

# What's next for Digital Health Applications in Epilepsy?

Applications of AI/ML in Neurology

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# Disclosures

- I have no relevant financial disclosures

# Digital Health in Epilepsy Care

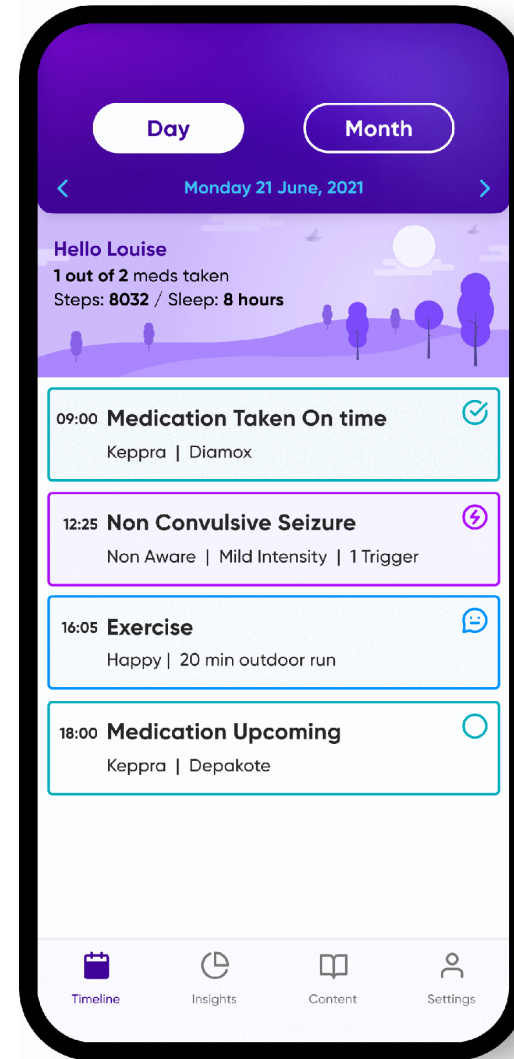




**Empatica Embrace**  
Heart rate, Accelerometer, Galvanic skin  
response, Temperature



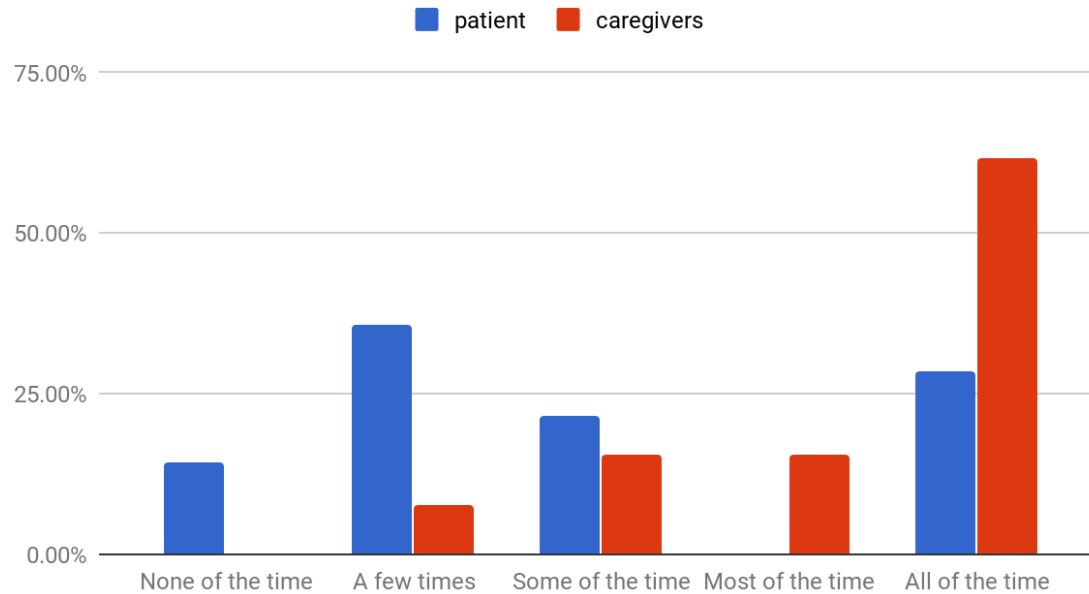
**Brain Sentinel**  
Electromyography (EMG)



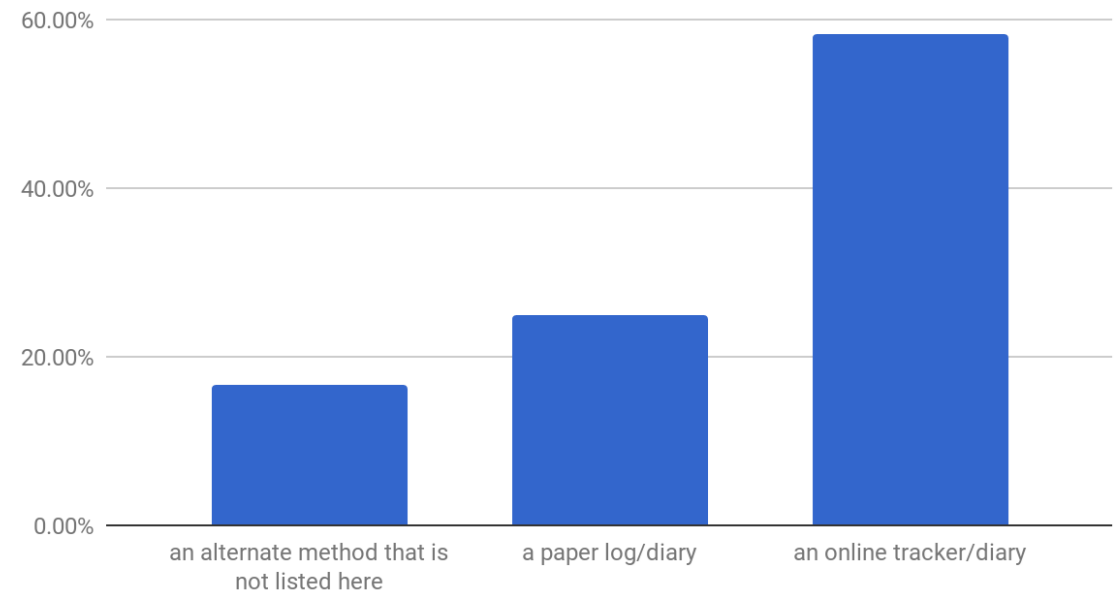
# Data Collection Findings

- Who collects data? How is data collected?

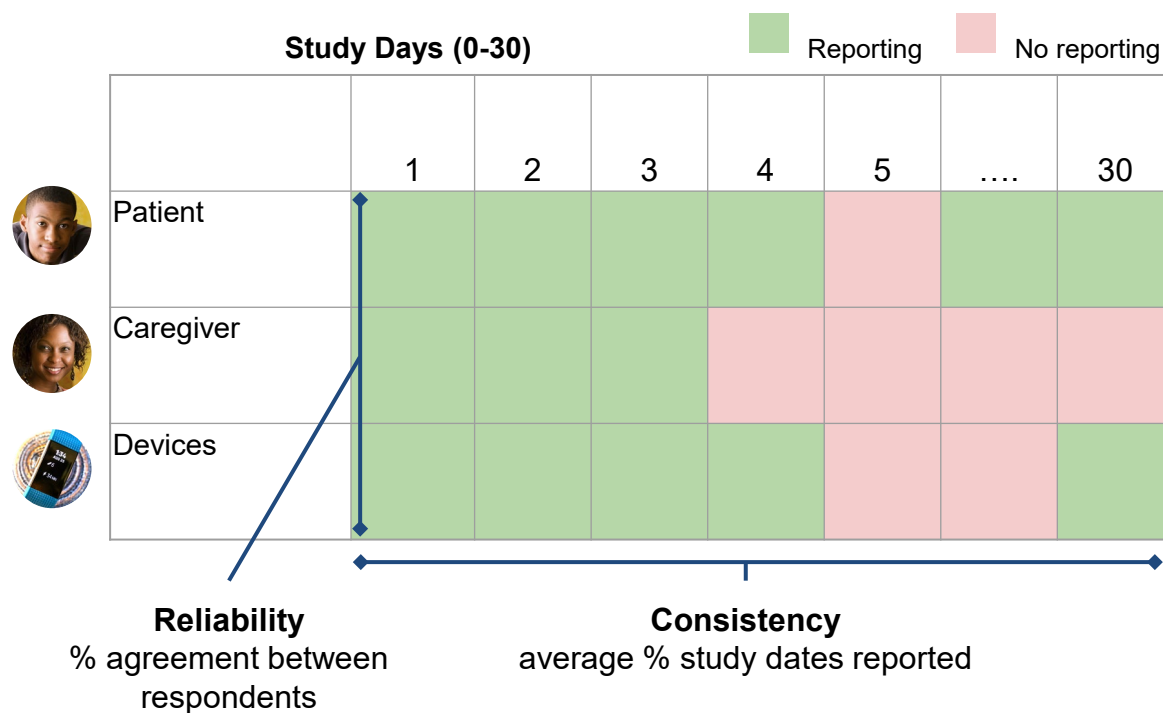
Intake survey responses: patients (n=14), caregivers (n=10)



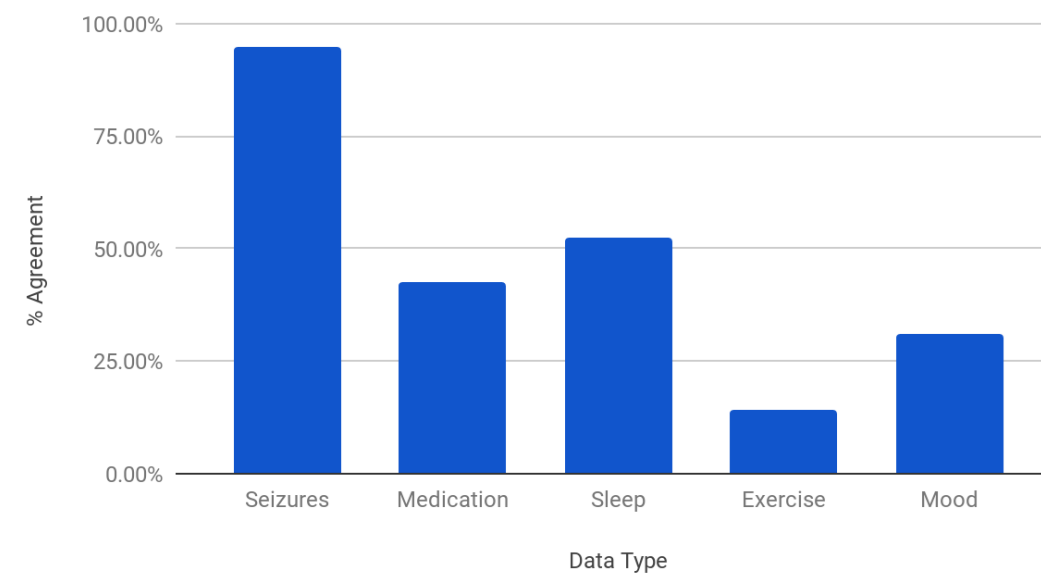
Patient Intake Survey Responses (n=12)



# Reliability Findings



Patient/Caregiver % Agreement (0-30 days)









EpiCare. Josh has taken his meds

Medication taken. Thank you!

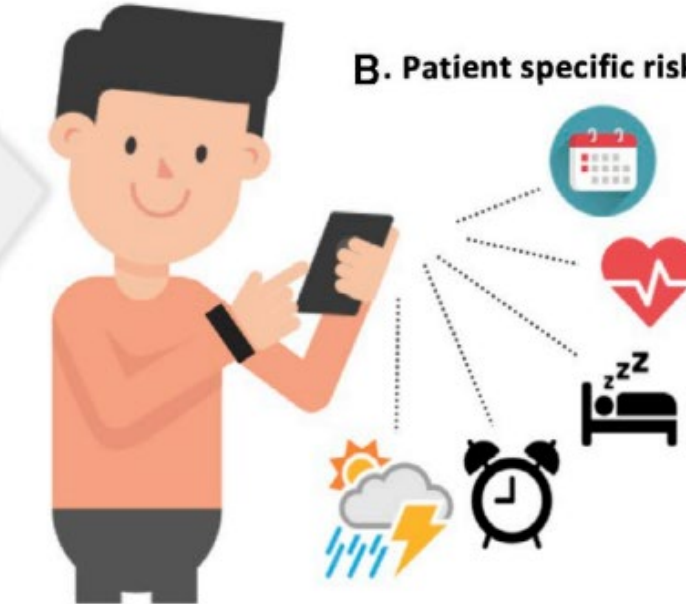




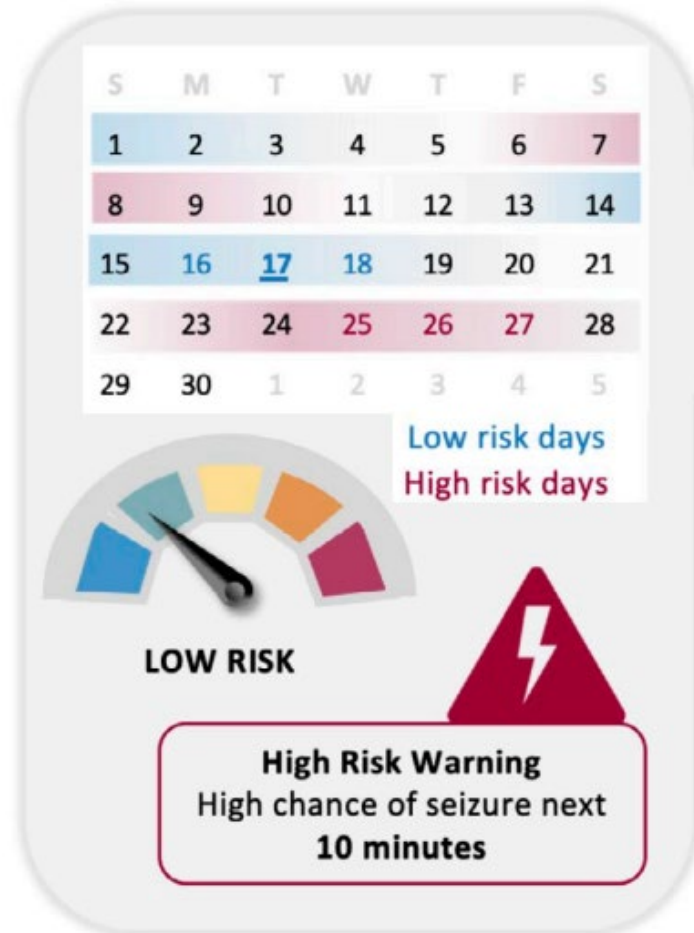
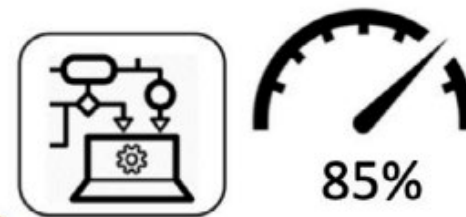
### A. Wearable, mobile, clinical, implantable



### B. Patient specific risk-factors



### C. Integrated forecast of seizure likelihood



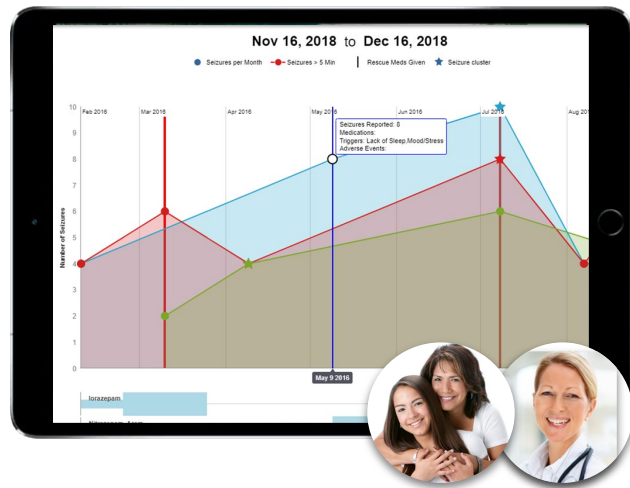
### D. Possible user interface designs

# New Software Standards are Enabling Adoption

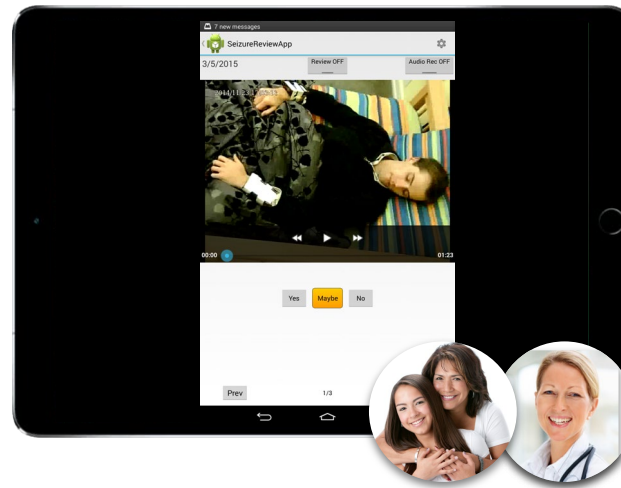


# Clinical Apps

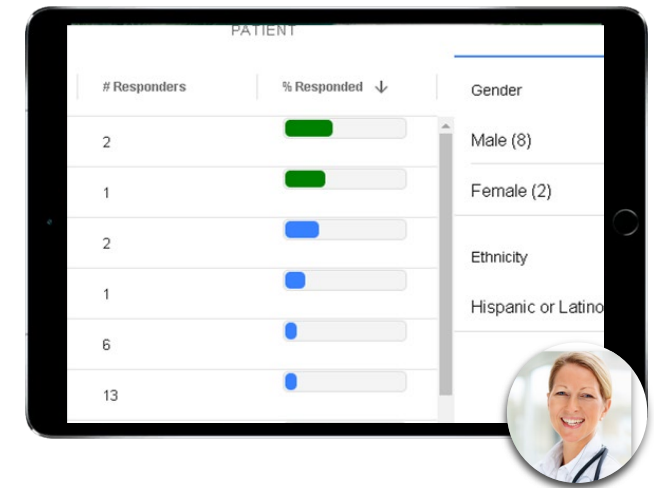
## Seizure History and Medication



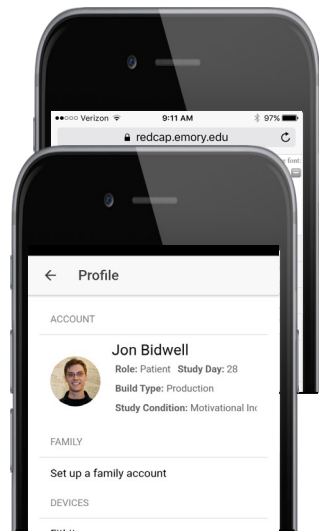
## Rejection of Non-Seizures from Video of Wristband Events



## Patient Cohort Dashboard



# Patient Apps



Daily Checklist

Daily Goal

22

23

24

25

26

27

28

Sun

Mon

Tues

Wed

Thur

Fri

Sat

Today

☐ Morning Survey Patient
 ☐ Weekly Survey Patient

Incomplete

☐ Intake Survey 4/2
 ☐ Morning Survey 4/2
 ☐ Morning Survey 4/3

BACK

SUBMIT

Daily Checklist

Seizure Report

My Dashboard

Rewards

2. How long did the seizure last? (minutes)

< 1

1

2

3

4

5

>5

BACK

SUBMIT

Daily Checklist

Seizure Report

My Dashboard

Rewards

Sleep

WEEK

MONTH

Powered by ZingChart

Daily Checklist

Seizure Report

My Dashboard

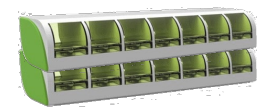
Rewards



Fitbit Charge 2



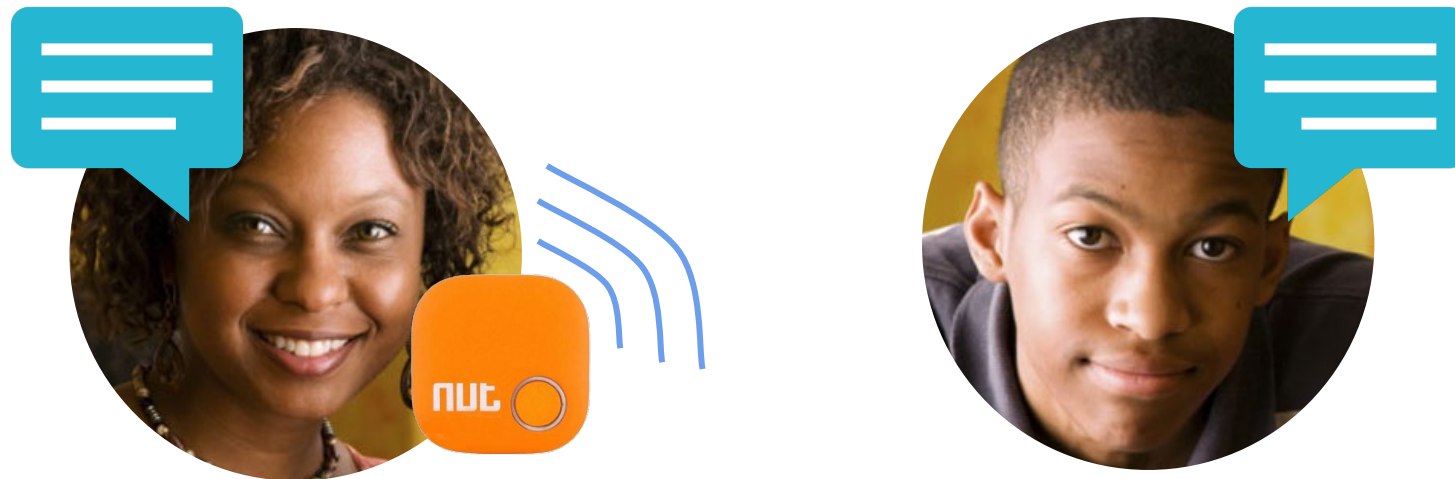
Bluetooth Tag



Bluetooth Pill Boxes

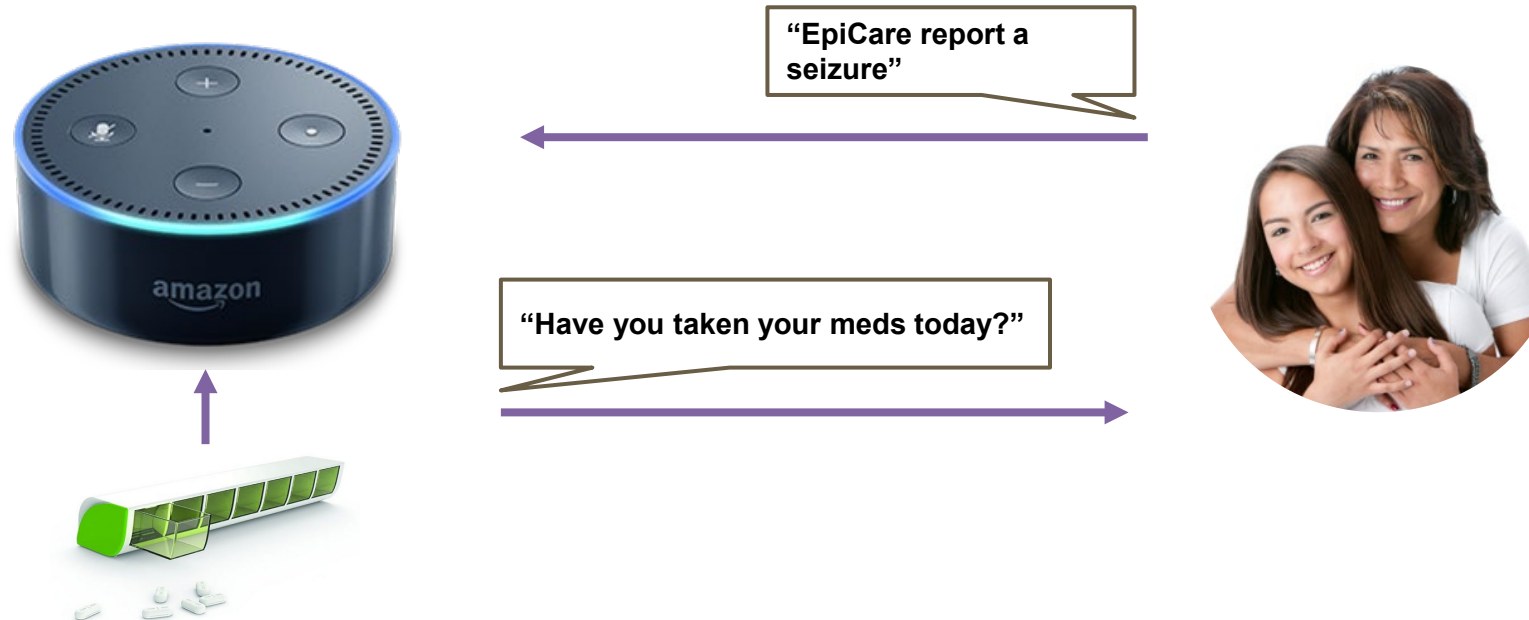
# Bluetooth Proximity Tags

Contingent reminders - triggered simultaneously on BOTH participants' phones



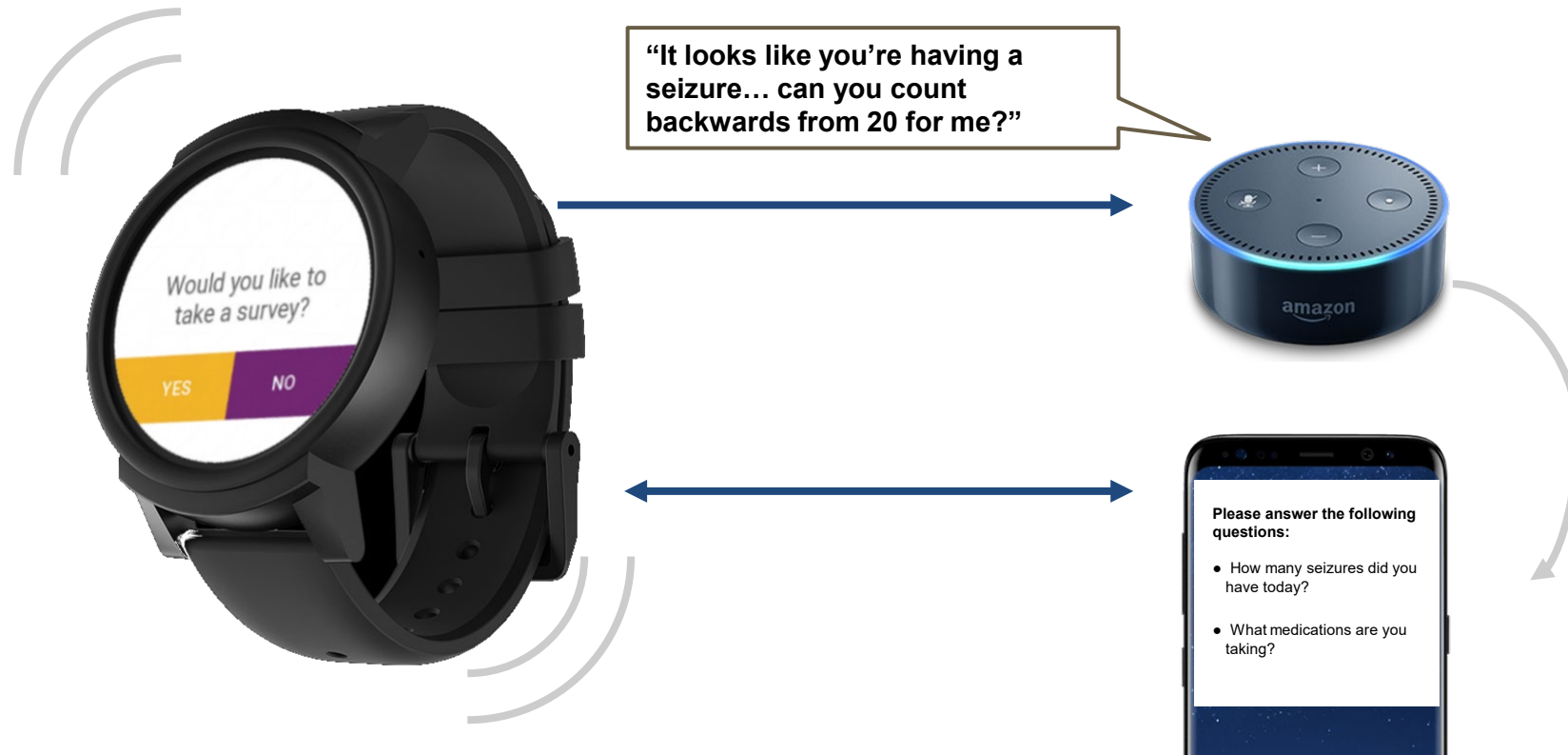
# Voice Assistant

- A voice assistant provides notifications and administers surveys



# Smartwatch

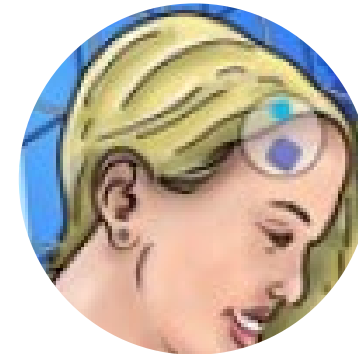
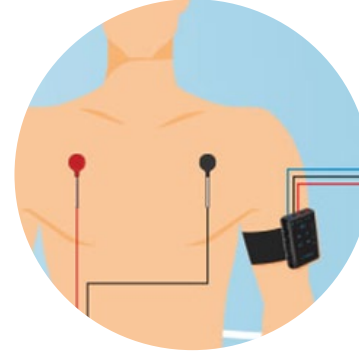
- A smartwatch administers surveys and attempts to evaluate patient cognition





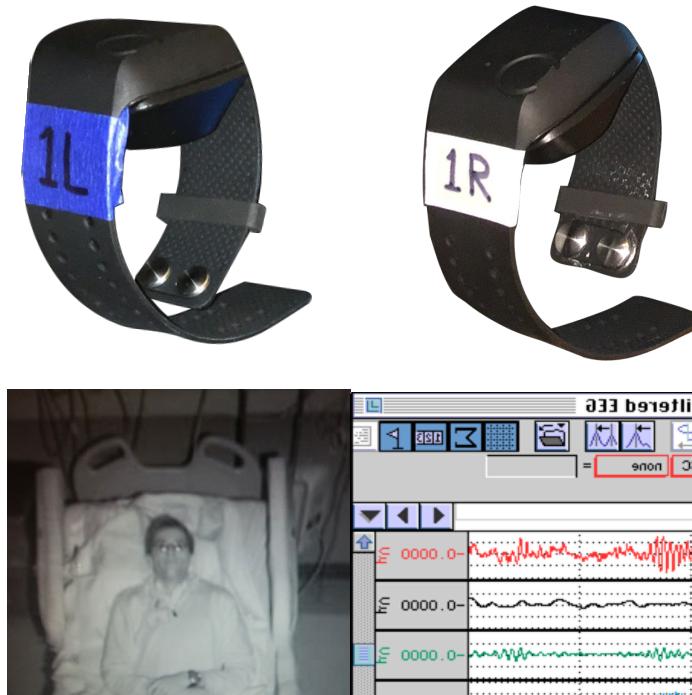
# History of Seizure Detection

- Smartwatch, EMG, EKG, Intercranial, Pressure, Video, Multimodal, Mobile



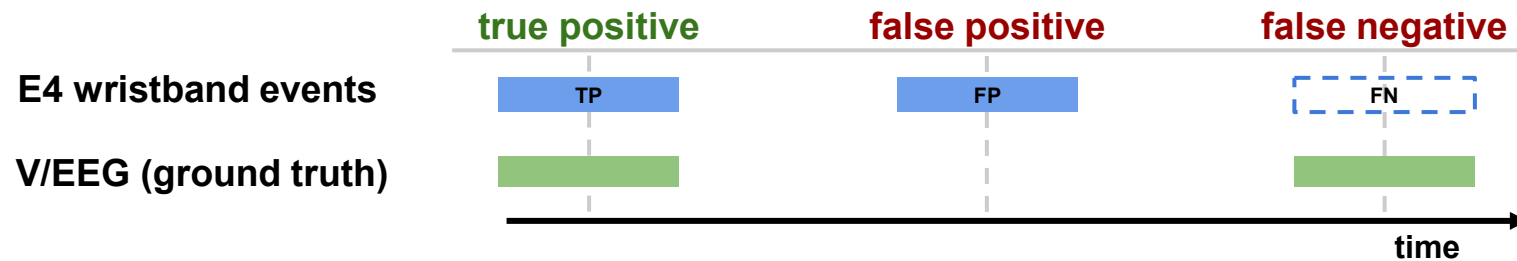
# Establishing Ground-truth

- Reviewers documented V/EEG onset and duration of seizure events
- Procedure
  - Document semiology
  - Electrographic and clinical onsets & durations
  - Clinical onset & duration
- 2 reviewers per seizure (EEG tech + board certified attending)
- 55 convulsive seizures (29/69 patients)
  - 6 focal tonic clonic seizures
  - 49 focal to bilateral tonic clonic seizures



# Results

- Evaluated E4 wristband performance in terms of precision, recall and F-score



		Predicted Seizures	
		True	False
Actual Seizures	True	TP = 52	FN = 3
	False	FP = 50	TN = NA

55 convulsive seizures total

$$\text{Precision} = \frac{tp}{tp + fp}$$

**Precision 50.98%**

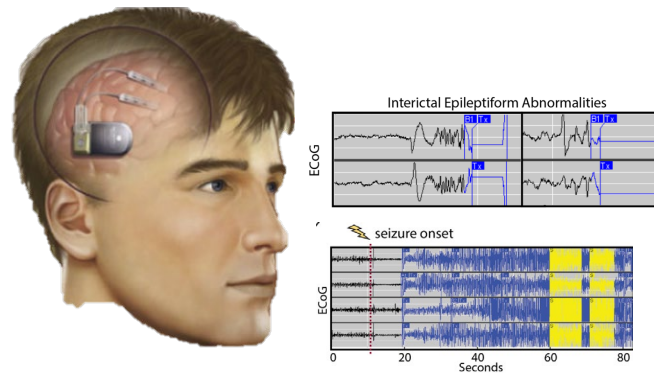
$$\text{Recall} = \frac{tp}{tp + fn}$$

**Recall 94.55%**

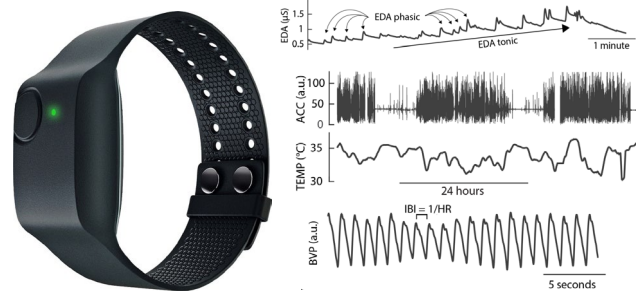
# Most devices only outperform self-reporting at night



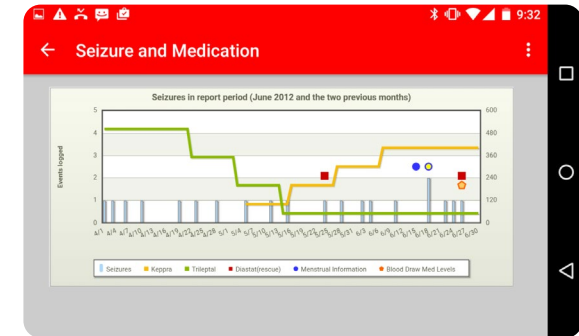
# New Discoveries from Longitudinal Monitoring



EEG measures of IEA and electrographic seizure activity



Electrodermal activity (EDA), accelerometry (ACC), temperature (TEMP), HR and HR variability (HRV)



Self-reported seizure dates and times

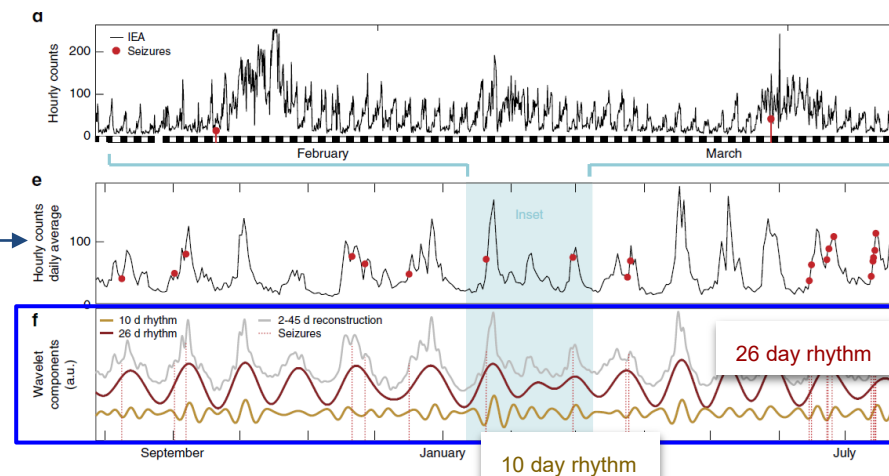
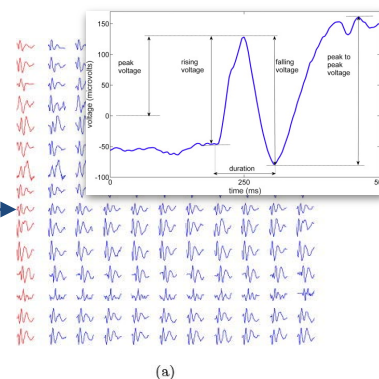
Maxime O. Baud, et al, Multi-day rhythms modulate seizure risk in epilepsy. *Nature*, 2018  
 Gregg, Nicholas M., et al. "Seizure occurrence is linked to multiday cycles in diverse physiological signals." *Epilepsia* (2023)  
 Karoly, Philippa J., et al. "Circadian and circaseptan rhythms in human epilepsy: a retrospective cohort study." *Neurology* (2018)



# Feature Extraction in Forecasting



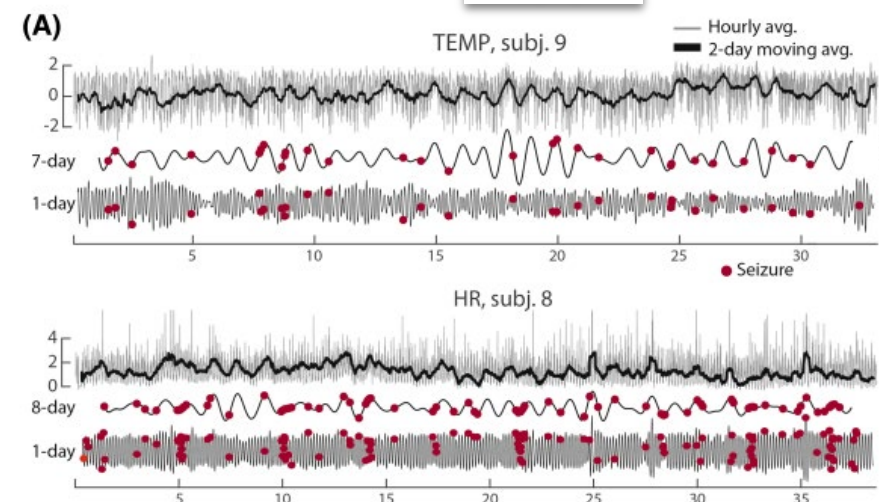
NeuroPace RNS Device



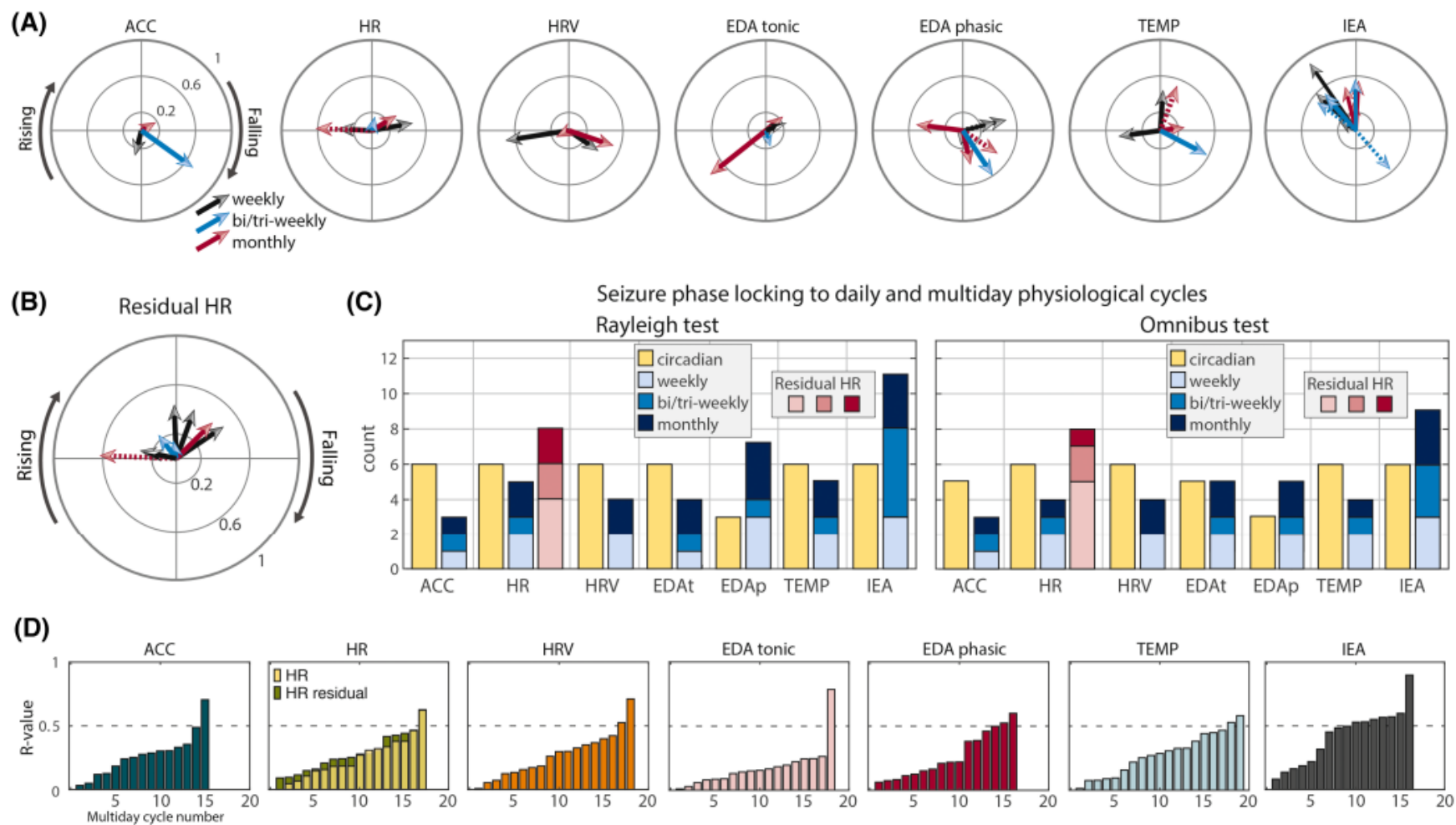
Empatica E4 wristband

Filter EDA (Lowpass, Butterworth)

Denoise, smooth and snip (ACC, HR, HRV, EDAt, EDAp, and TEMP)



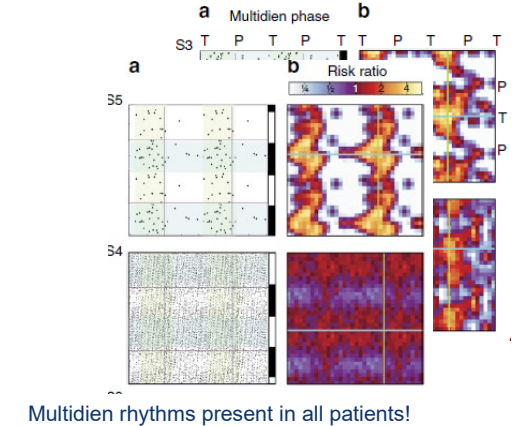
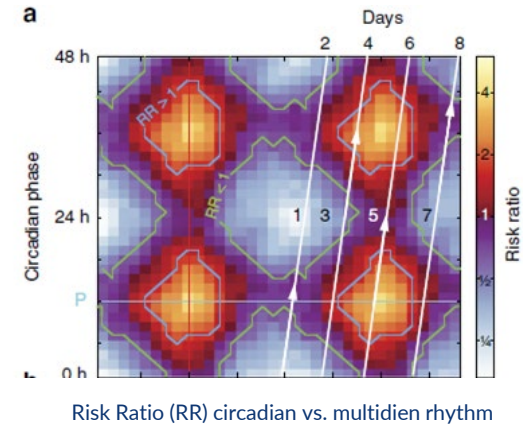
# Cycles in Seizure Forecasting



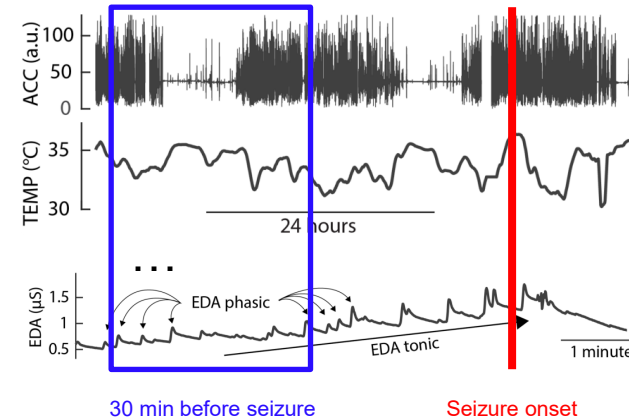


# Patient-specific Seizure Forecasting

## 1. Probabilistic seizure risk



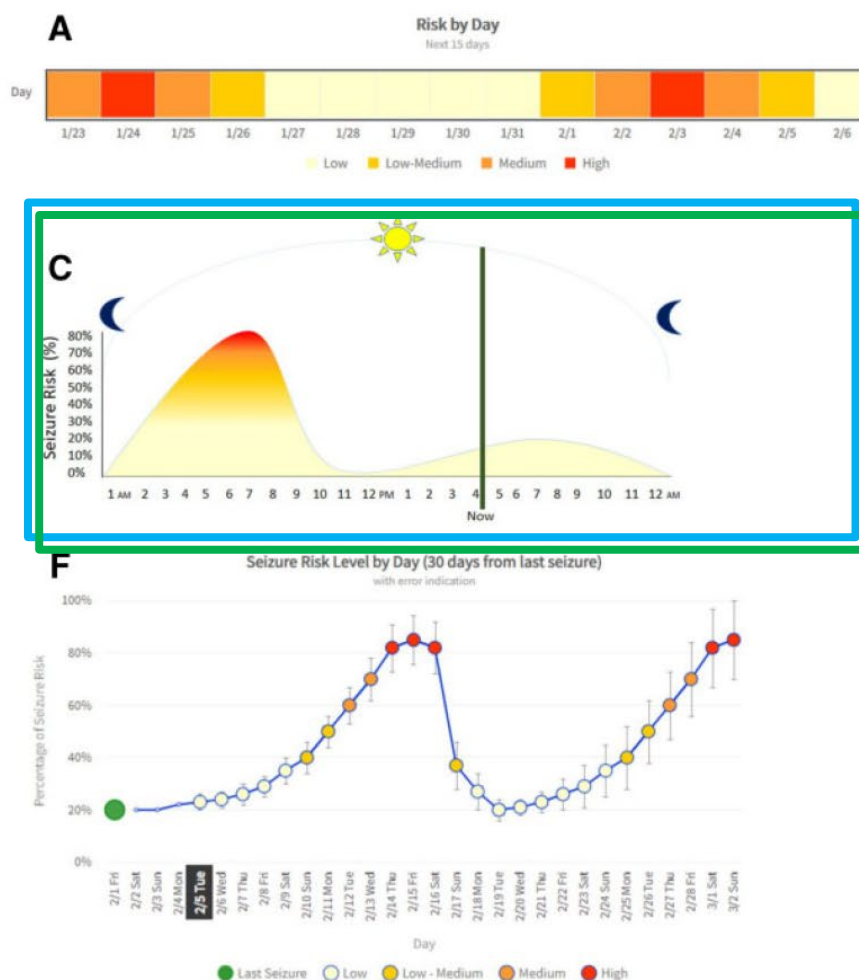
## 2. Discrete seizure warnings



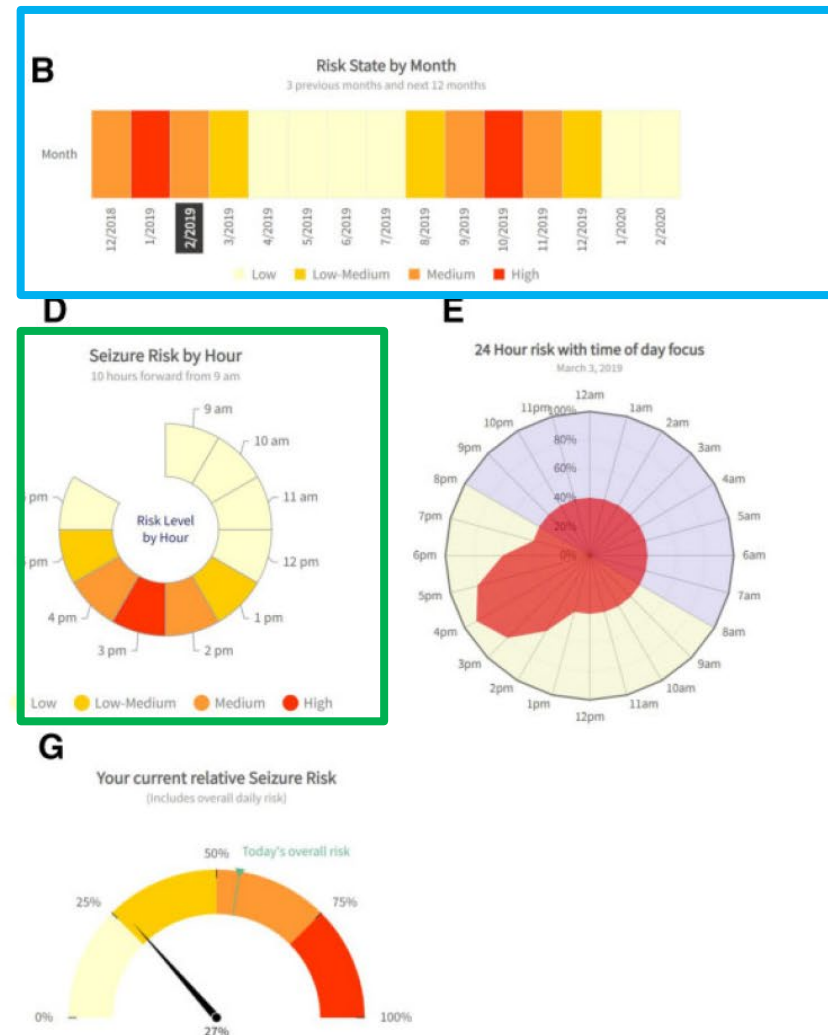
$$\text{Risk Ratio (RR)} = \frac{TP / (TP + FP)}{FN / (TN + FN)}$$

# Communicating Seizure Forecasts

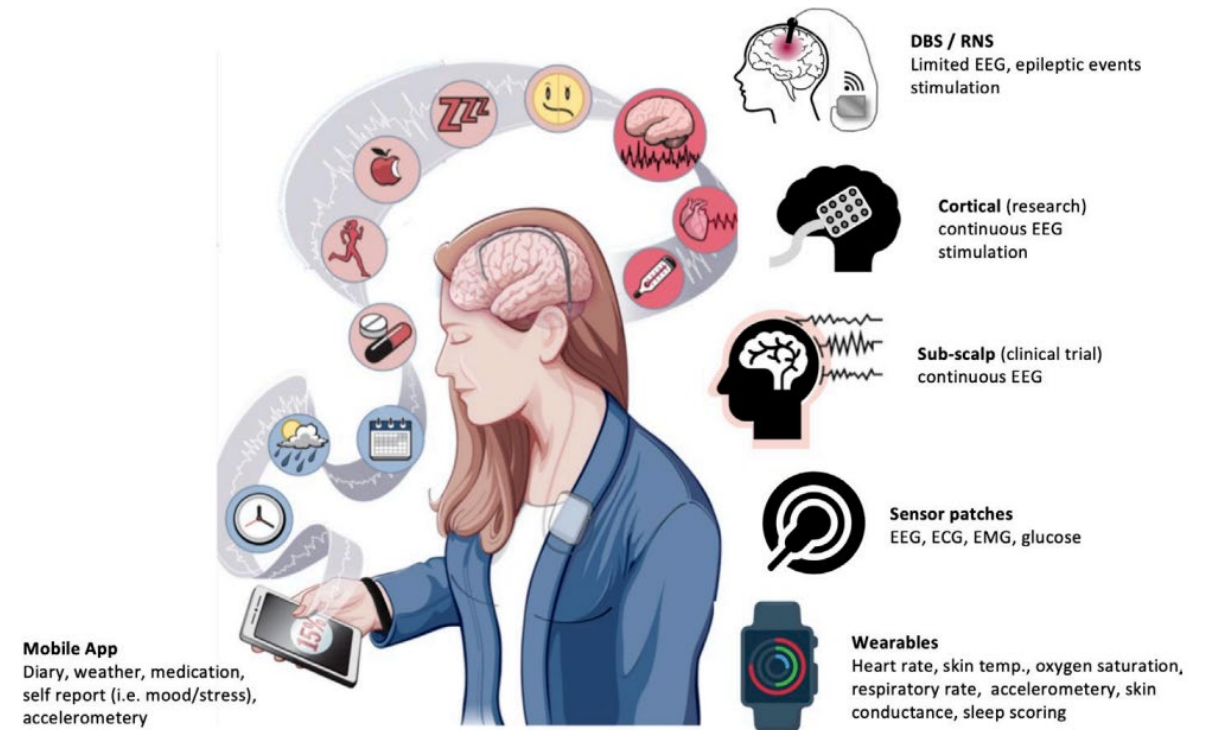
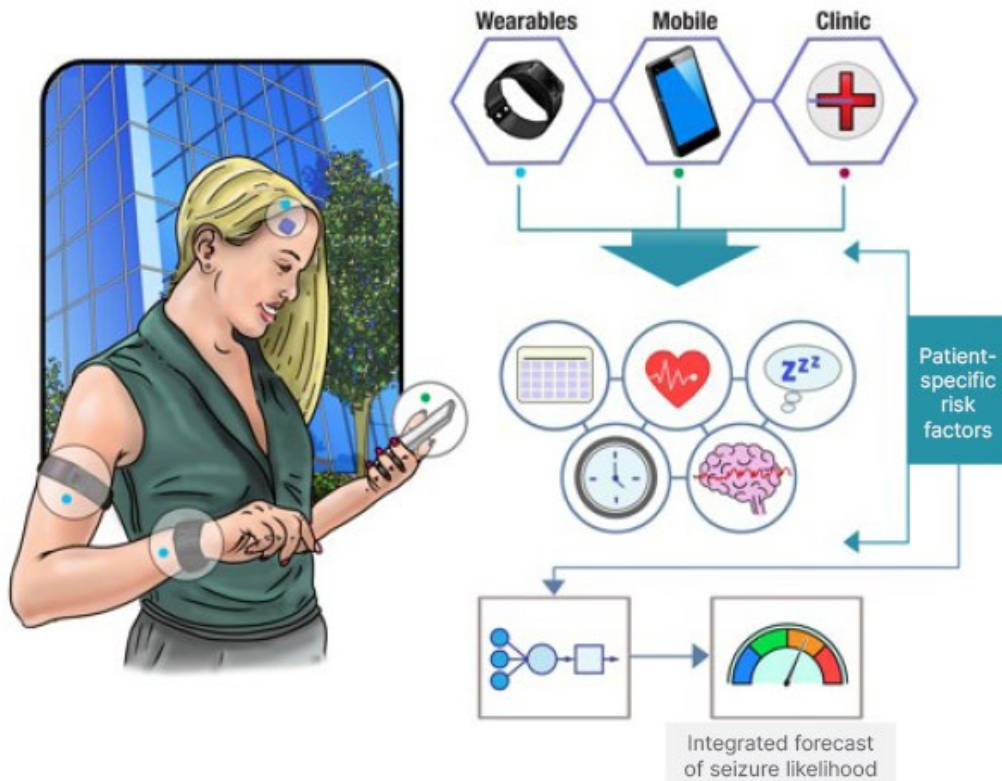
Patient



Clinician



# Multi-modal forecasting concepts



## **Need help with Health Tech? Lets collaborate**

- Applied AI/ML,
- Computer vision / robotics,
- Writing grants,
- Developing EHR apps

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