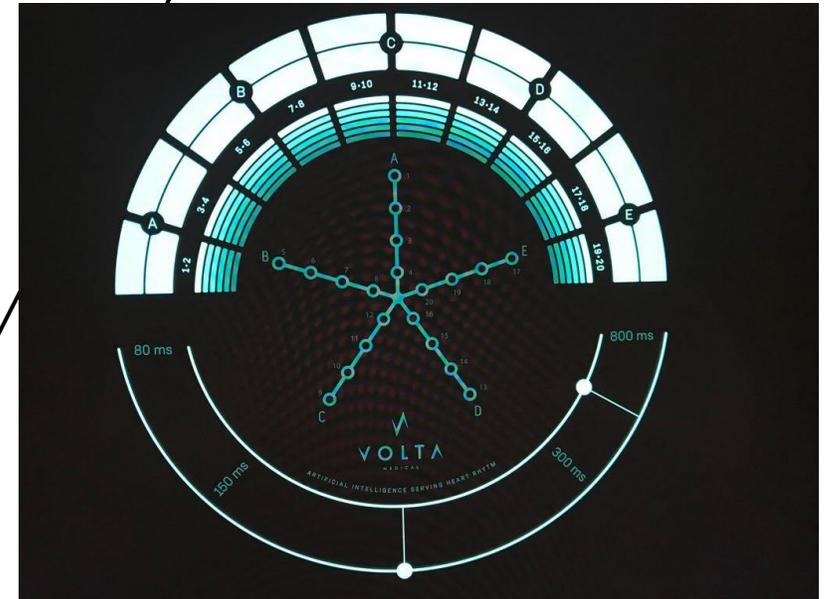
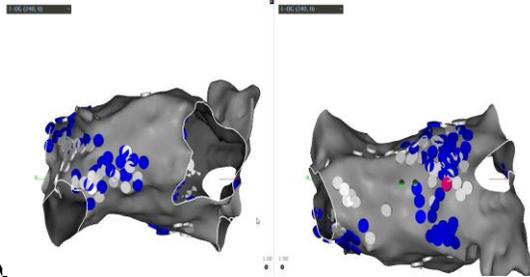
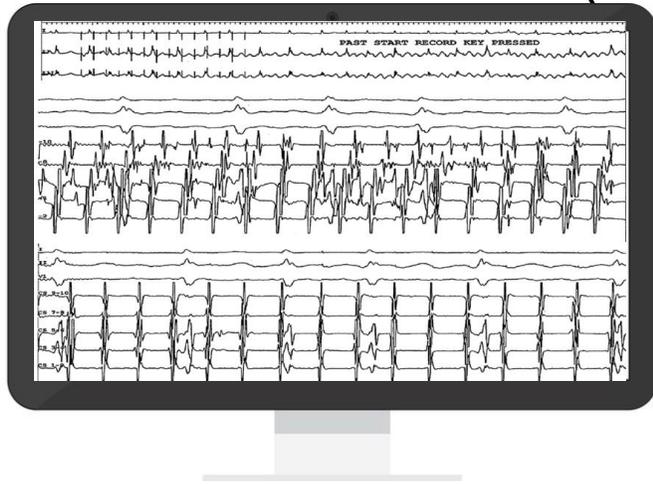
Mapping



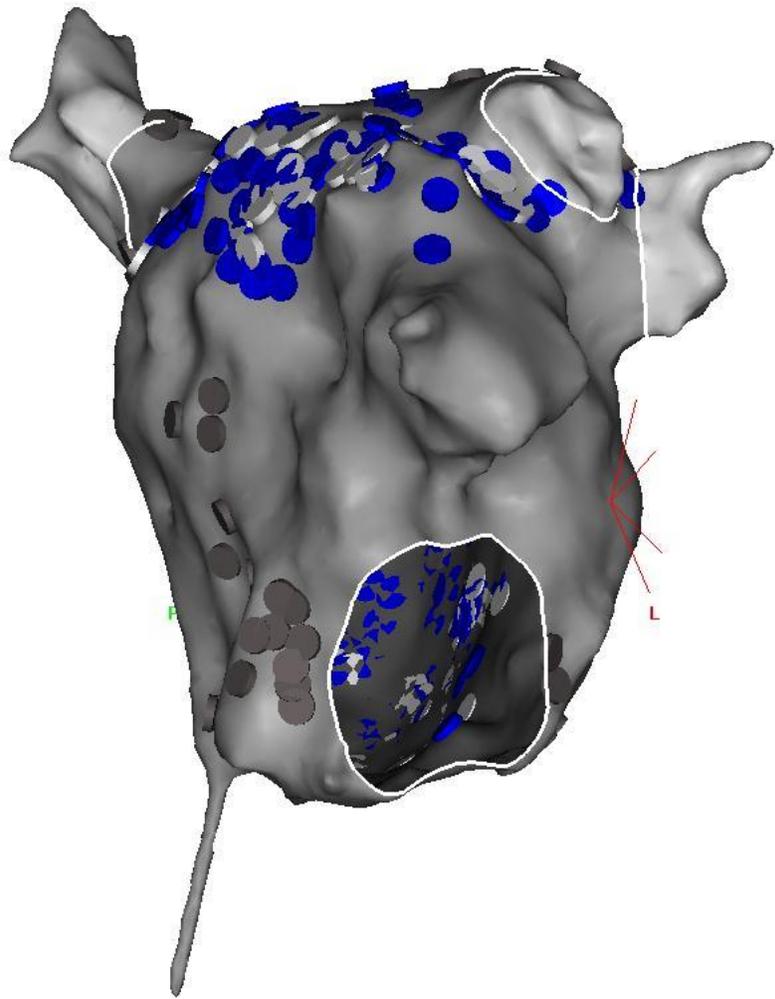
# VX1



# Double Blind Tests



1-OG (1983, 0)

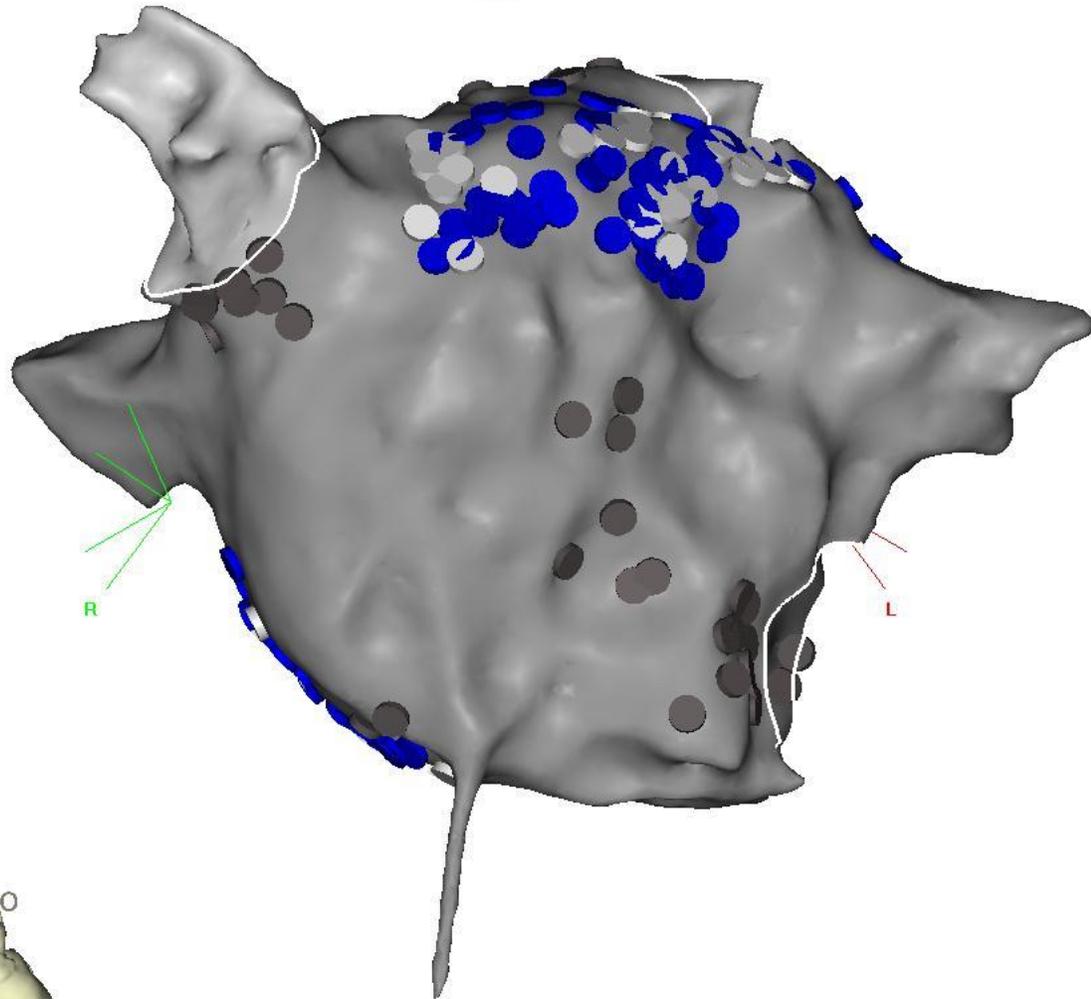


1.40



AP PA LAO RAO LL RL INF SUP

1-OG (1983, 0)



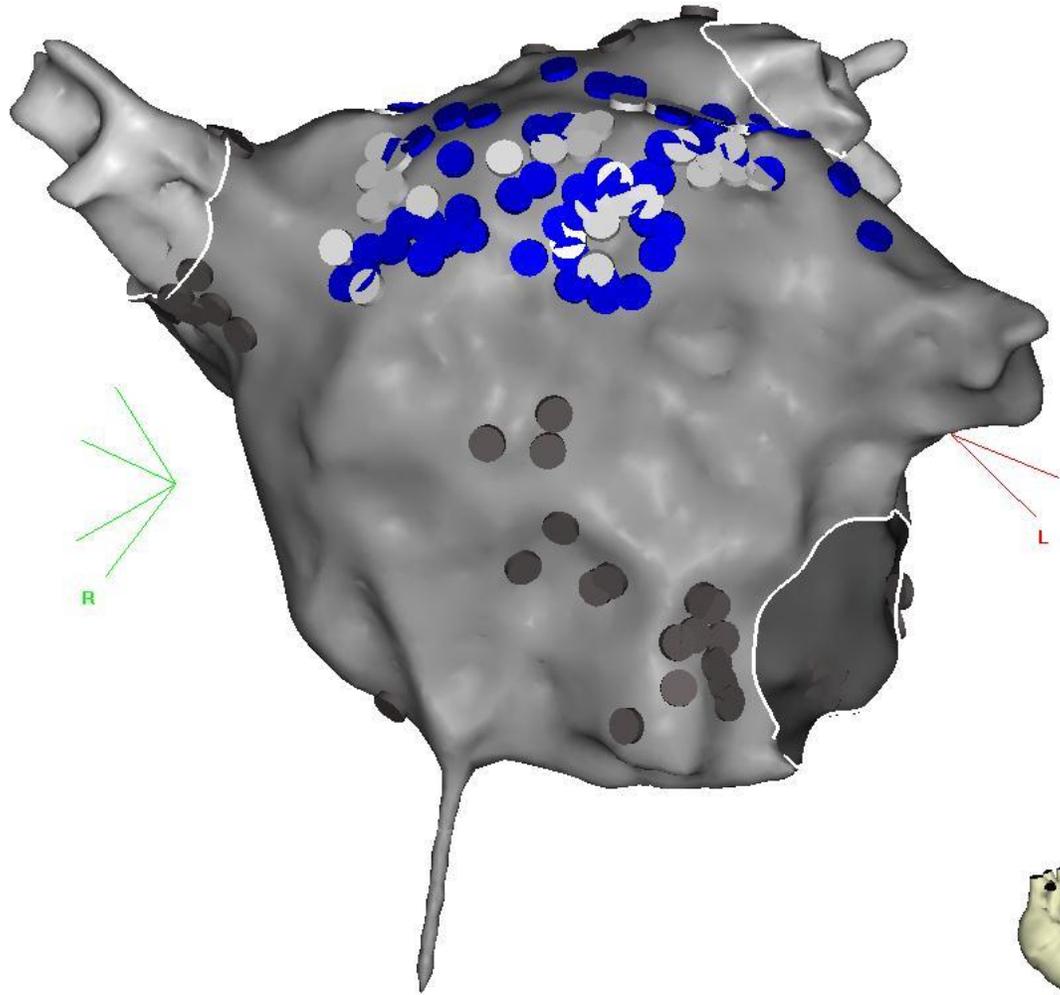
1.34



AP PA LAO RAO LL RL INF SUP

None

1-OG (1983, 0)

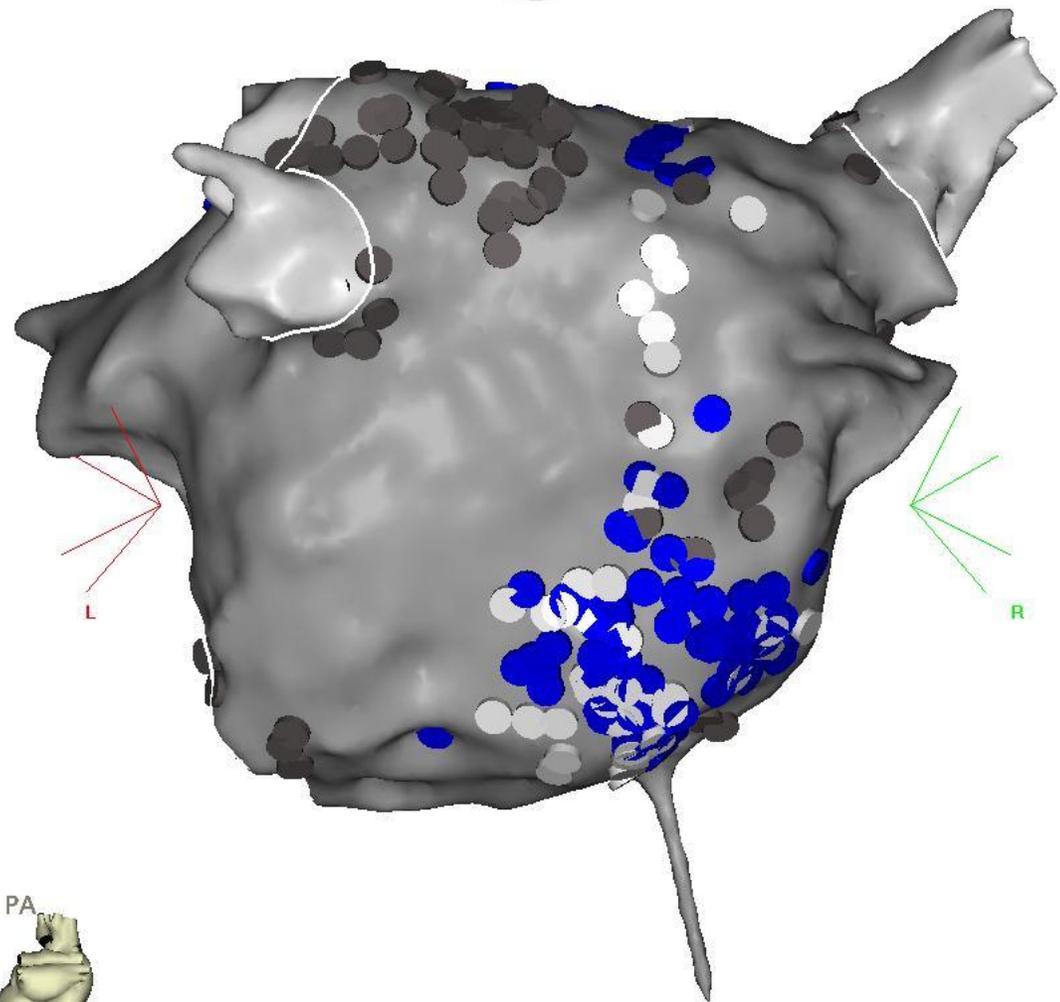


1.40



AP PA LAO RAO LL RL INF SUP

1-OG (1983, 0)



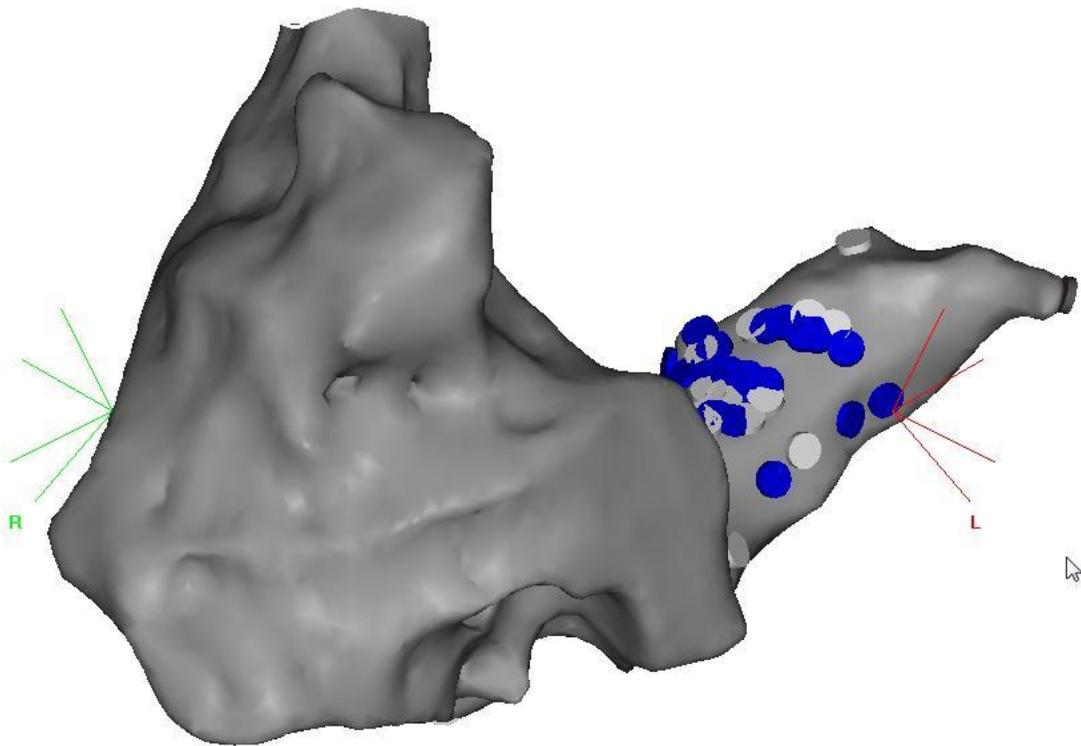
1.34



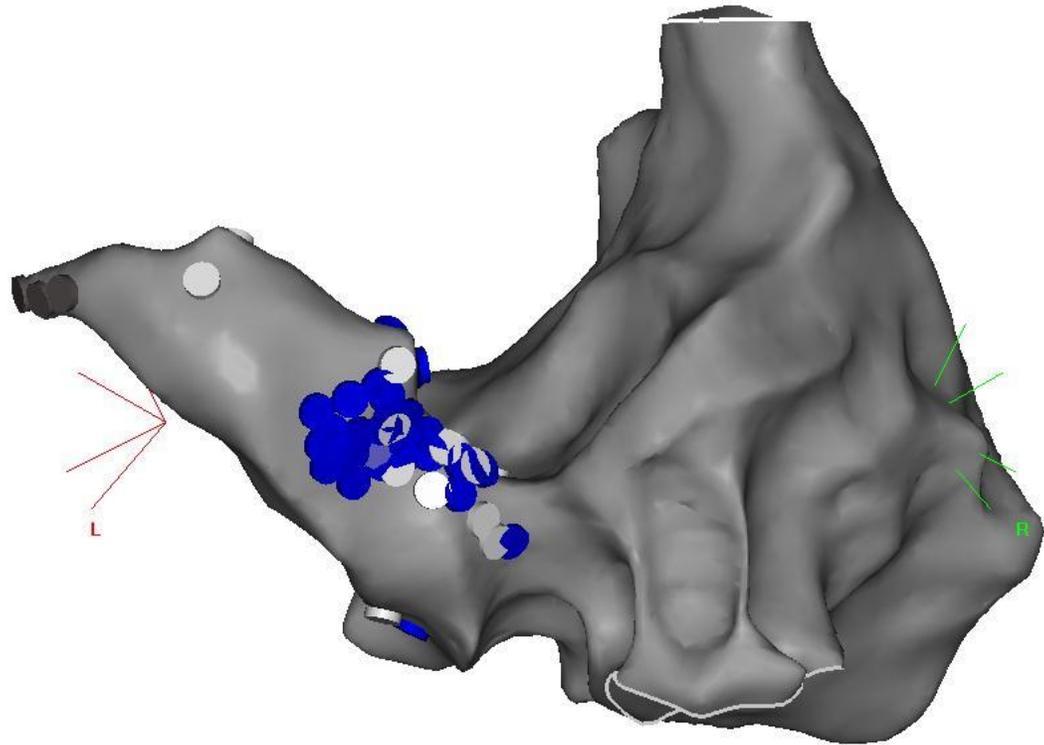
AP **PA** LAO RAO LL RL INF SUP

None

2-OD (1547, 0)



2-OD (1547, 0)



16

1.40



AP PA LAO RAO LL RL INF SUP

AP PA LAO RAO LL RL INF SUP

1.34

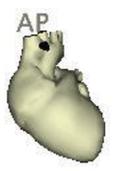
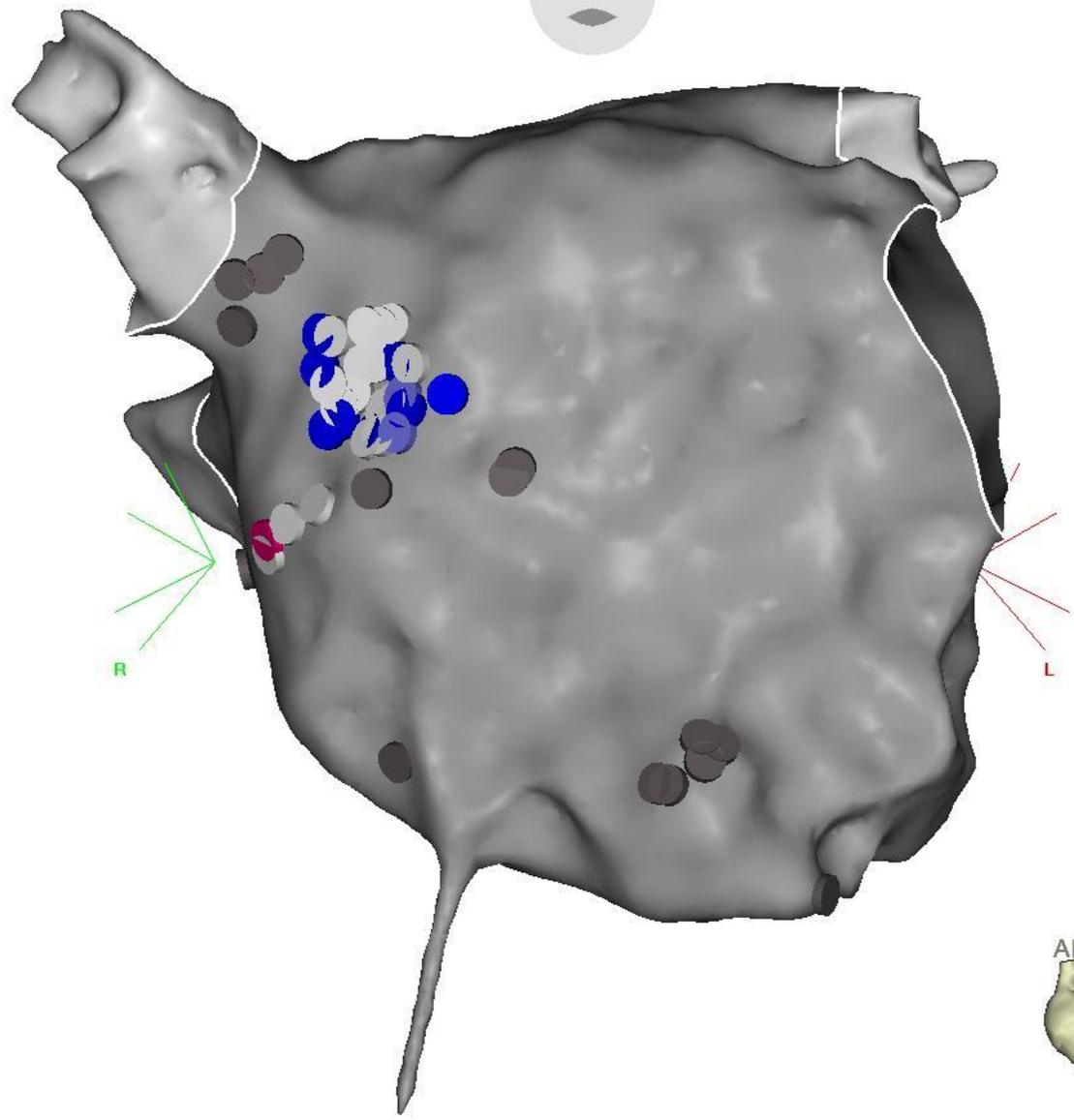


AP PA LAO RAO LL RL INF SUP

AP PA LAO RAO LL RL INF SUP

None

1-1-1-1-... (361, 0)

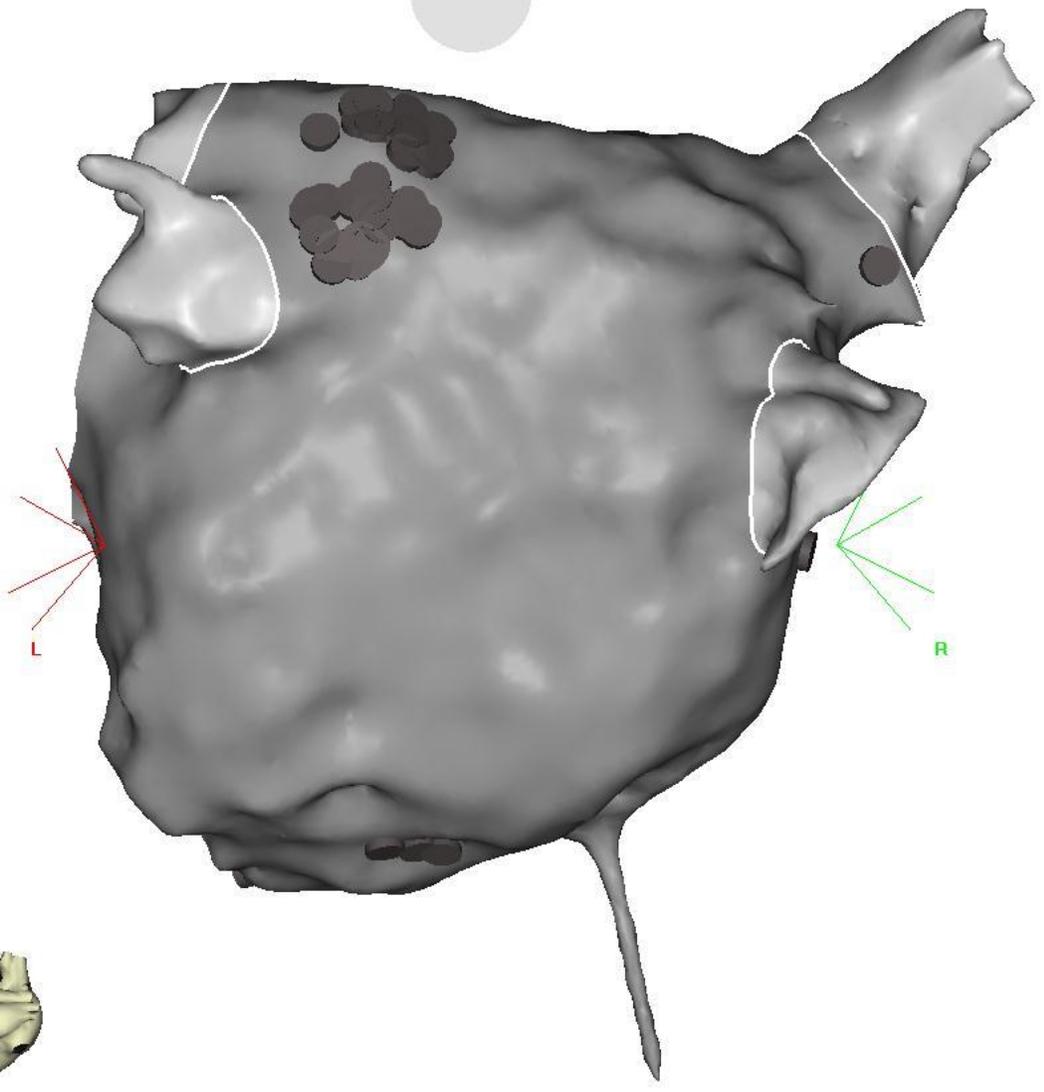
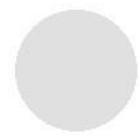


1.21



AP PA LAO RAO LL RL INF SUP

1-1-1-1-... (361, 0)



1.21



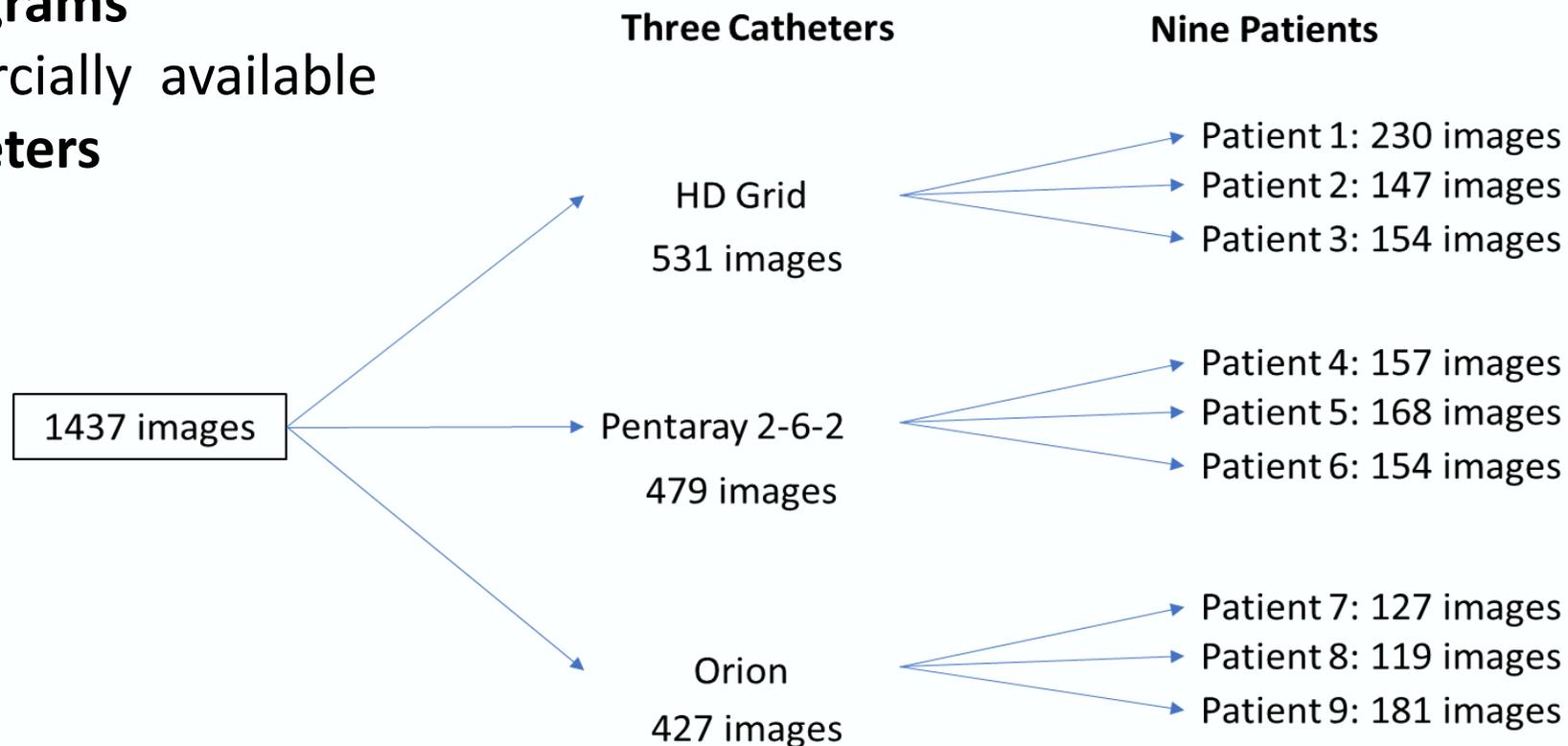
AP PA LAO RAO LL RL INF SUP

None

# The « Reader » Study

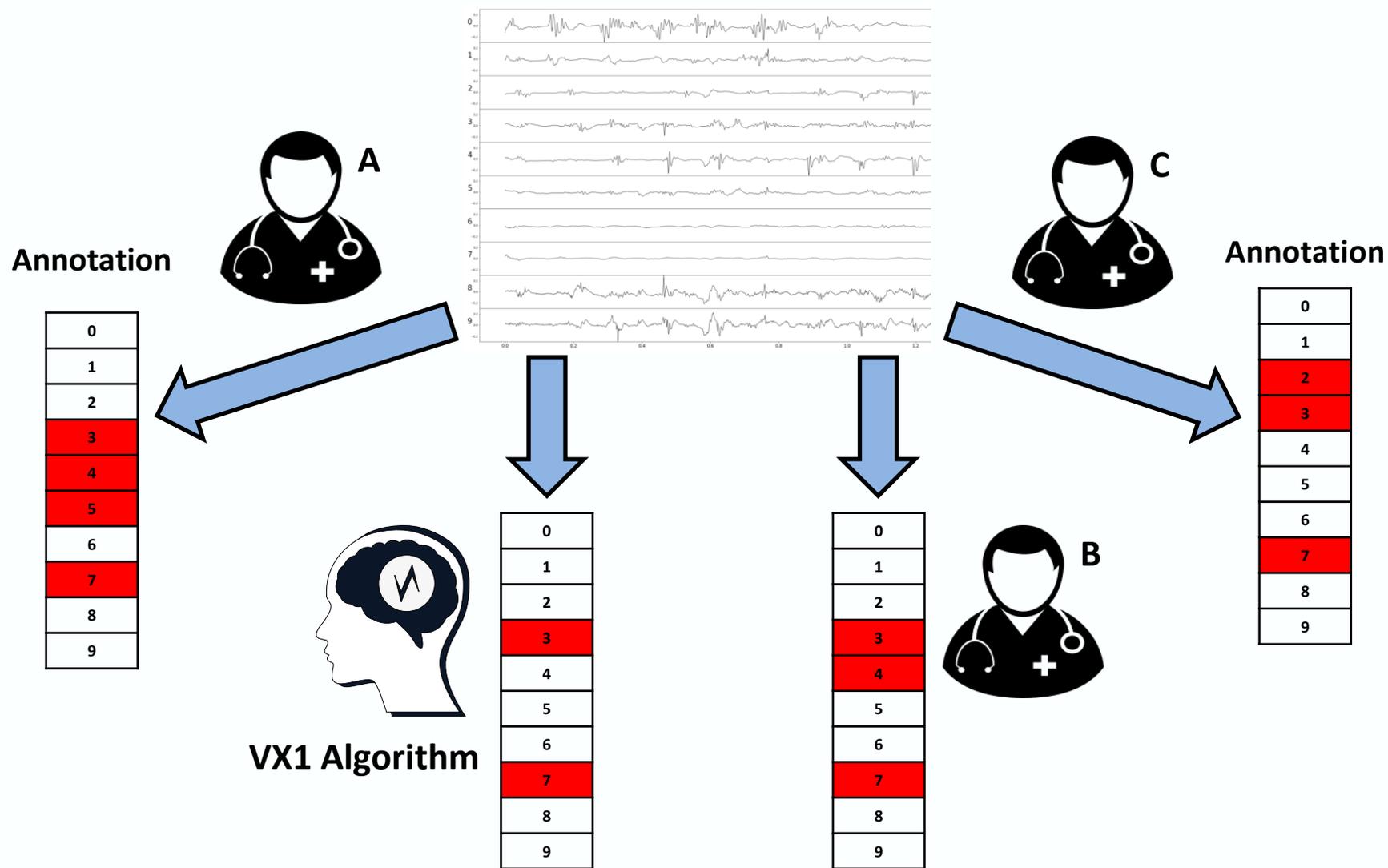
## *Dataset*

- **14370** electrograms
- **Three** commercially available mapping catheters
- **9** patients



# The « Reader » Study

## Methods



# The « Reader » Study

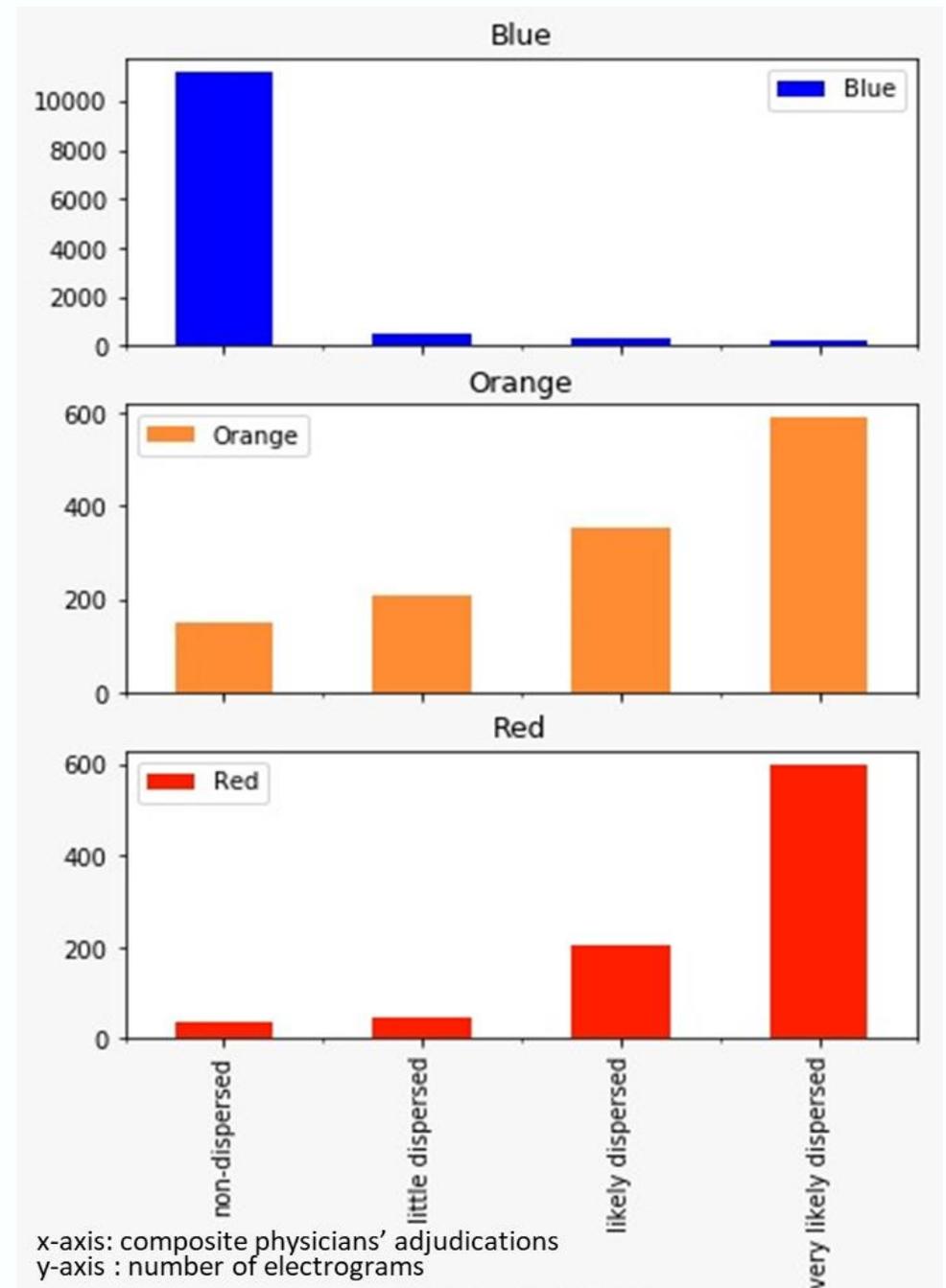
## *Methods*

- Electrograms adjudicated as **non-dispersed** by each of the three readers are considered “**non-dispersed**”;
- Electrograms adjudicated as dispersed by **one reader only** are considered “**little dispersed**”;
- Electrograms adjudicated as dispersed by **two readers** are considered “**likely dispersed**”;
- Electrograms adjudicated as dispersed by **each of the three readers** are considered “**very likely dispersed**”.

# The « Reader » Study

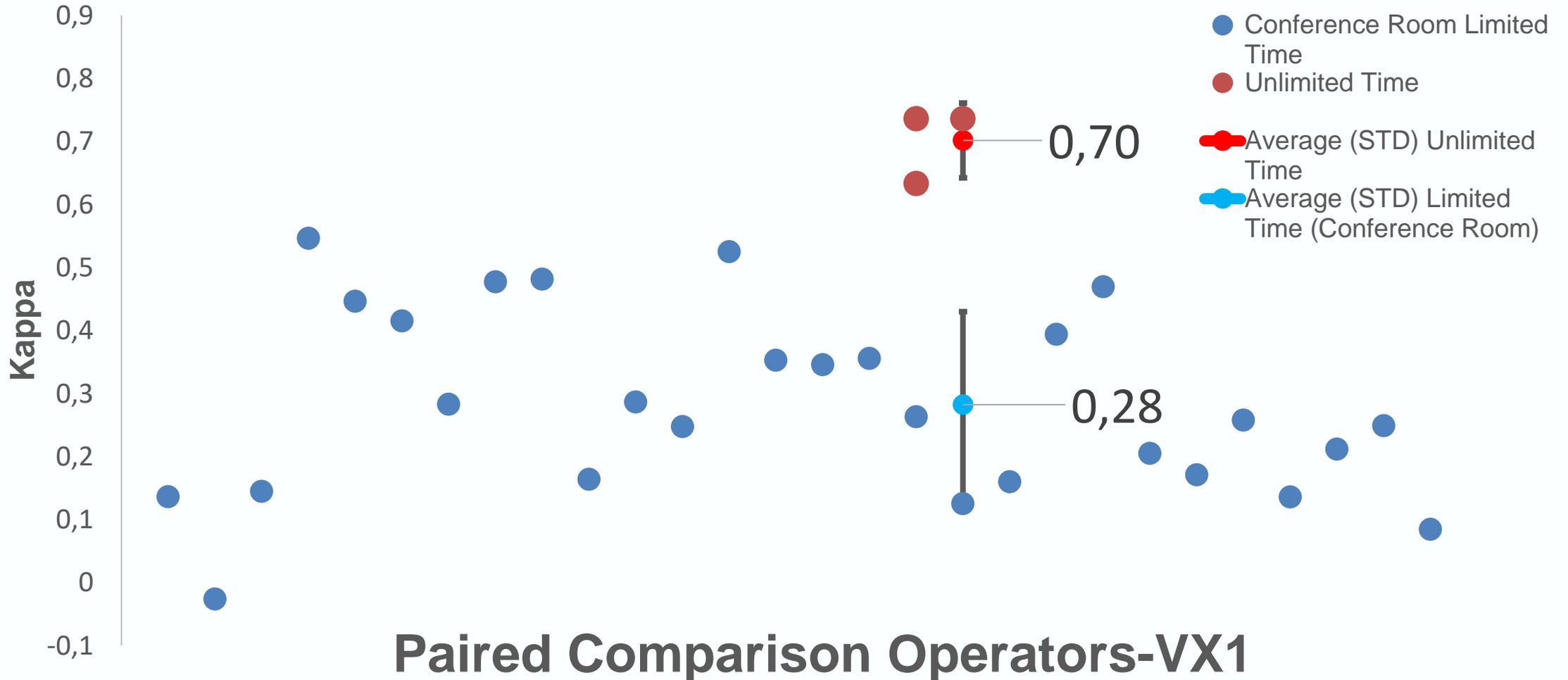
Three histograms of electrograms:

- those annotated by VX1 as **blue (normal zone)**,
- those annotated by VX1 as **orange (region of interest)**
- those annotated by VX1 as **red (region of special interest)**.



# The « Reader » Study

## *Operator-VX1 Agreement: Limited vs. Unlimited Time*



# The « Reader » Study

## *Conclusions*

- (i) VX1 adjudications highly correlate with the likelihood of electrograms to be classified as dispersed by a group of trained operators with unlimited time.
  - (ii) Agreement levels are much higher when operators are given unlimited analysis time.
  - (iii) VX1 cannot be distinguished from a trained operator with unlimited analysis time but works in a real-time configuration.
- ➡ VX1 is able to mimic a specific clinical expertise at its best.

Comment le logiciel est-il intégré au bloc opératoire?

# AF module of Volta software

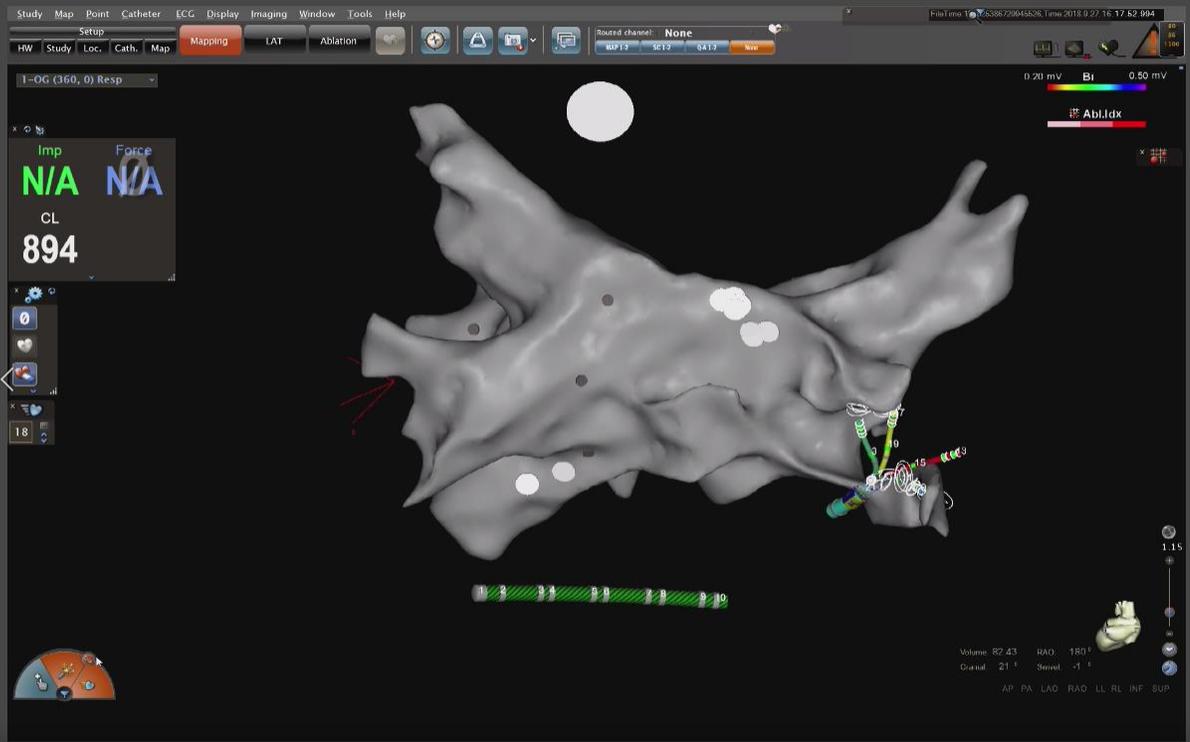
Needs multipolar endocardial AF signals



# Our workstation

Films et TV

## Atrial 3D reconstruction



Study Map Point Catheter ECG Display Imaging Window Tools Help

Setup

Round channel: None

HW Study Loc. Cath. Map Mapping LAT Ablation

1-OG (360, 0) Resp

Imp N/A Force N/A

CL 894

0.20 mV BI 0.50 mV

Volume: 82.43 Area: 21.1

AP PA LAO RAO LL RL INF SUP

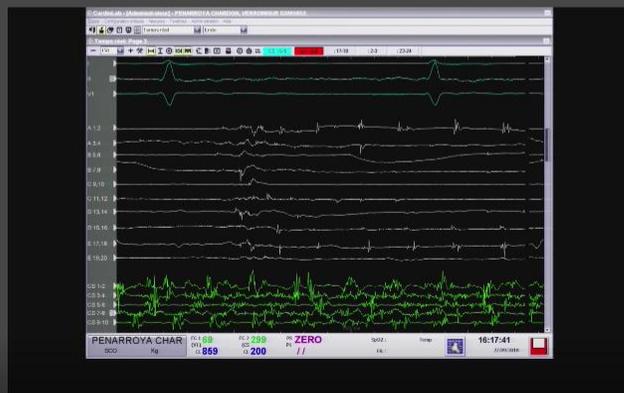
## Electrograms analysis



VOLTA

START TRANSDON MAPPING

## Electrograms recording



Channel: [Dropdown] Time: [Display]

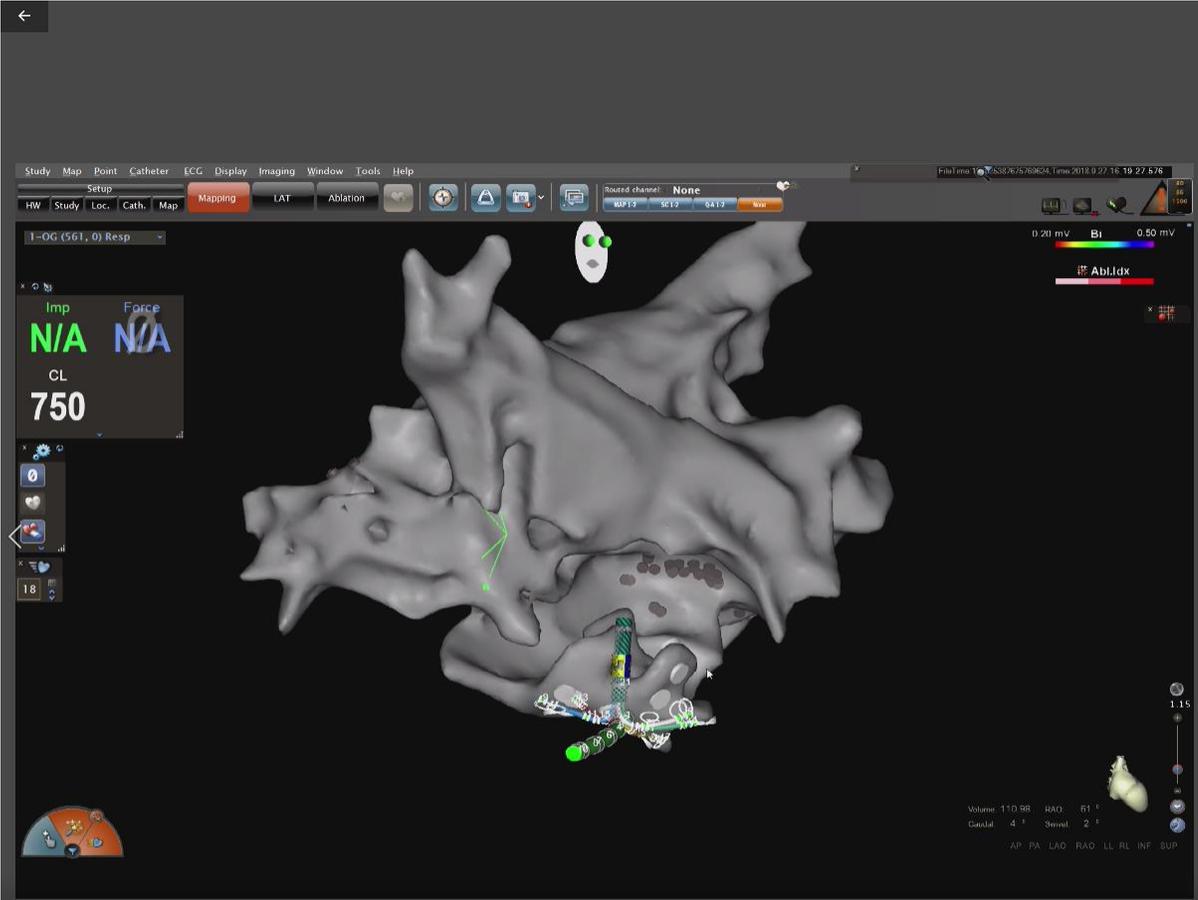
PENARROYA CHAR

CL 894 ZERO

16:17:41

00:12:18 01:28:04





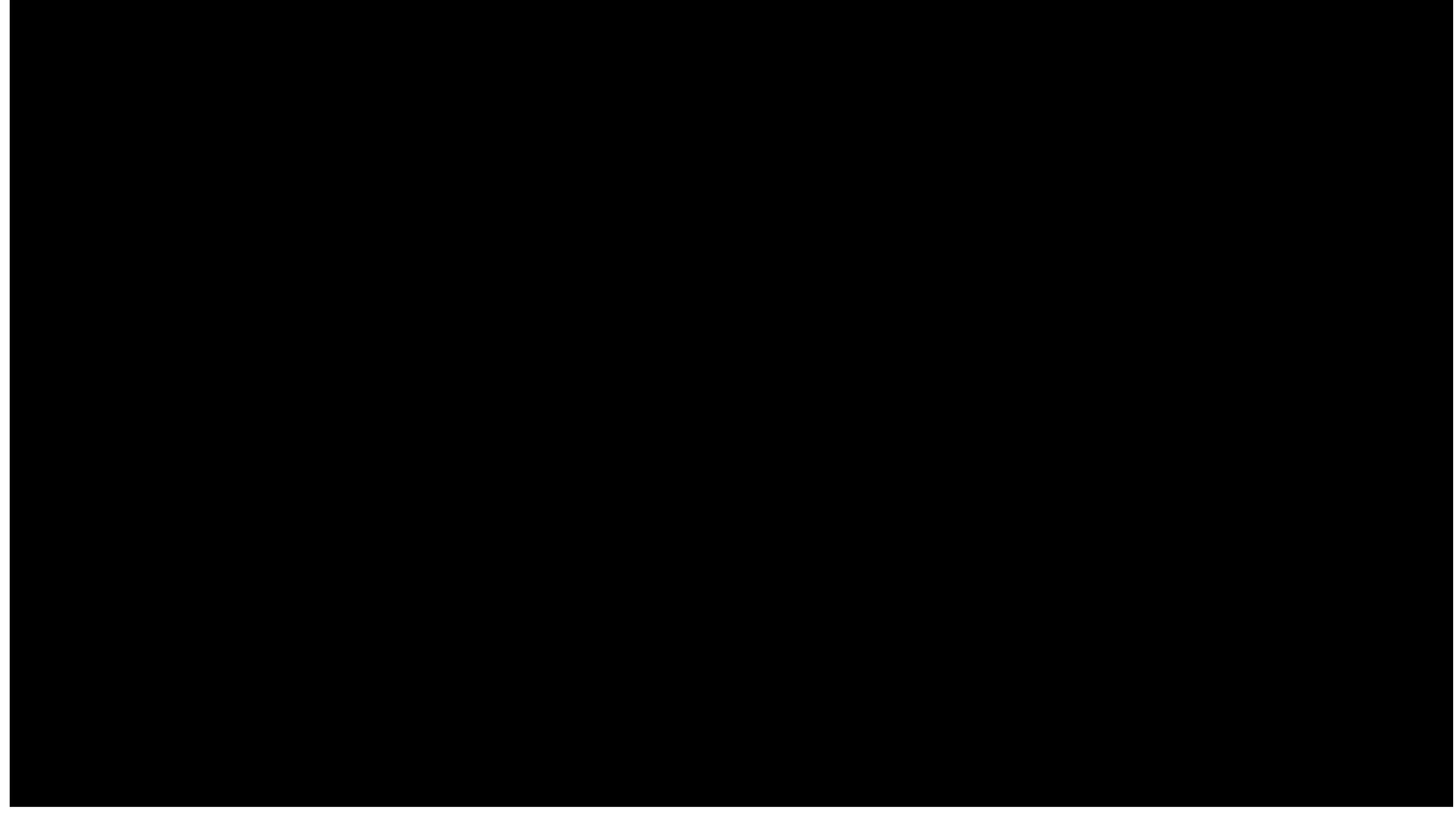
# HOT REGION



00:13:53

01:26:29

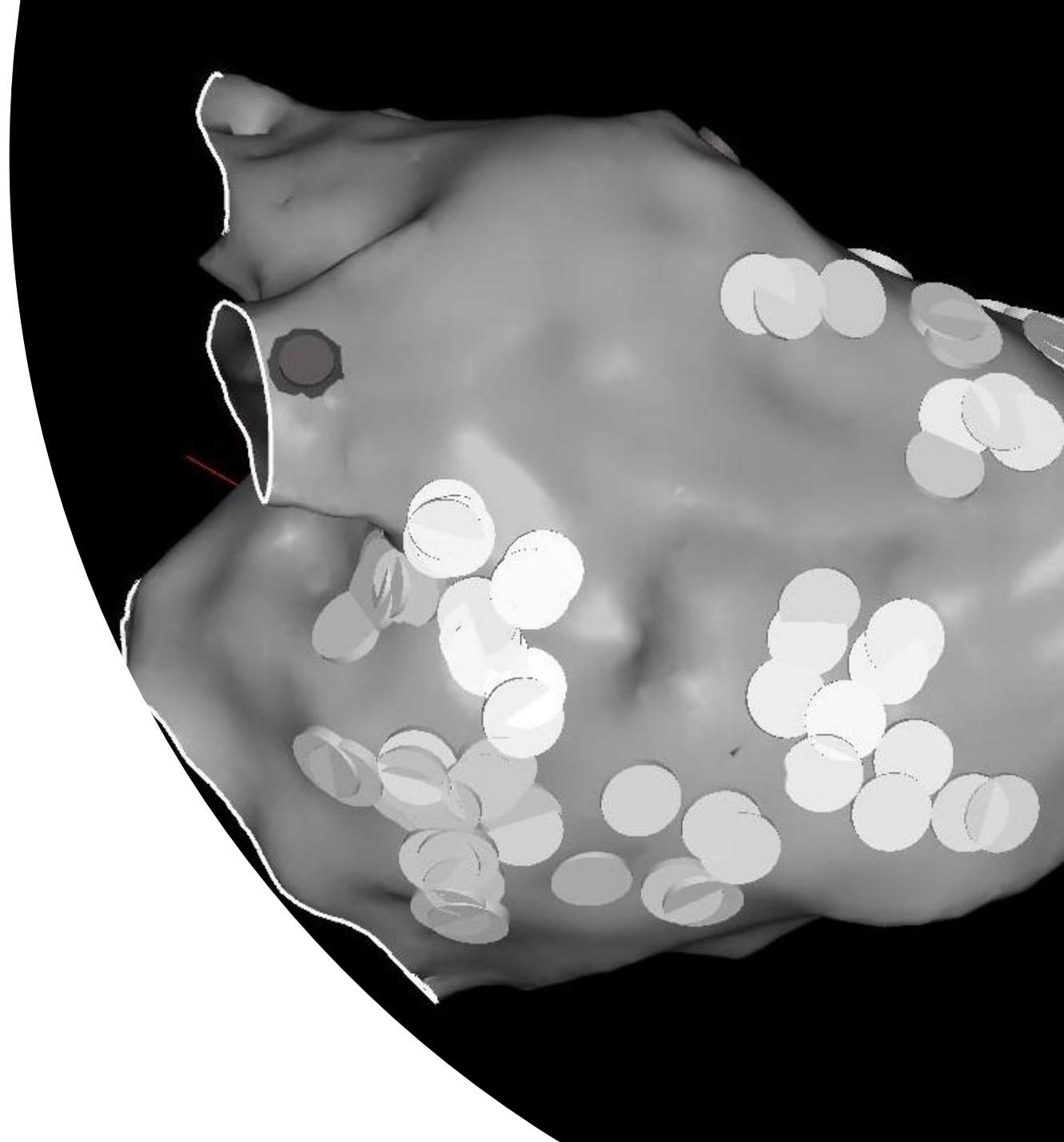
Volume control, play/pause, and navigation icons.



# AI-guided Regional HD Approach

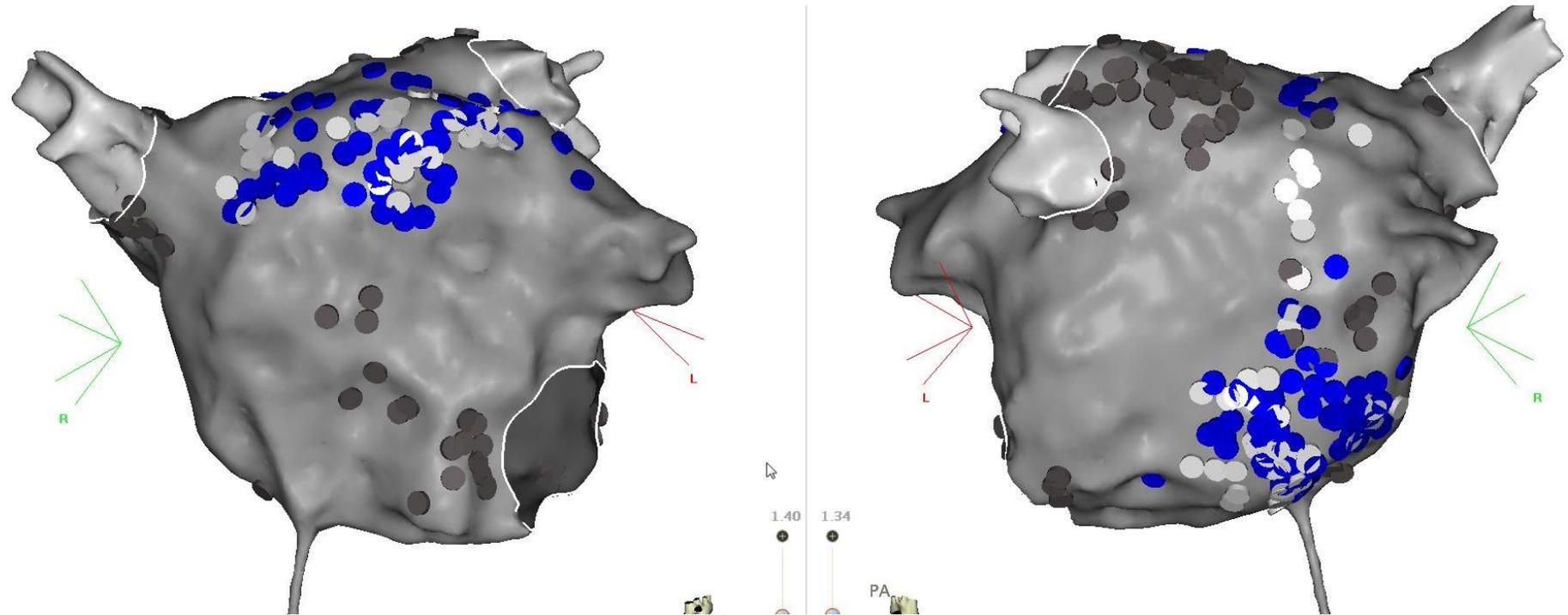
---

- High density maps
- Patient-tailored
- Easy to use
- Precisely locating AF drivers
- Guided mapping
- Data-driven performance



# Improvements & Limitations

- Learn from failures
- Ablate less
- Predict the zones
- Ablation support



# Towards an AI-based guidance

Data-driven tools may revolutionize interventional electrophysiology



A young girl with dark hair, wearing a white cardigan with a pink floral pattern and a pink backpack, is holding hands with a white robot. The robot has a round head with a blue circular light on its right side and is holding a tablet. The robot is decorated with a garland of pink cherry blossoms. The background is a blurred festival scene with many lights and people.

**Thank you**



VOLTA

MEDICAL

ARTIFICIAL INTELLIGENCE SERVING HEART RHYTHM





# EGMs Quizz

28 cardiac electrophysiologists



1	6
2	7
3	8
4	9
5	10

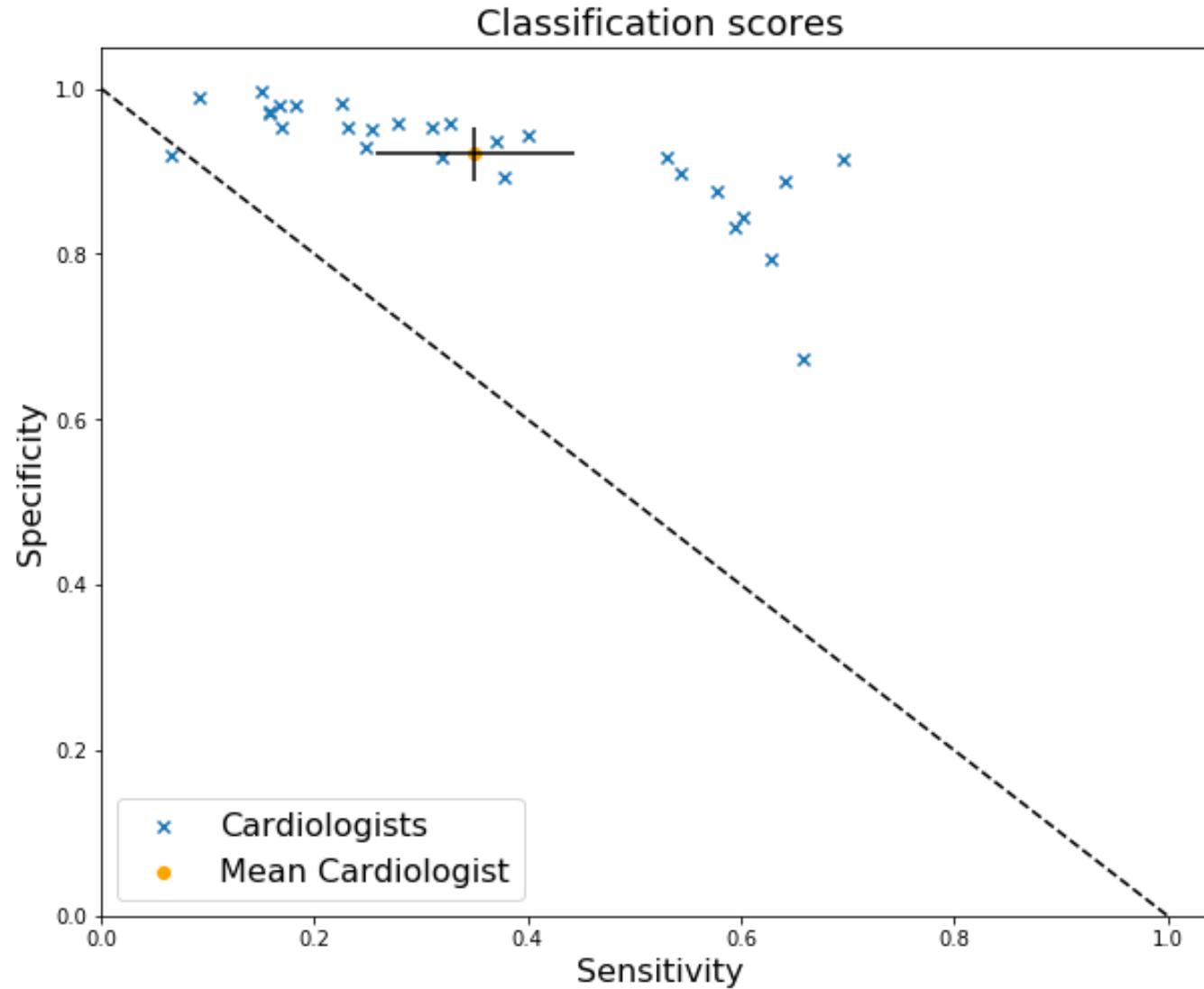
17 sec.  
to answer

102 still-images=1020 EGMs

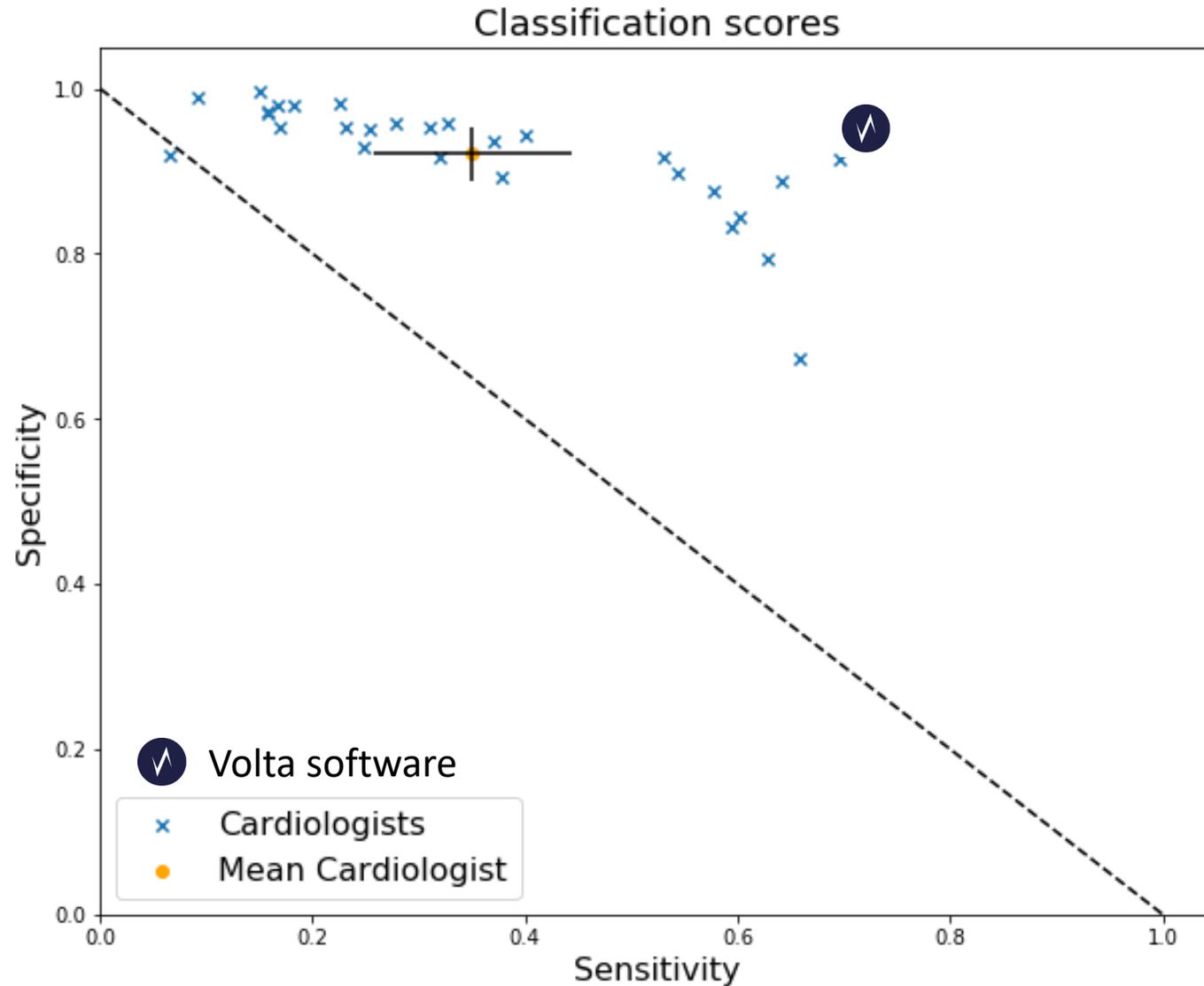
60 % from AF termination sites (“hot” signals)

***At which of those electrogram locations would you ablate?***

# Cardiologists



# EPs vs Volta Software

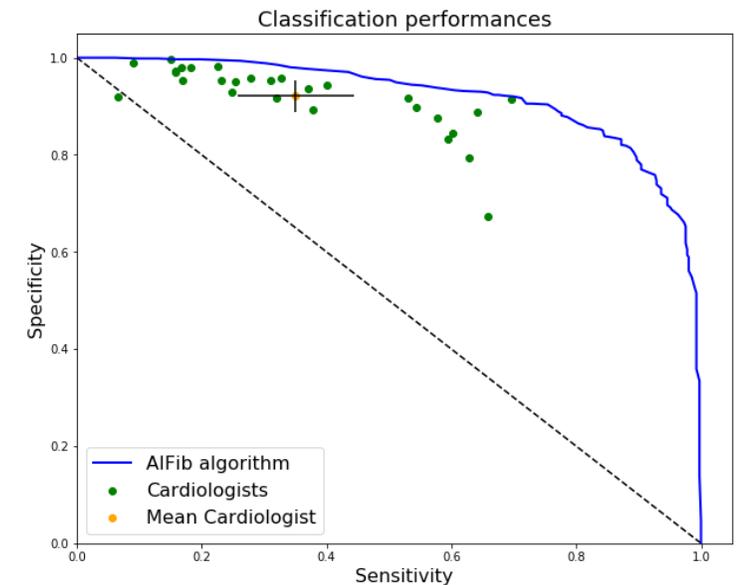


***Volta software  
outperforms a panel of  
28 EPs experts in EGM-  
based AF ablation***

# AI Fib outperforms Humans

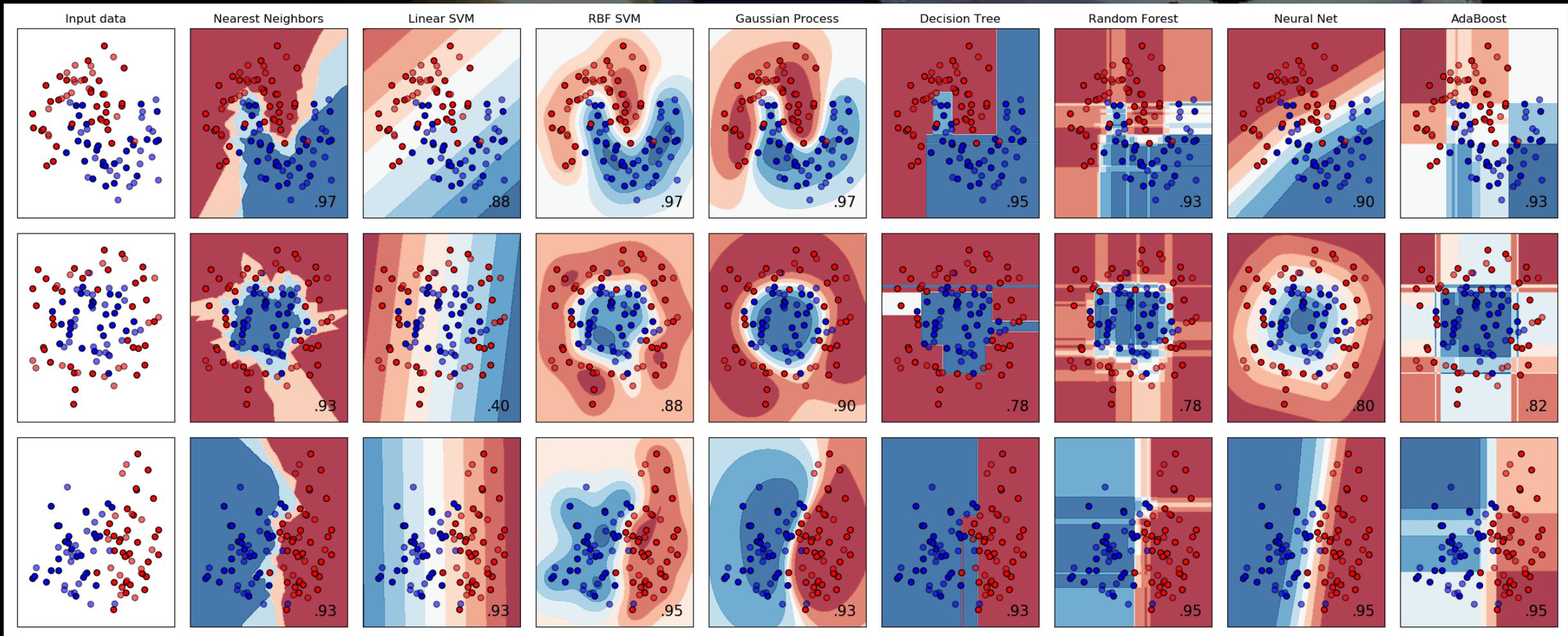
Our pre-clinical and clinical studies met all endpoints with outstanding results <sup>1</sup>

- **Monocentric clinical trial:**
  - **Double-blind maps** during atrial fibrillation
  - ✓ **Less aggressive:** Ablated regions were significantly smaller ( $23.4 \pm 12.6$  vs.  $30.0 \pm 7.6$  cm<sup>2</sup>,  $p=0.046$ )
  - **Ablation guidance in 76 patients** in Marseille
  - ✓ **92% of acute atrial fibrillation termination**
- **Comparative test** with a panel of **experienced electrophysiologists**
- ✓ **AI Fib outperforms all 28 cardiac electrophysiologists** (1020 signals)

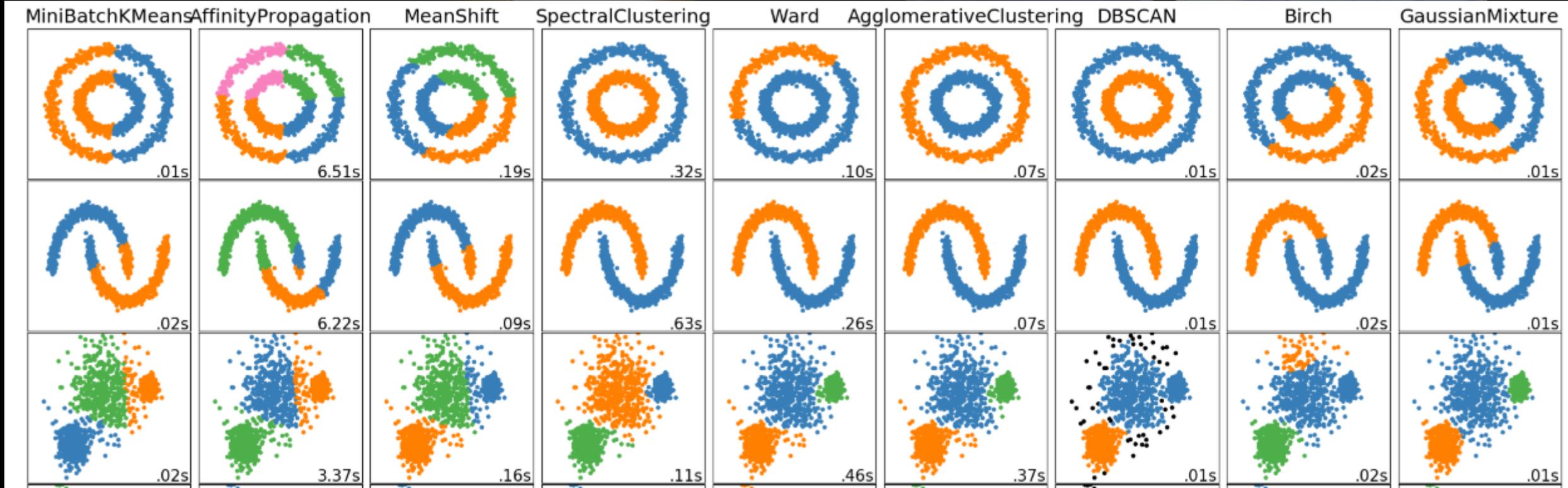


1. Submitted to the Heart Rhythm Society Late Breaking Clinical Trials Session

# Principales Limites



# Principales Limites



# Echec

1997

DeepBlue gagne face à Garry Kasparov



# Natural Language Processing

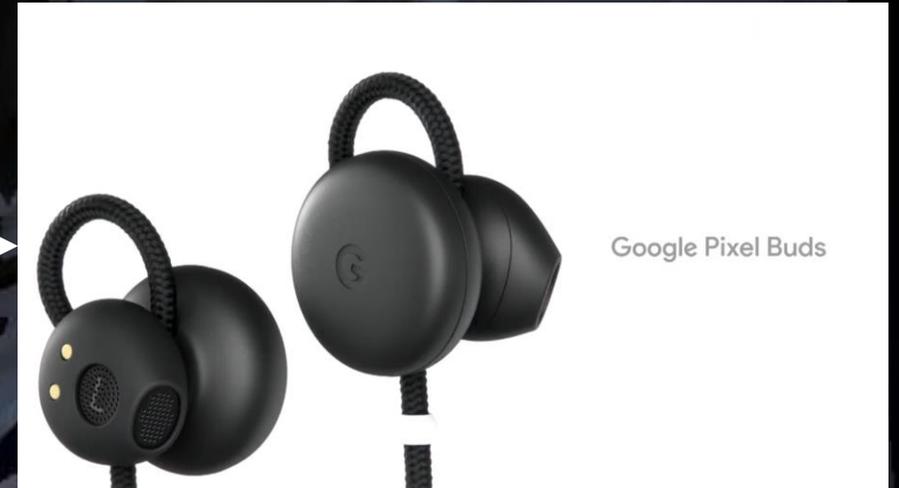
Translation



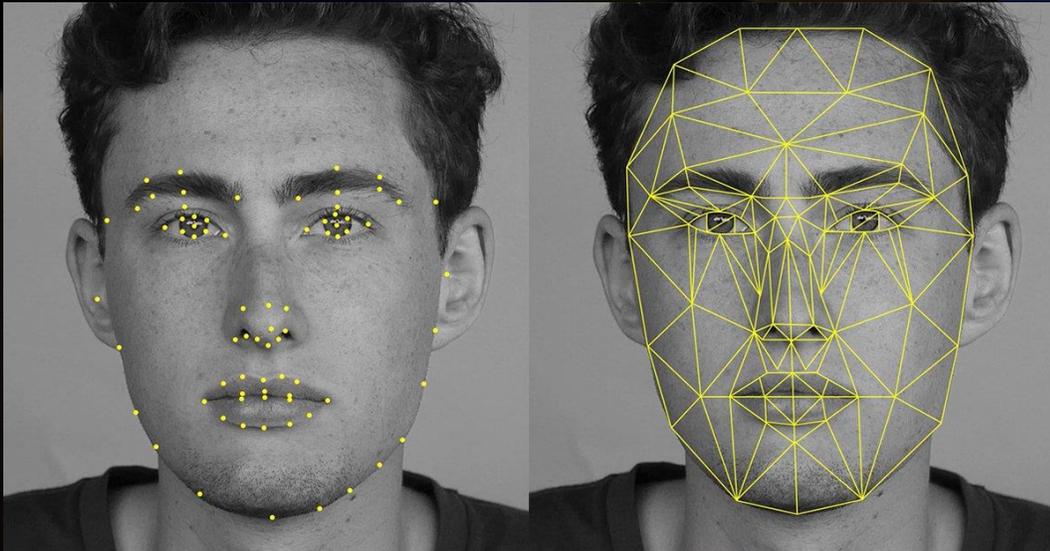
Speech Recognition



# Natural Language Processing



# Face Recognition



The image shows two astronauts in white space suits against a dark blue background. The astronaut on the left is wearing a gold helmet and has a NASA logo on their chest. The astronaut on the right is wearing a white helmet and has an American flag patch on their chest. The text "How to get a labelled DataBase?" is overlaid in the center in a bold, white, sans-serif font.

# How to get a labelled DataBase?

The image shows two astronauts in space suits. The astronaut on the left is wearing a gold helmet and a white suit with a NASA logo on the chest. The astronaut on the right is wearing a white helmet and a white suit with an American flag patch on the chest. The background is a dark blue gradient. The text "Either you pay..." is centered over the image in a white, bold, sans-serif font.

**Either you pay...**

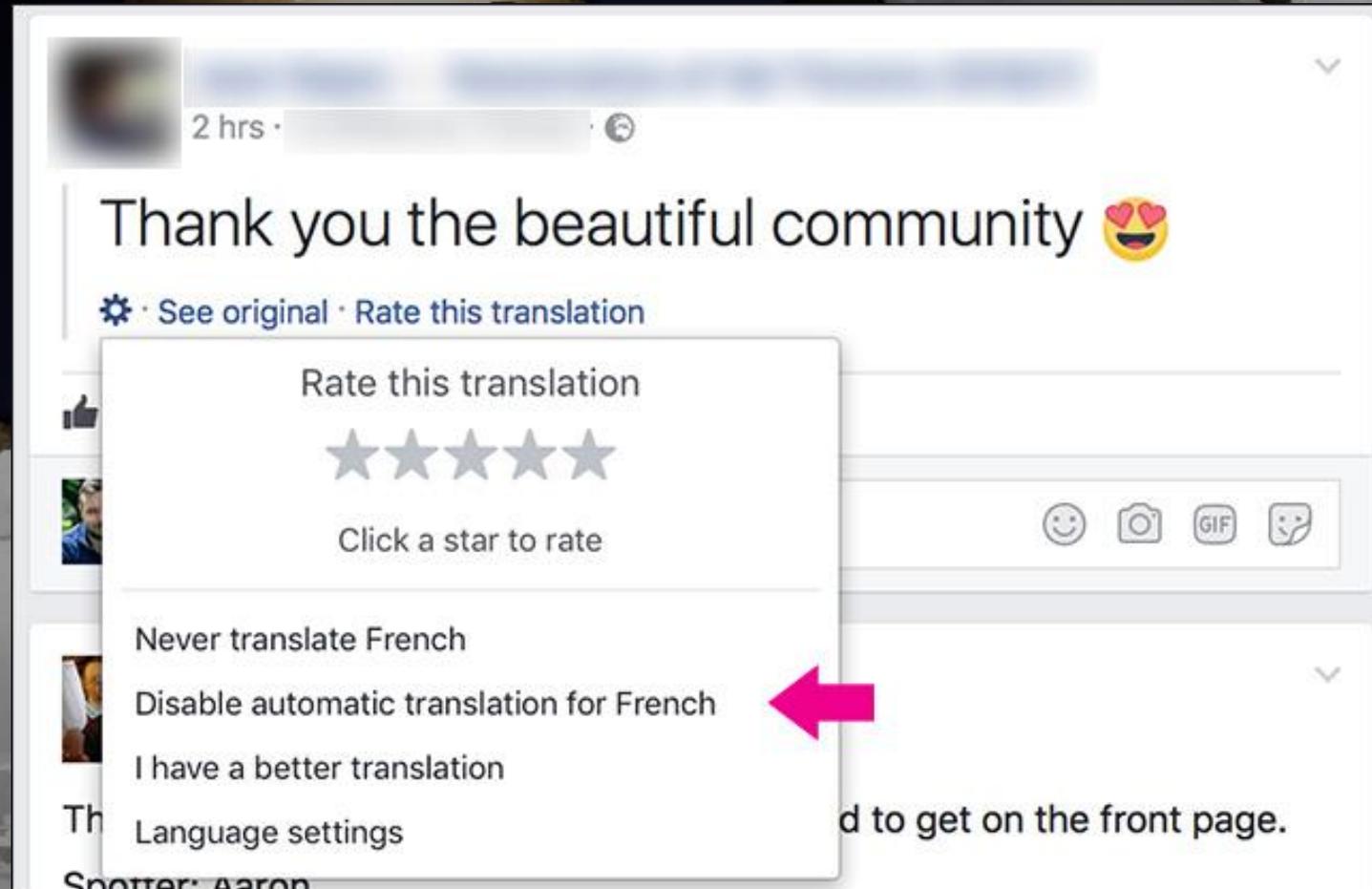
VOLTA

The image shows two astronauts in white space suits against a dark blue background. The astronaut on the left is wearing a gold helmet and has a NASA logo on their chest. The astronaut on the right is wearing a white helmet and has an American flag patch on their chest. The text "Let users do the job for you !" is overlaid in the center in a bold, white, sans-serif font.

**Let users do the job for you !**

# Let users do the job for you !

## Facebook translation



A screenshot of a Facebook post. The post text is "Thank you the beautiful community 😍". Below the text are options: "See original" and "Rate this translation". A white overlay box titled "Rate this translation" contains five stars and the text "Click a star to rate". Below this is a settings menu with options: "Never translate French", "Disable automatic translation for French" (highlighted with a pink arrow), "I have a better translation", and "Language settings".

2 hrs ·

Thank you the beautiful community 😍

⚙️ · See original · Rate this translation

Rate this translation

★ ★ ★ ★ ★

Click a star to rate

Never translate French

Disable automatic translation for French

I have a better translation

Language settings

Spotter: Aaron

d to get on the front page.

# Let users do the job for you !

## Face Recognition Facebook

The image shows a screenshot of a Facebook post by Nicholas Carlson, dated January 23, shared via Instagram. The post features a group photo of several people. A white box highlights a man in the photo, and a dropdown menu is open, listing names starting with 'Ni'. The list includes Nicholas Carlson (Me), Nick O'Neill, Nick Denton, Nicole Schumacher, Nick Bilton, Angela Nibbs, Nicholas Saint, and Barrett Nichols. The right side of the screenshot shows the post's interaction area, including a 'Done Tagging' button, a list of likes from Danielle Lacombe and Owen Thomas, and a comment box. Below the post, there are sponsored advertisements for Dewar's and Target.

**Ni**

- Nicholas Carlson (Me)**  
Silicon Alley Insider · Davidson
- Nick O'Neill**  
Social Times, Inc. · American
- Nick Denton**  
Gawker Media · New York, New York
- Nicole Schumacher**  
Columbia · New York, New York
- Nick Bilton**  
The New York Times Company · San Francisco, California
- Angela Nibbs**  
maven · San Francisco, California
- Nicholas Saint**  
Haverford · Brooklyn, New York
- Barrett Nichols**

**Nicholas Carlson**  
January 23 via Instagram

SAI! <http://instagr.am/p/kCxOr/>

Done Tagging Add Location Edit

Like · Comment · Unfollow Post · Share · Edit

Danielle Lacombe and Owen Thomas like this.

**Owen Thomas Nerds.**  
January 23 at 6:35pm · Like · 1

Write a comment...

Sponsored

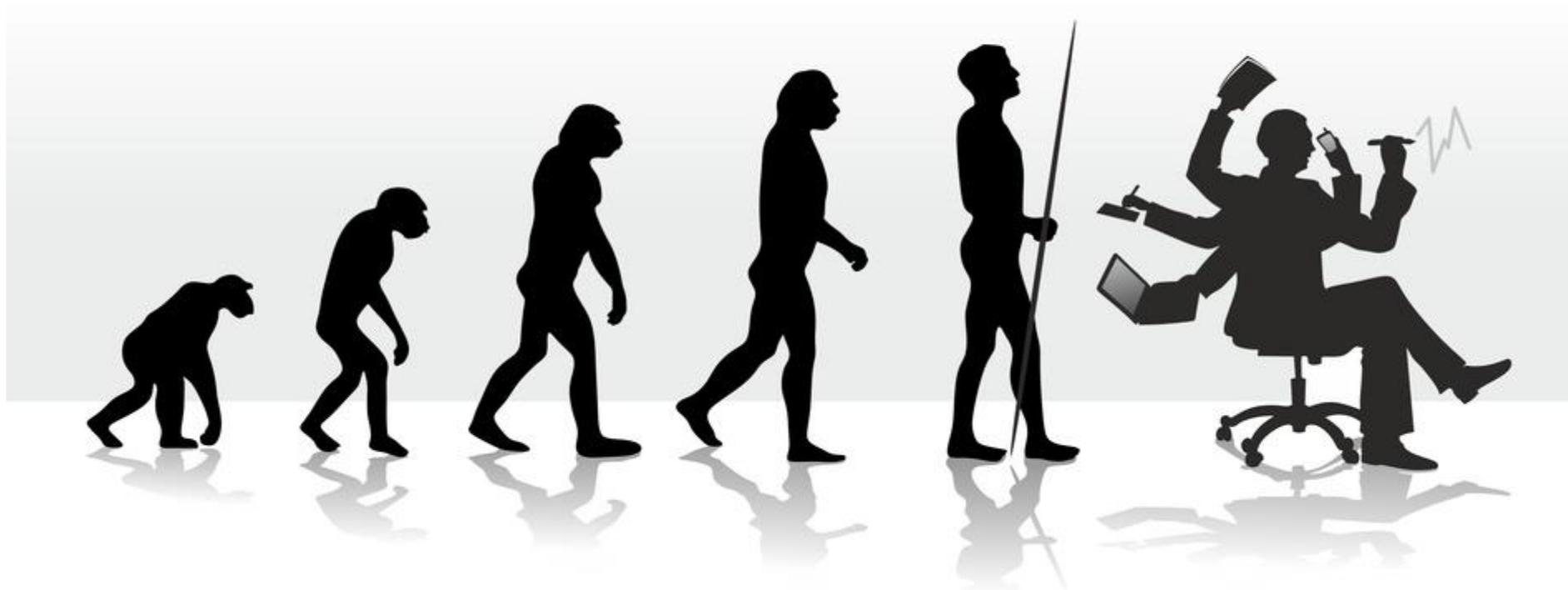
Mazyar Kazerooni likes Dewar's.

**Dewar's**  
Like

Justin Smith likes Target.

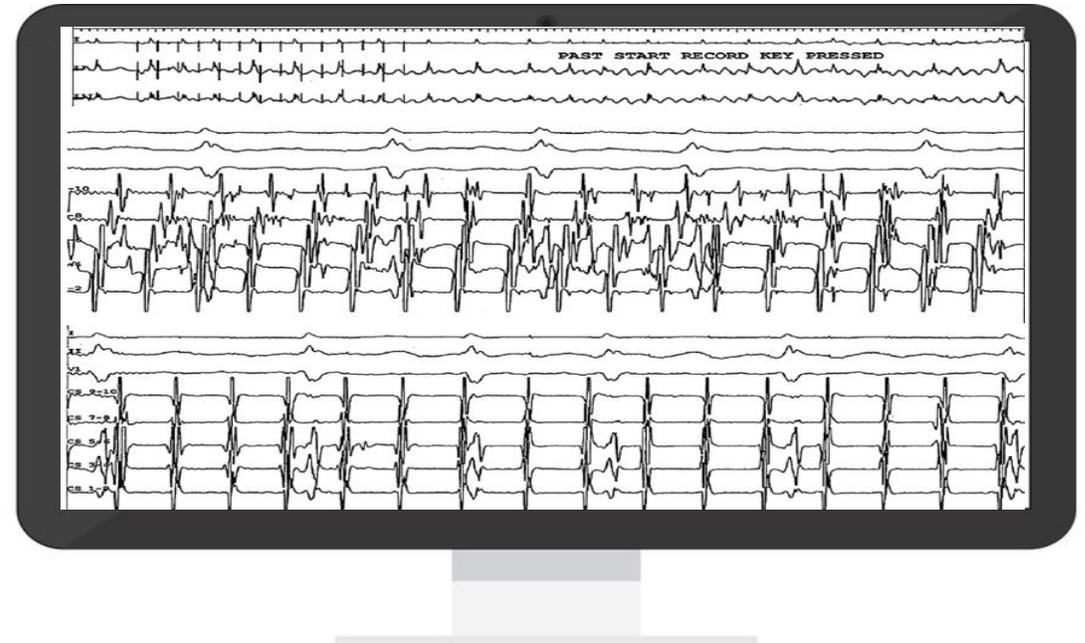
**Target**  
Like

# Un grand besoin d'automatisation



# Currently available local electrograms analytical tools

- Voltage Maps
- CFAE Maps (CARTO, SJM versions)
- Dominant Frequency Maps



# Several attempts with conventional methods

- **Too many analytical parameters:** frequency, voltage, fractionation, sequential activation
- Each patient is unique: **too many types of electrograms**
- During ablation **EGM morphology can change** (with AF cycle length increase)
- Unable to **associate the prediction with a probability**

# AlFib

