sweet dreams

Presented by Green group

Ageing and Rehabilitation Engineering

GROUP MEMBERS

Sleep Quality Algorithm

- Di Rocco Gloria
- Dorigatti Tommaso
- Doto Tommaso
- Menetti Marcello

APP Design and Development

- Bocchi Gemma
- Falcone FrancescoFlavio
- Topbas Dilek Ece

Lying Detection Algorithm

- Venturi Viola

Literature Research

- Roncassaglia Elena

SLEEP DISTURBANCES IN ONCOLOGY PATIENTS

💤 Sleep is crucial for recovery, immunity, and well-being, especially in cancer care.

📉 Up to **60%** of cancer patients suffer from **chronic sleep disturbances** (i.e insomnia).

🚨 **Underdiagnosed** and **undertreated** problem.

⚠️ **Poor sleep quality** leads to severe physical, emotional, and clinical consequences.

💊 Current solutions (pharmacological & therapy) are **inadequate.**

🌟 Critical need for a more **accessible**, **tailored**, and **scalable** solution.

Savard J, Morin CM. Insomnia in the context of cancer: A review of a neglected problem. J Clin Oncol. 2001
Savard J, Simard S, Blanchet J, Ivers H, Morin CM. Prevalence, clinical characteristics, and risk factors for insomnia in the context of breast cancer. Sleep. 2001
Cheng KK, Lee DT. Effects of pain, fatigue, insomnia, and mood disturbance on functional status and quality of life of elderly patients with cancer. Crit Rev Oncol Hematol. 2011
Howell D, Oliver TK, Keller-Olaman S, et al. Sleep disturbance in adults with cancer: A systematic review of evidence for best practices in assessment and management for clinical practice
George M, Elias A, Shafiei M. Insomnia in cancer-associations and implications

WHY SLEEP DISTURBANCES MATTER IN CANCER CARE

🩺 Physical Consequences

- 📉 Weakens immune response
- 📈 Increases pain sensitivity
- ⚠️ Worsens chemotherapy & radiation side effects

🧠 Mental & Emotional Toll

- 😟 Heightens anxiety, depression, distress
- 💡 Linked to cognitive dysfunction

🎯 Impact on Daily Life & Treatment Adherence

- 💤 Fatigue & cognitive issues
- ❌ Lower treatment adherence
- 📉 Reduced overall quality of life

Savard J, Morin CM. Insomnia in the context of cancer: A review of a neglected problem. J Clin Oncol. 2001
Cheng KK, Lee DT. Effects of pain, fatigue, insomnia, and mood disturbance on functional status and quality of life of elderly patients with cancer. Crit Rev Oncol Hematol. 2011
Miaskowski C, Lee K, Dunn L, et al. Sleep-wake circadian activity rhythm parameters and fatigue in oncology patients before the initiation of radiation therapy
Van Onselen C, Dunn LB, Lee K, et al. Relationship between mood disturbance and sleep quality in oncology outpatients at the initiation of radiation therapy
Lindviksmoen G, Hofsø K, Paul SM, Miaskowski C, Rustøen T. Predictors of initial levels and trajectories of depressive symptoms in women with breast cancer undergoing radiation therapy
Howell D, Oliver TK, Keller-Olaman S, et al. Sleep disturbance in adults with cancer: A systematic review of evidence for best practices in assessment and management for clinical practice
George M, Elias A, Shafiei M. Insomnia in cancer-associations and implications

CURRENT SOLUTIONS AND MARKET GAPS

Solution	Pros ✅	Cons ❌	References
CBT-I (In-Person)	Long-term benefits No side effects Personalized	Limited access Time-consuming Expensive Patient resistance	Eva Rames Nissen et al, Interventions for insomnia in cancer patients and survivors
Pharmacological Treatments	Quick relief Widely available Short-term solution	Side effects Dependency Tolerance build-up	Lianqi Liu, Sonia Ancoli-Israel, Sleep Disturbances in Cancer Lavinia Fiorentino, Sonia Ancoli-Israel, Dysfunction in Patients with Cancer
Digital CBT-I (e.g., Sleepio, SHUTi)	Accessible Cost-effective Self-paced Scalable	Not oncology-specific Technology barriers Limited interaction	Kyong-Mee Chung et al., A Pilot Study Testing the Efficacy of dCBT in Patients With Cancer Experiencing Sleep Problems
General Sleep Apps (e.g., Calm, Headspace)	Easy to use Variety of techniques Free/low-cost Portable	Not clinically validated Limited efficacy No professional guidance	Sachin Ananth, Sleep apps: current limitations and challenges Sushanth Bhat et al., Is There a Clinical Role For Smartphone Sleep Apps?

💡 HOW OUR DIGITAL SOLUTION FILLS THE GAPS

🎯Oncology-Specific Customization

Tailored for cancer-related sleep disturbances

Tracks symptoms & treatment effects on sleep

🏥 Integration with Oncology Care

Links with clinicians for real-time sleep monitoring

Better treatment adjustments

Adapts interventions to patient’s condition & feedback

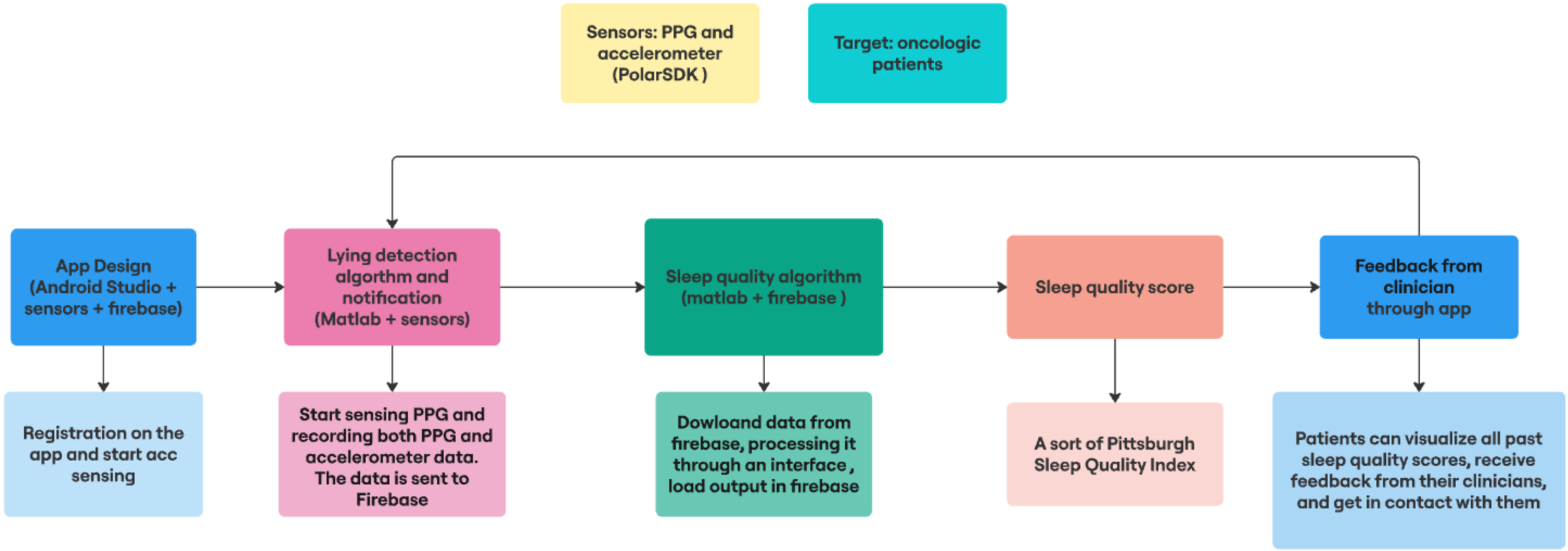
📱Accessibility & Ease of Use

Low cost/free

Easy to use for all patient demographics

GENERAL IDEA

Our idea behind the project can be summarized by the following flowchart:



PURPOSE OF THE APP

- Why did we develop this app?

  Improve sleep quality

  ⟶ Oncologic patients

  ⟶ Healthy individuals

sweet dreams

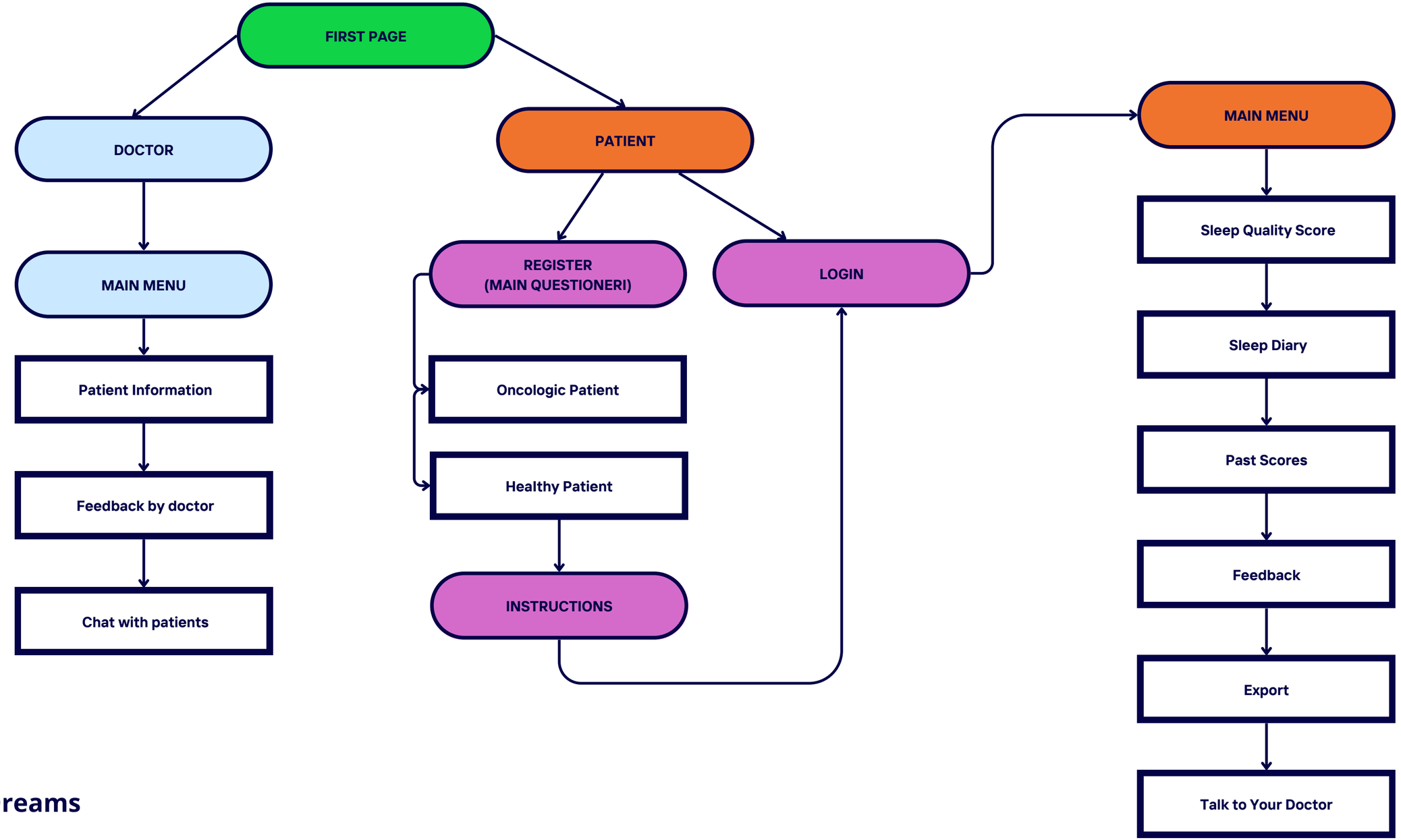
- What we offer to users?

  Personalized feedback

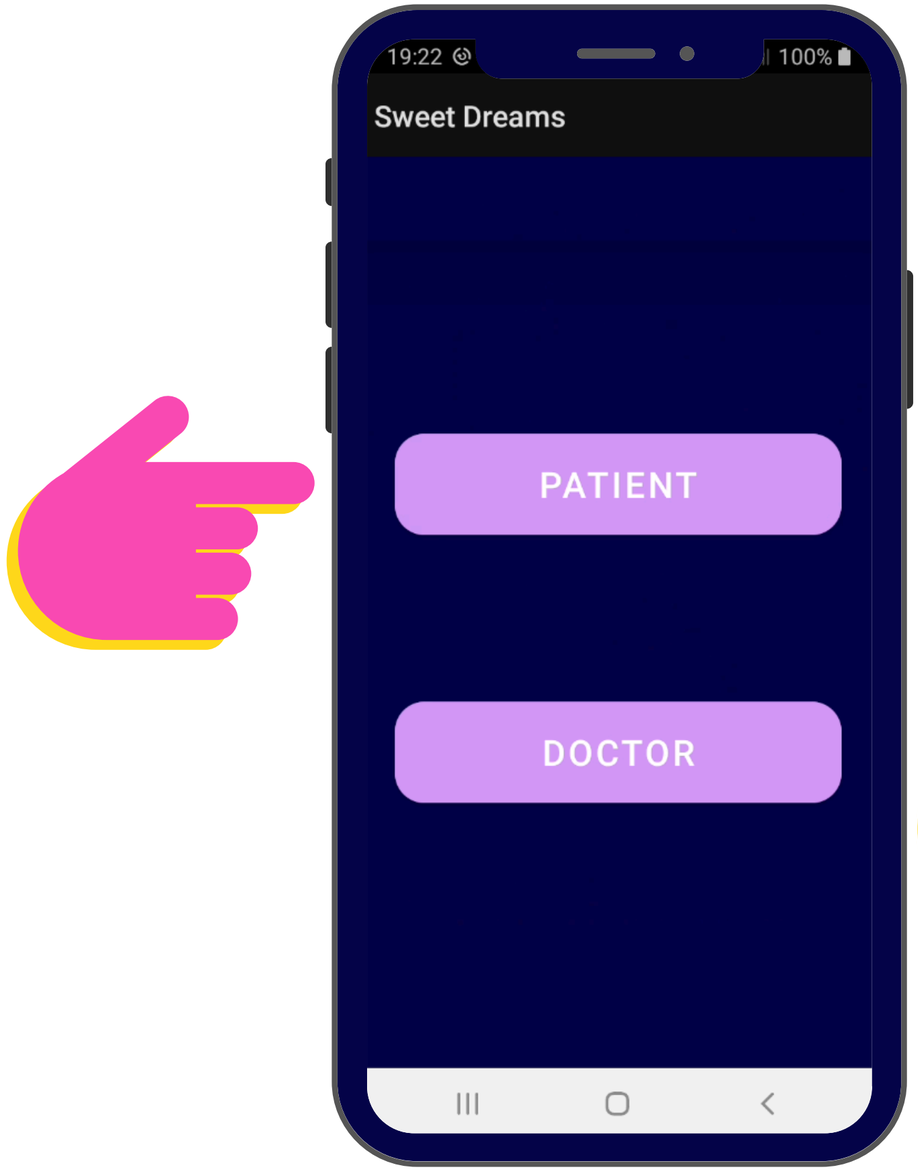
  A user-friendly interface

  Real time communication and data sharing with doctors

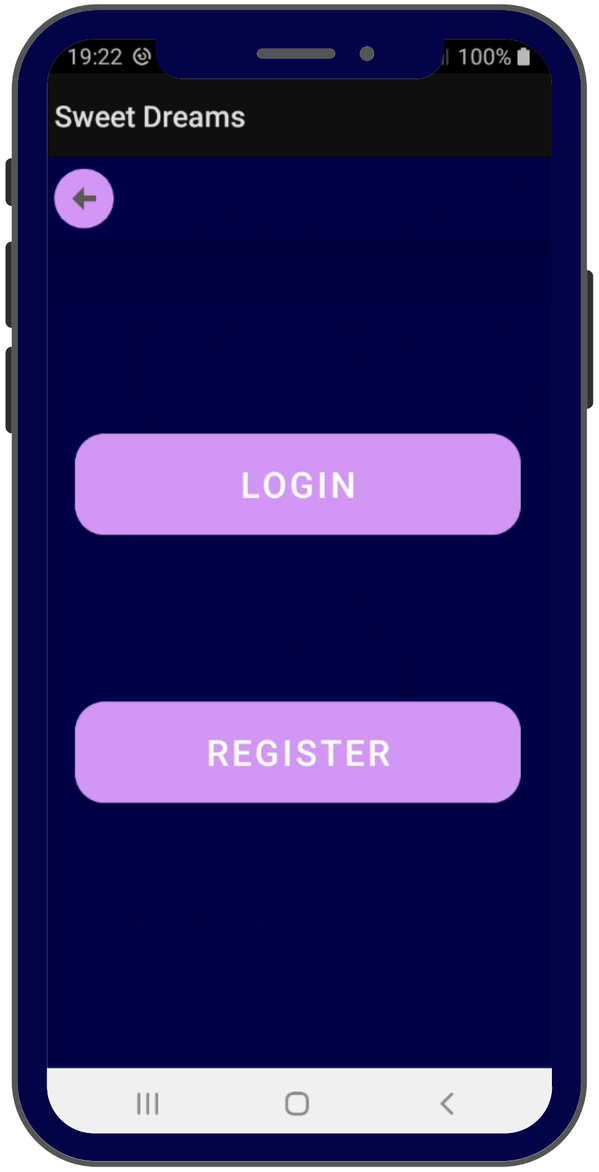
GENERAL CONCEPT OF APP



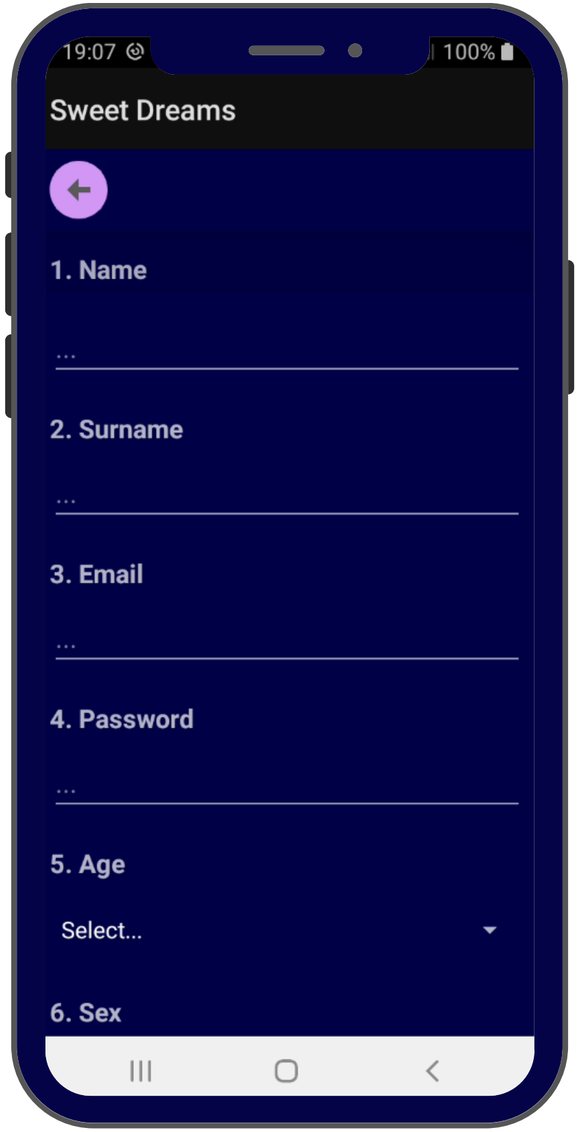
First main page

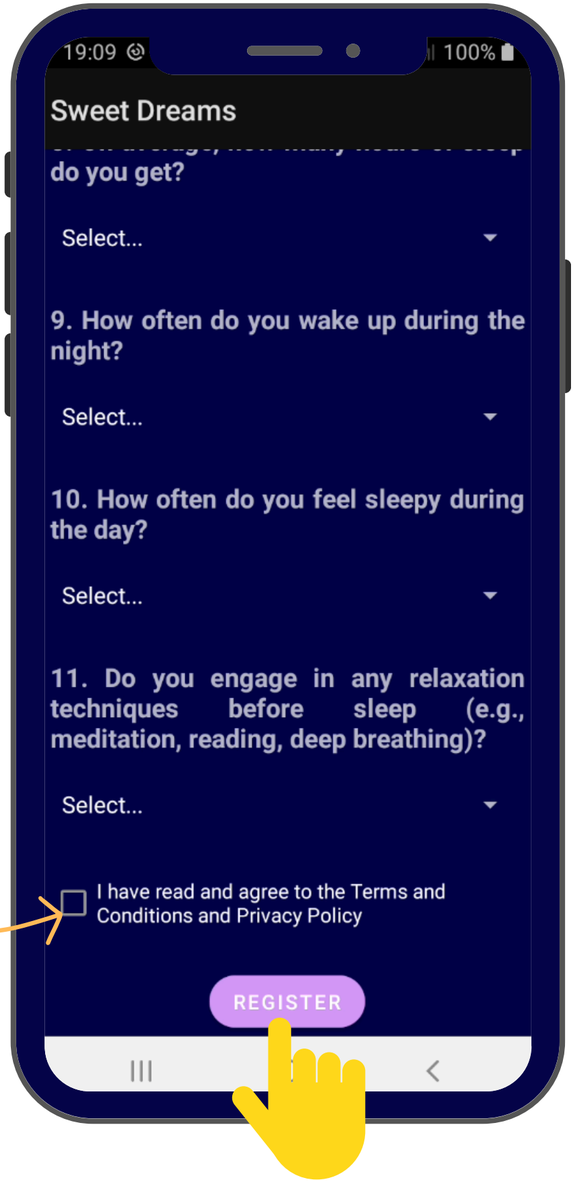


Login/Register

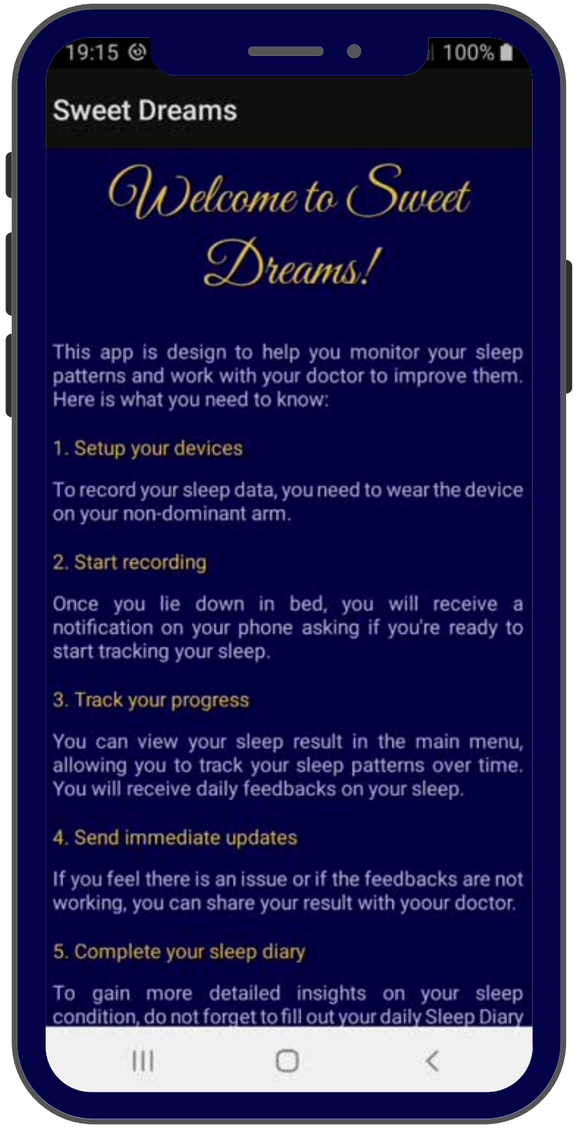


Main Questionnaire





Instructions



LYING DETECTION ALGORITHM

Lying detection algorithm is designed to identify when the subject is lying down or not by comparing the accelerations of a sensor worn on the non-dominant arm with the ones recorded by another sensor worn on the chest.
To do so, different sensors, environments and dataset have been tested on Matlab.
The used sensors are the Movella DOT, Polar Verity Sense and Polar H10.

LYING DETECTION ALGORITHM: 1ST VALIDATION

2 subjects based on 16 minutes recordings with a specific protocol

Protocol:
- 2 minutes standing up.
- 2 minutes sitting down with both arms close to the body.
- 2 minutes sitting down with both arms resting on the table.
- 8 minutes lying down (every 2 minutes the position was modified).
- 2 minutes sitting down with non-dominant arm raised up.

2 sensors used: Movella DOT

Design of lying detection algorithm

Through raw accelerations plot

Determine the posture

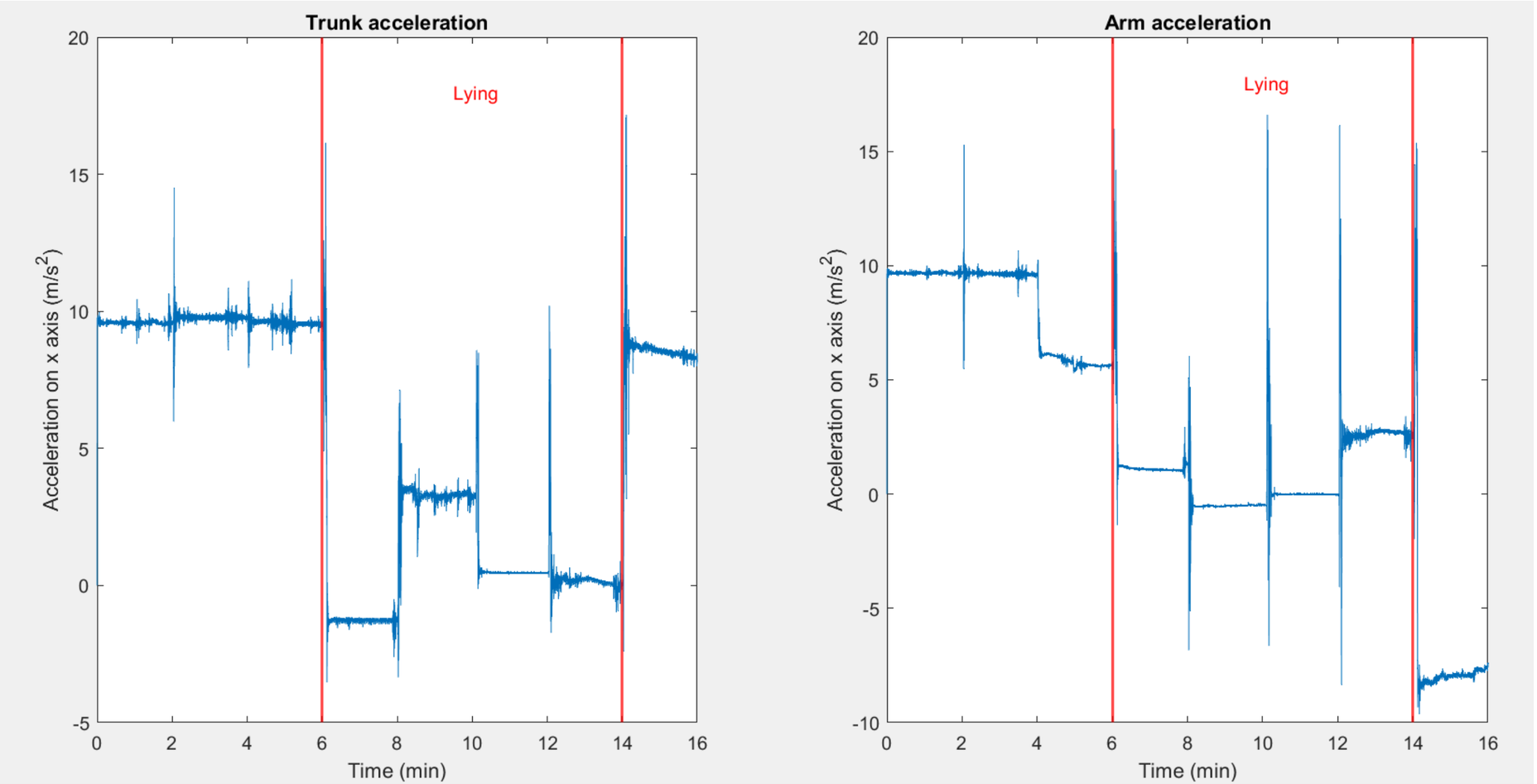
Consider only the x-axis acceleration for both sensors

Set proper thresholds to detect lying position

Acceleration between -g/2 and +g/2

LYING DETECTION ALGORITHM: 1ST VALIDATION

When the acceleration is close to 0, both sensors are able to correctly detect the lying position and the arm sensor can be considered as the gold standard.



LYING DETECTION ALGORITHM: 2ND VALIDATION

5 subjects based on 24h recordings without a specific protocol

2 sensors used: Polar H10 and Polar verity sense

Re-used the same designed algorithm

Through raw accelerations plot

Determine the posture

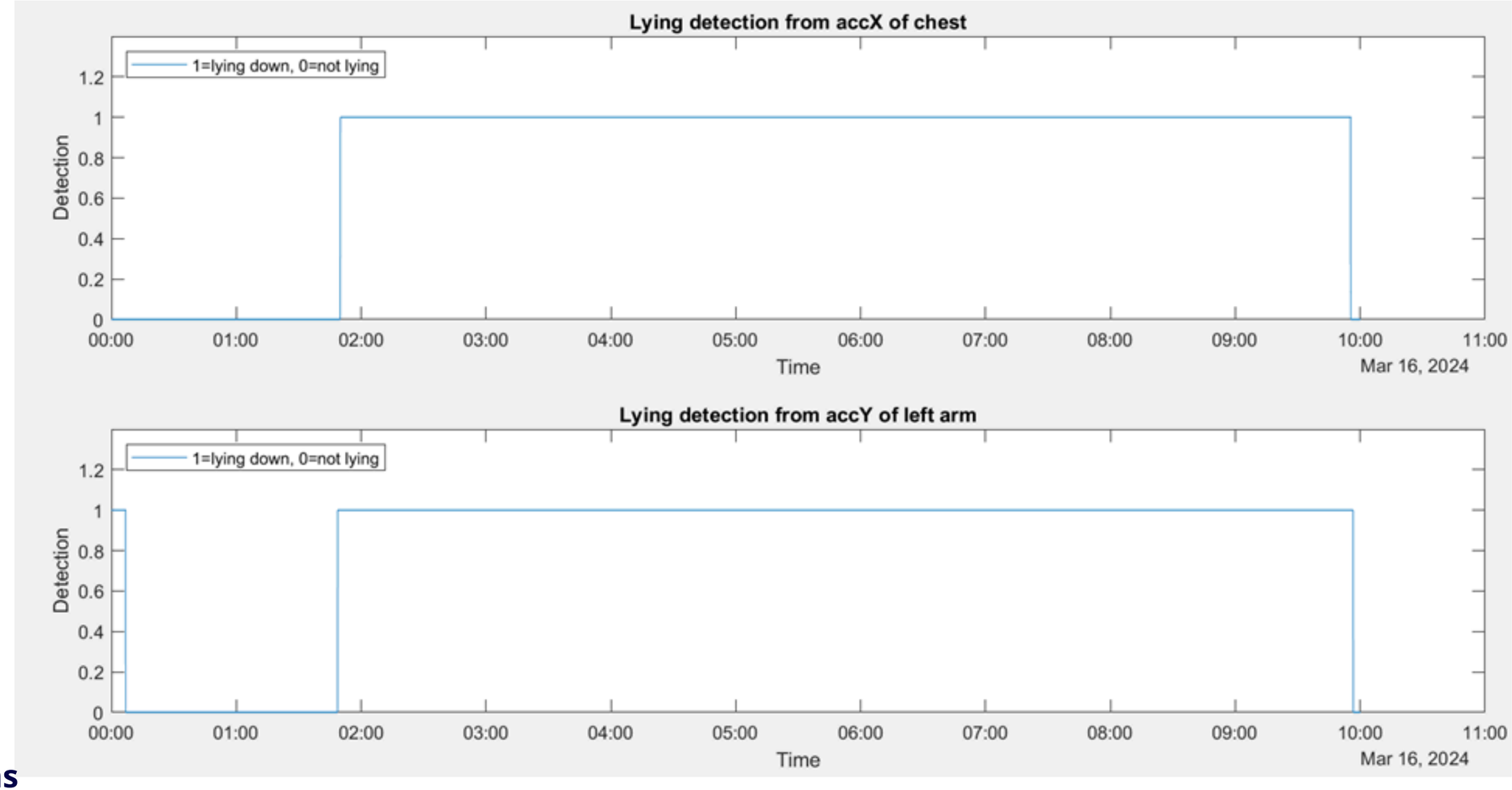
Moving average for the y-axis acceleration of the arm

Set proper thresholds to detect lying position

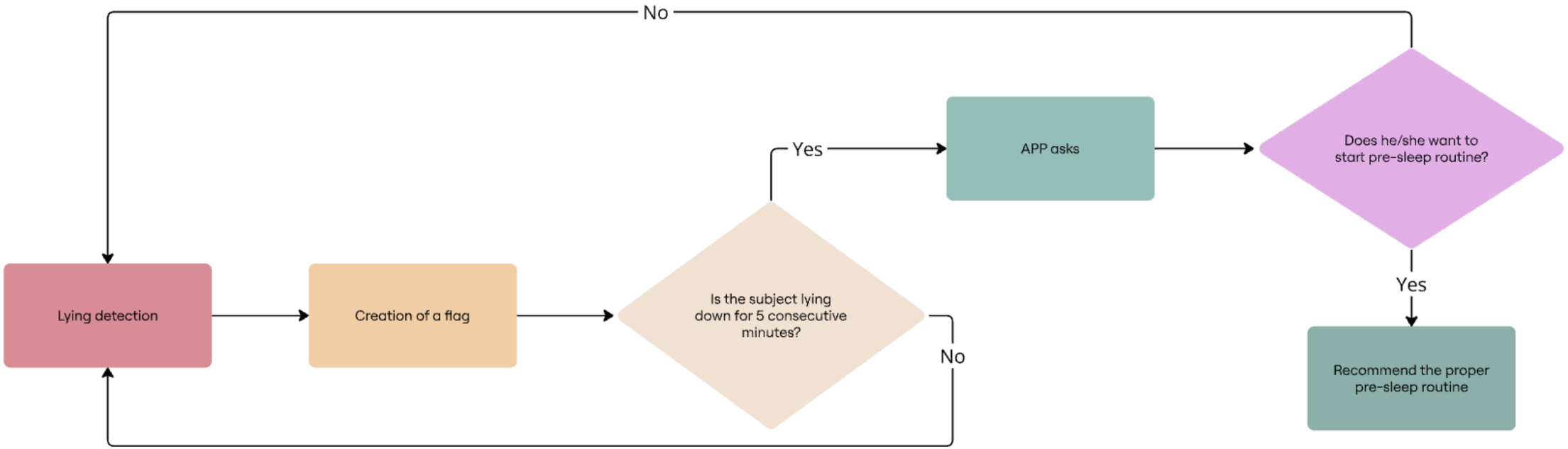
Acceleration between -g/2 and +g/2

LYING DETECTION ALGORITHM: 2ND VALIDATION

Again, when the acceleration is close to 0, both sensors are able to properly detect when the subject is lying, and the arm sensor can be considered as the gold standard.



LYING DETECTION ALGORITHM: 2ND VALIDATION

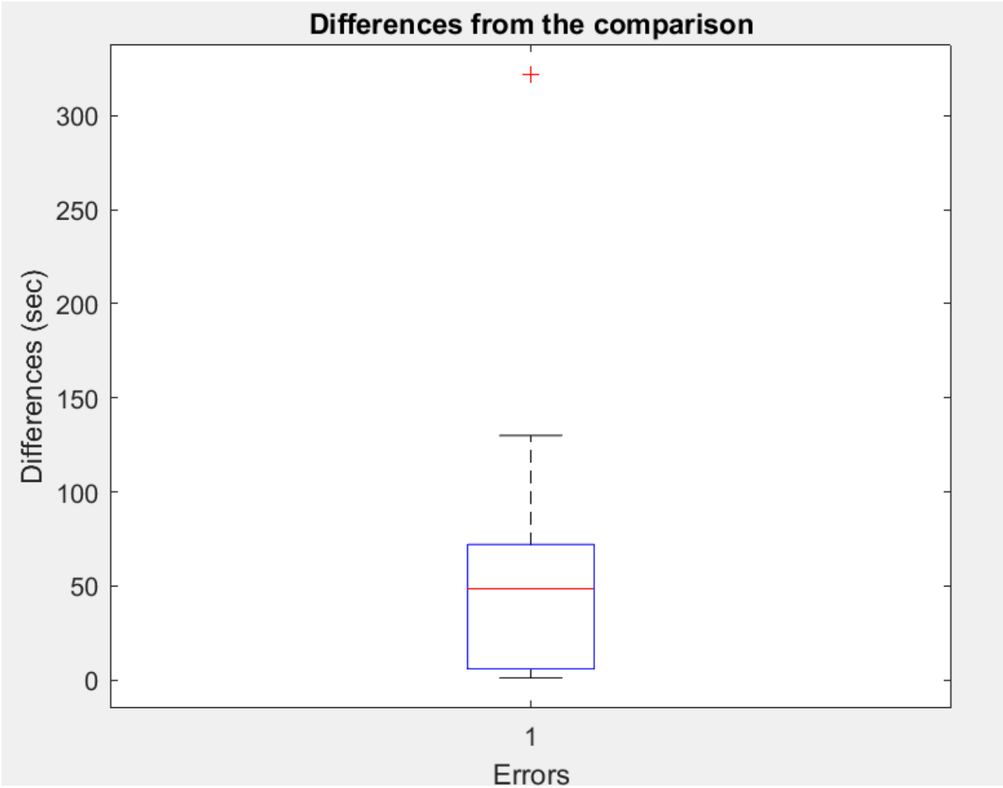


The answer of the subject corresponds to the input of the APP. Subsequently, I translated the Matlab code into Kotlin, so that we can have a real time detection inside the APP.

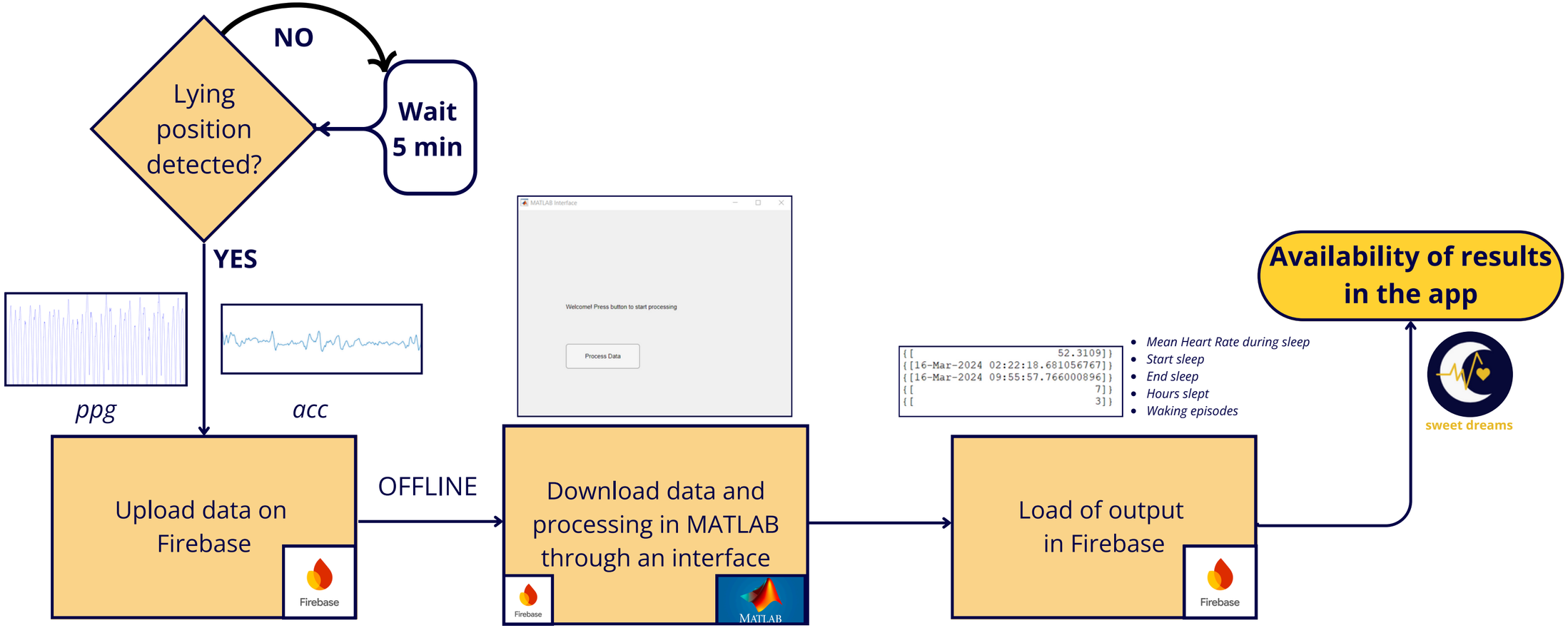
LYING DETECTION ALGORITHM: STATISTICAL ANALYSIS

Even though the validation is incomplete, I carried out a statistical analysis to obtain the mean value and standard deviation of the errors committed by the algorithm, comparing the initial and final time determined by the algorithm with those reported in a sleep diary as lie down data.

Mean value, M=72 seconds.
Standard deviation, SD=96 seconds.

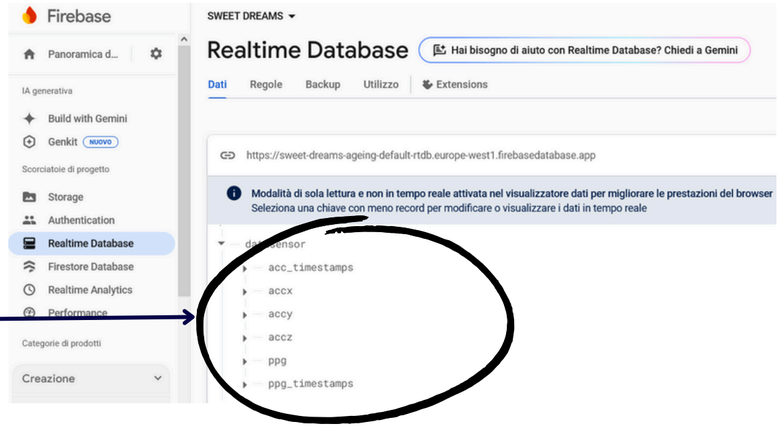


WORKFLOW OF SLEEP QUALITY ALGORITHM

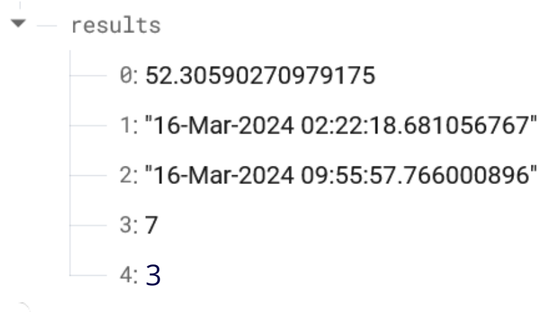


FIREBASE

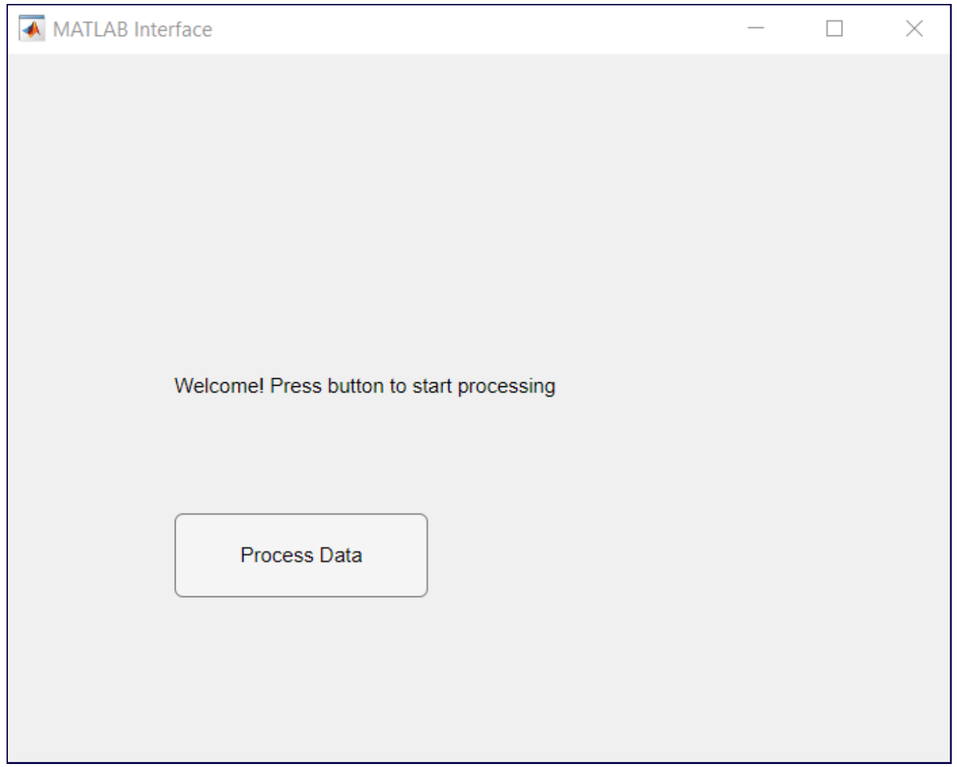
- Unique identification of users
- Loading of data from app in realtime during sleep period
- Downloading offline in Matlab interface
- Upload of output



1. *Mean Heart Rate during sleep*
2. *Start sleep*
3. *End sleep*
4. *Hours slept*
5. *Waking episodes*



MATLAB INTERFACE



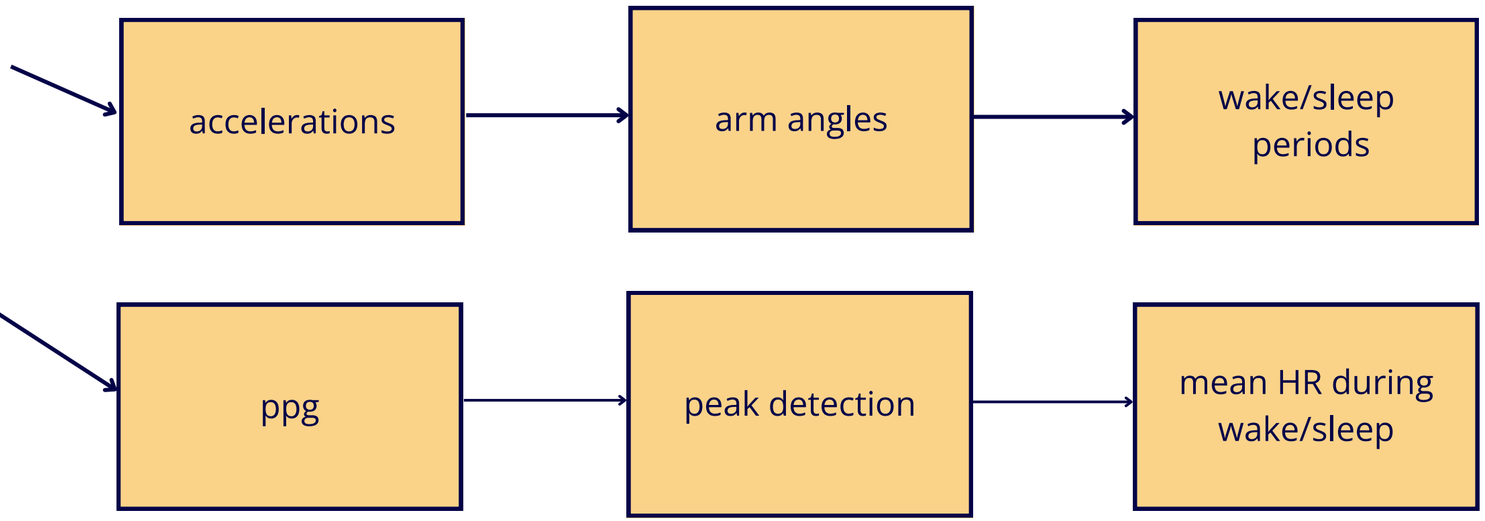
- Easy processing - only by clicking a button - for the clinician.
- Automatic download of data from Firebase and upload of output.

INTRODUCTION SLEEP ALGORITHM

Data acquired during sleep period are **photoplethysmogram** (ppg) and **accelerations** (acc).

Data are processed through Matlab, and 2 algorithms are applied:

1. Van Hees algorithms.
2. PPG processing.



SLEEP DETECTION ALGORITHM: HDCZA

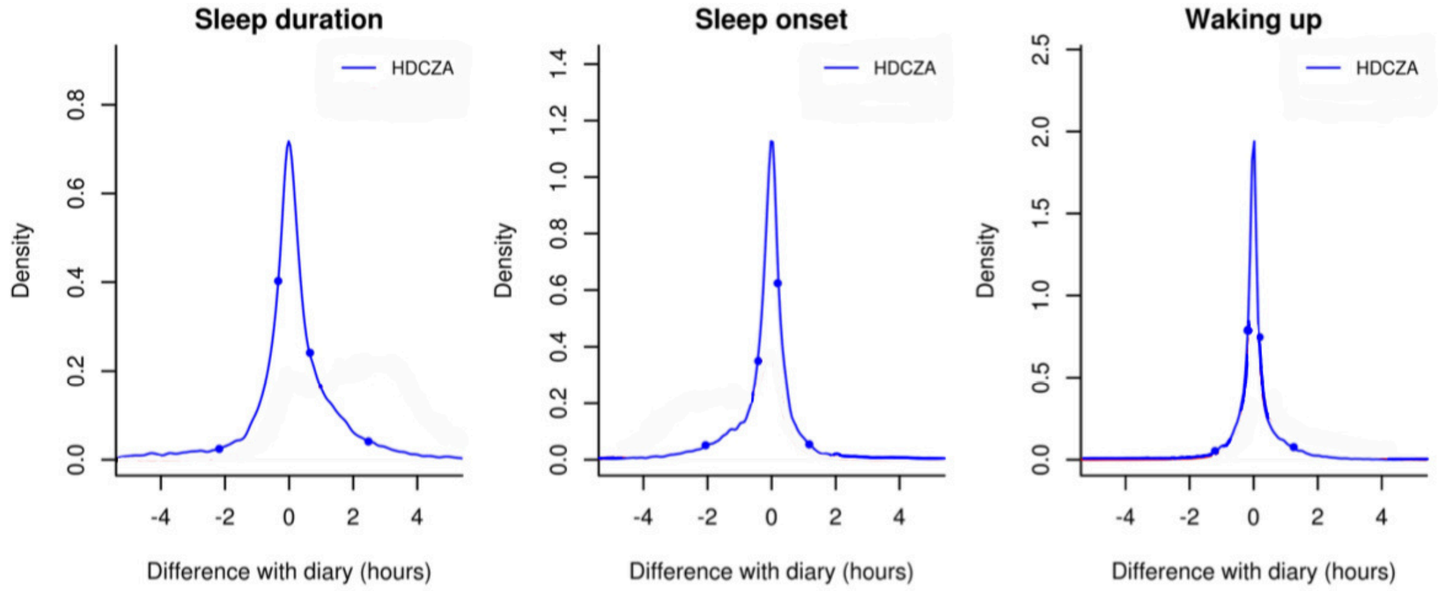
Aim: detect the SPT window

(2018) **Estimating sleep parameters using an accelerometer without sleep diary**

Vincent Theodoor van Hees[1], S. Sabia[2,3], S. E. Jones[4], A. R. Wood[4], K. N. Anderson[5], M. Kivimäki[3], T. M. Frayling[4], A. I. Pack[6], M. Bucan[7,8], M. I. Trenell[9], Diego R. Mazzotti[6], P. R. Gehrman[6,8], B. A. Singh-Manoux[2,3] & M. N. Weedon[4]

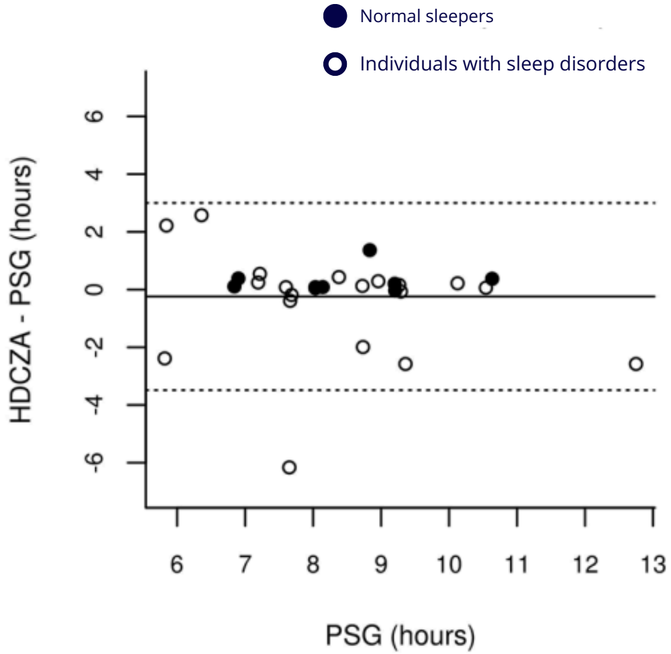
HDCZA ALGORITHM: VALIDATION ON GOLD STANDARDS

Probability density distributions for the differences between sleep parameters estimates from algorithm and sleep diary



N indiviiduals = 3752; sleep onset time mean difference = -12.5 min;
waking time mean difference: -1.6 min

Bland-Altmann plot - SPT window duration



28 sleep clinic patients, 6 of whiich with with a sleep disorder

HDCZA algorithm: implementation

Based on different steps:

- Calculation of z-angle per 5 seconds starting from raw accelerations with the formula:

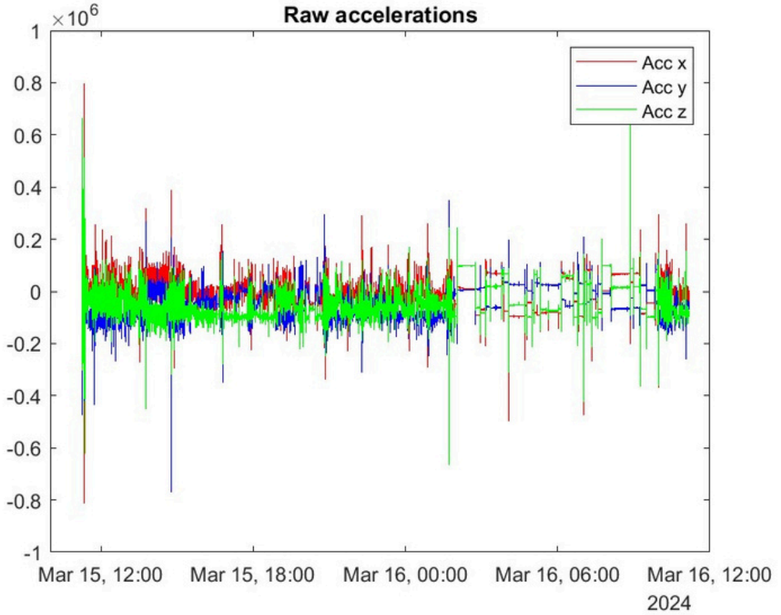
$$angle = \tan^{-1}\left(\frac{a_z}{\sqrt{a_x^2 + a_y^2}}\right) \times \frac{180}{\pi}$$

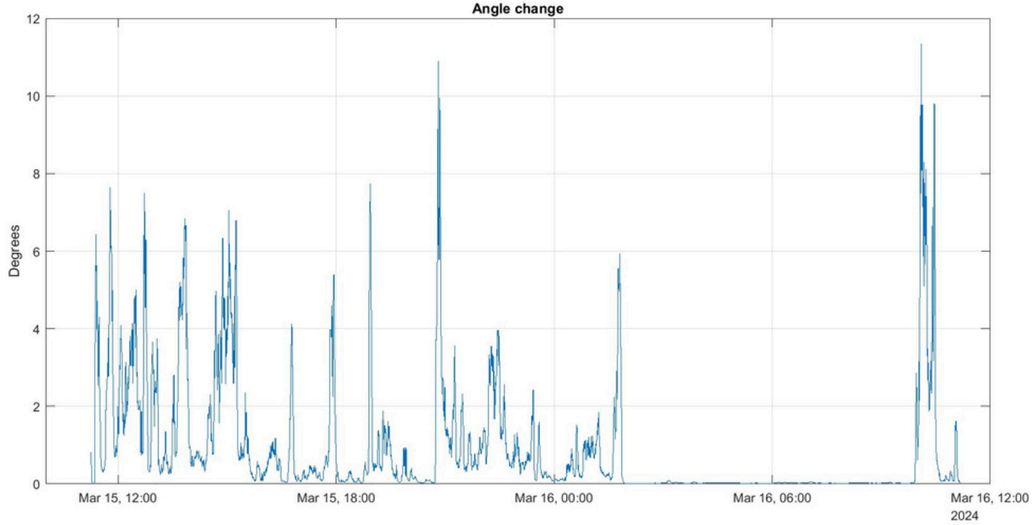
- Calculation of 5 minutes rolling median of absolute differences between sucessive 5 second averages of z angle

- Creation of **threshold,** given by the 10th percentile of previous calculation multiplied by 15

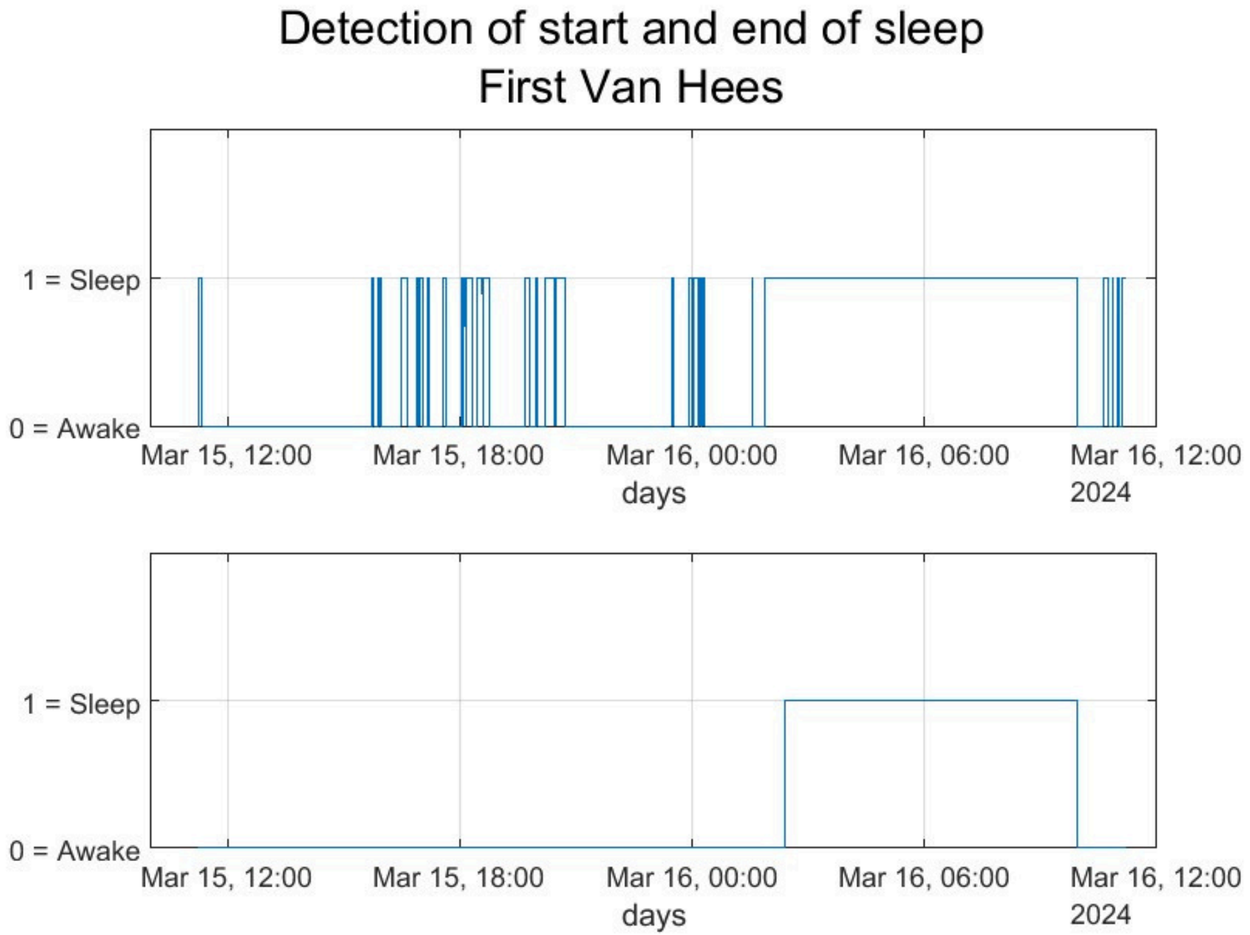
- Find **observation blocks:** below critical threshold for more than 30 minutes

- The longest block in day will be the main SPT-window, that is the time elapsed between **sleep onset** and **waking time**





SLEEP DETECTION ALGORITHM: SPT WINDOW



SLEEP DETECTION ALGORITHM: POTENTIAL AWAKENESS EPOCHS

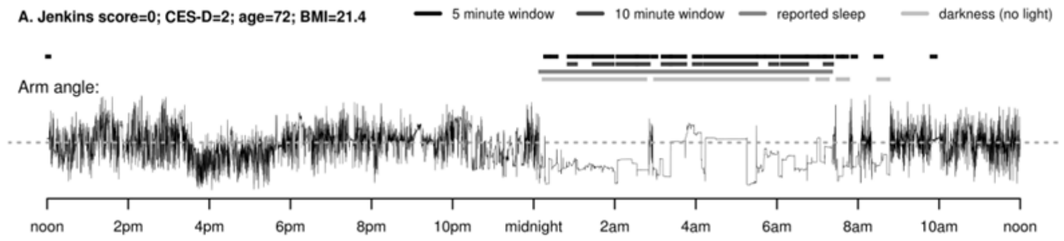
AIM: Identification of period of potential awakeness in the detected SPT-window

(2015)

RESEARCH ARTICLE

A Novel, Open Access Method to Assess Sleep Duration Using a Wrist-Worn Accelerometer

Vincent T. van Hees[1,2☯*], Séverine Sabia[3☯], Kirstie N. Anderson[4], Sarah J. Denton[1], James Oliver[4], Michael Catt[1], Jessica G. Abell[3], Mika Kivimäki[3], Michael I. Trenell[1], Archana Singh-Manoux[3,5]



HOW DOES THE ALGORITHM WORK?

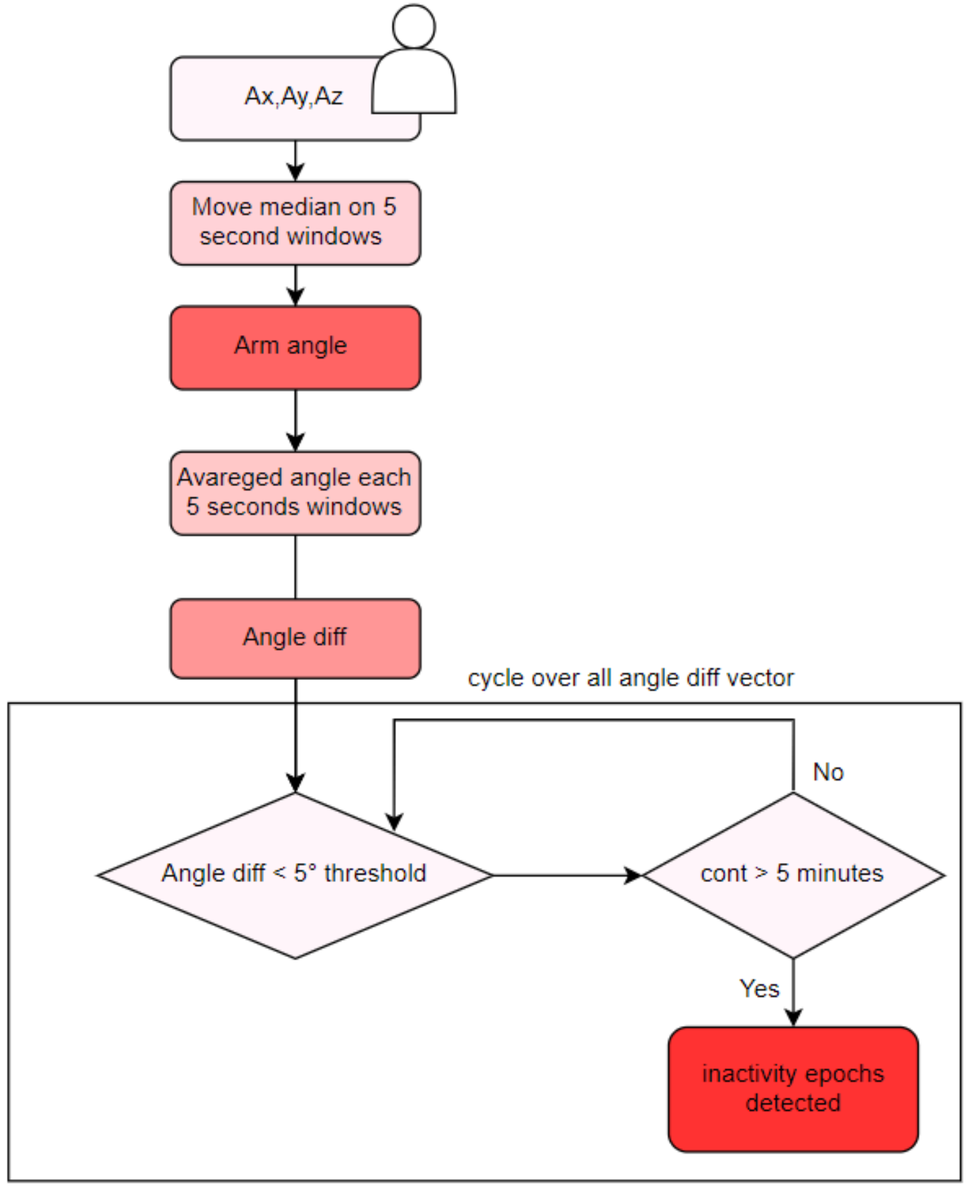
- Arm angle relative to the **horizontal plane** is computed given the **median** values of the three accelerations.

$$angle = \tan^{-1}\left(\frac{a_z}{\sqrt{a_x^2 + a_y^2}}\right) \times \frac{180}{\pi}$$

- Estimated arm angles were averaged per **5 second epoch** and used to assess absolute change in arm angle between successive 5 second epochs.

- Periods of time during which there was **no change larger than 5° over at least 5 minutes** were classified as bouts of sustained inactivity, or **potential sleep periods**.

- As difference, we calssified the period not satisfying the threshold as **potential awakness epochs.**

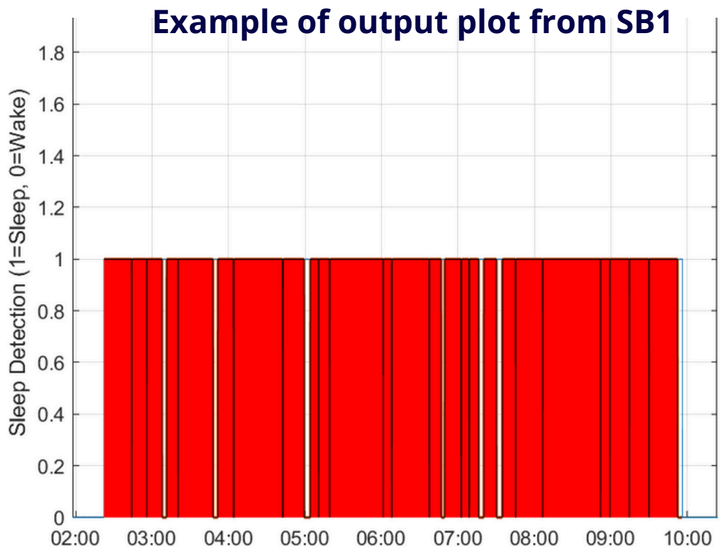


WASO ESTIMATION

The sum of all the **potential awakness epochs** gives the estimation of the **Wake After Sleep Onset (WASO)**.

WASO is the total number of minutes that a person is awake after having initially fallen asleep.

potential sleep periods



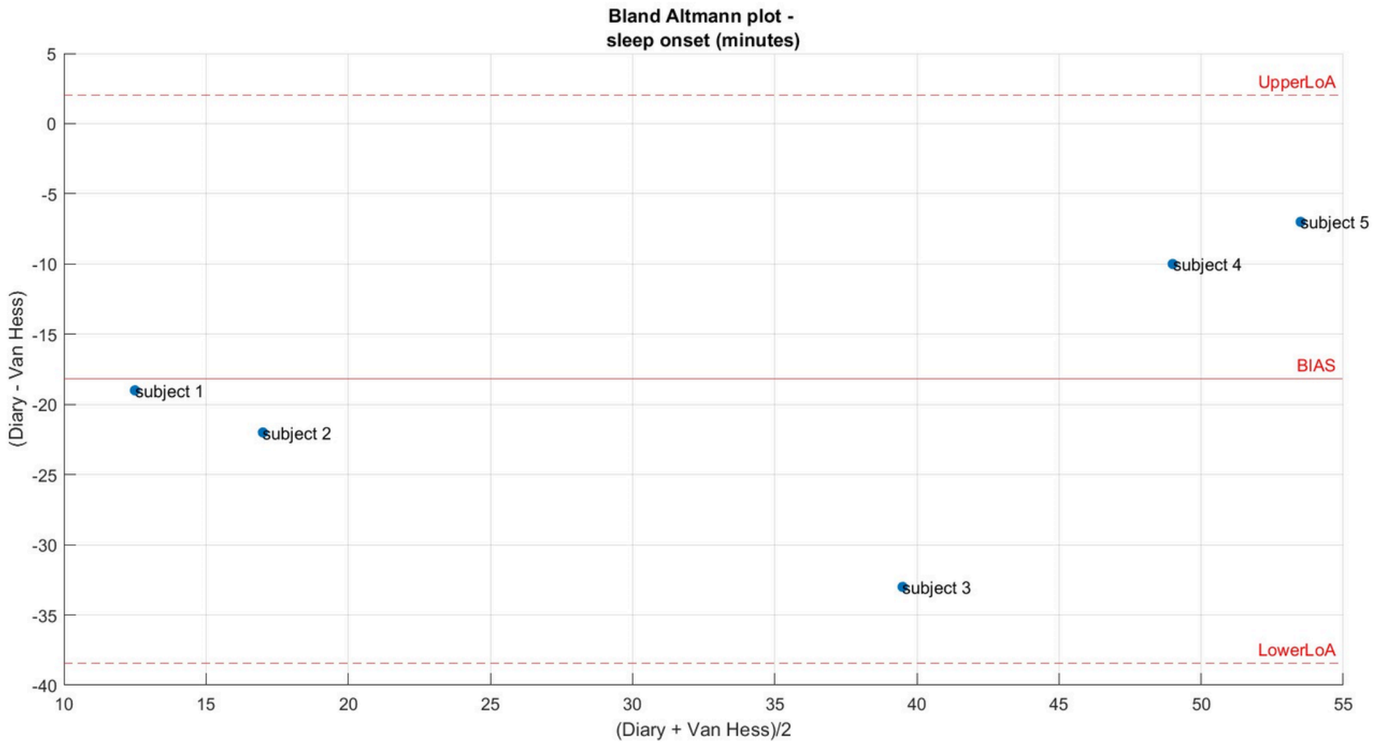
5 healthy subjecst has been tested

	WASO [min]	SLEEP EFFICIENCY
SB1	32.5	93%
SB2	34	93%
SB3	31	94%
SB4	30	94%
SB5	37	93%

SLEEP DETECTION ALGORITHM: STATISTICAL ANALYSIS

Sleep onset time

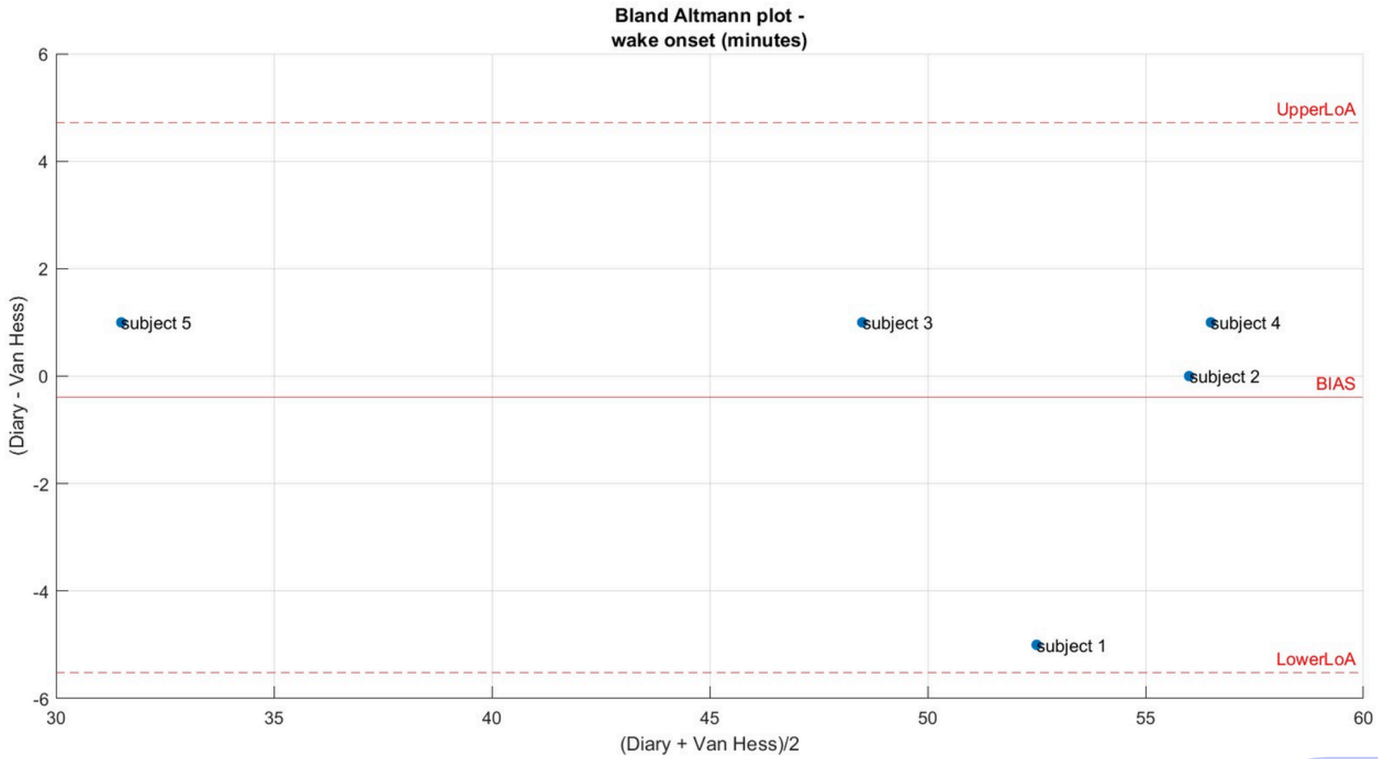
	SLEEP DIARY (light off)	VAN HEES
SUBJECT 1	2.03	2.22
SUBJECT 2	01.06	01.28
SUBJECT 3	01.23	01.56
SUBJECT 4	23.44	23.54
SUBJECT 5	00.50	00.57



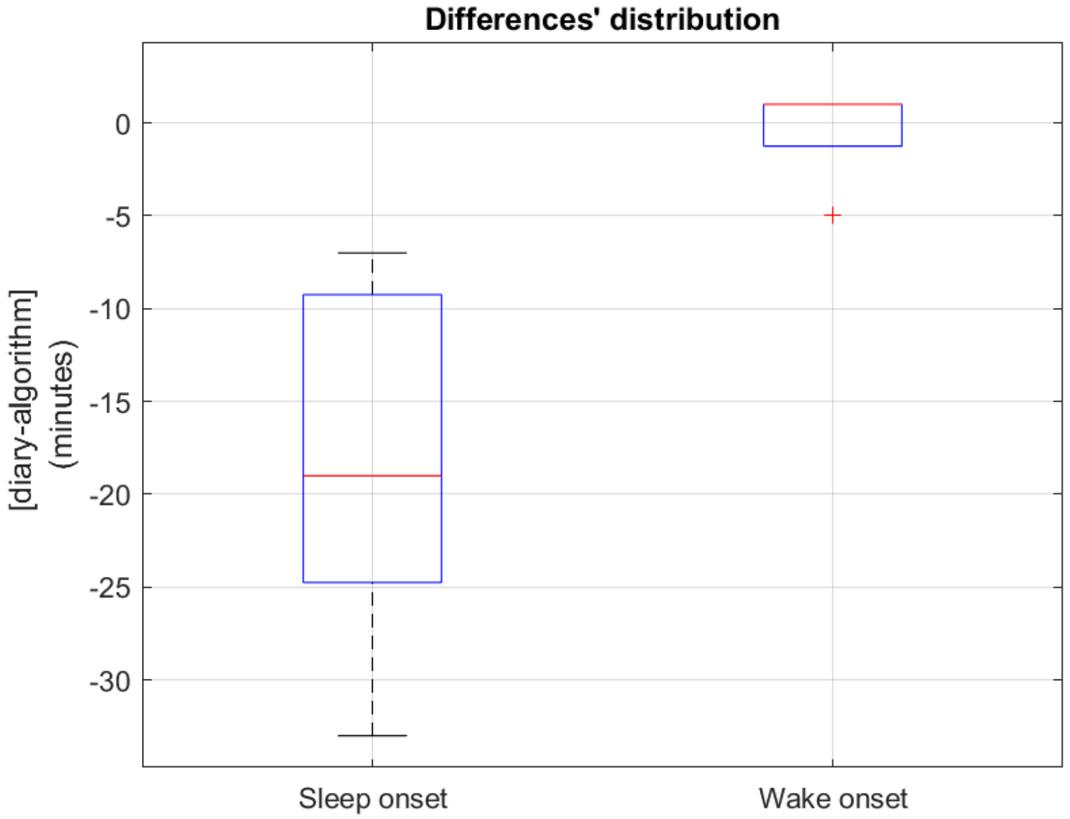
SLEEP DETECTION ALGORITHM: STATISTICAL ANALYSIS

Wake onset time

	SLEEP DIARY	VAN HEES
SUBJECT 1	9.50	9.55
SUBJECT 2	7.56	7.56
SUBJECT 3	08.49	08.48
SUBJECT 4	08.57	08.56
SUBJECT 5	08.32	08:31



SLEEP DETECTION ALGORITHM: STATISTICAL ANALYSIS

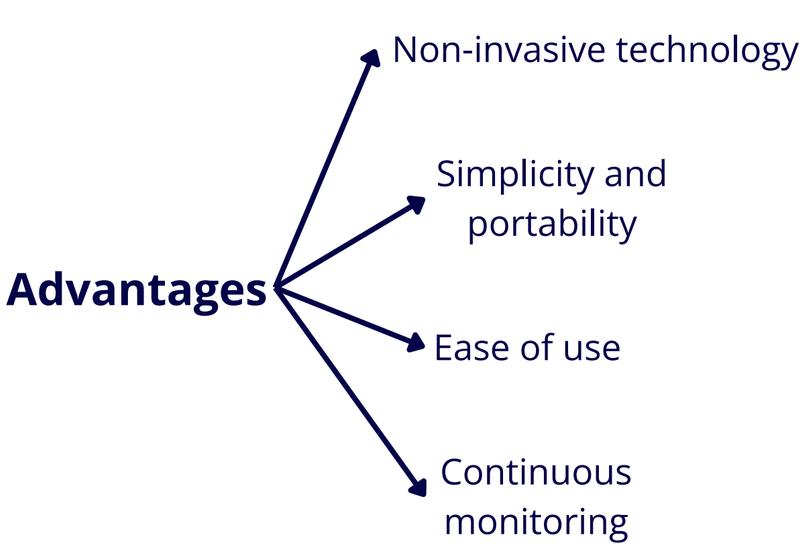


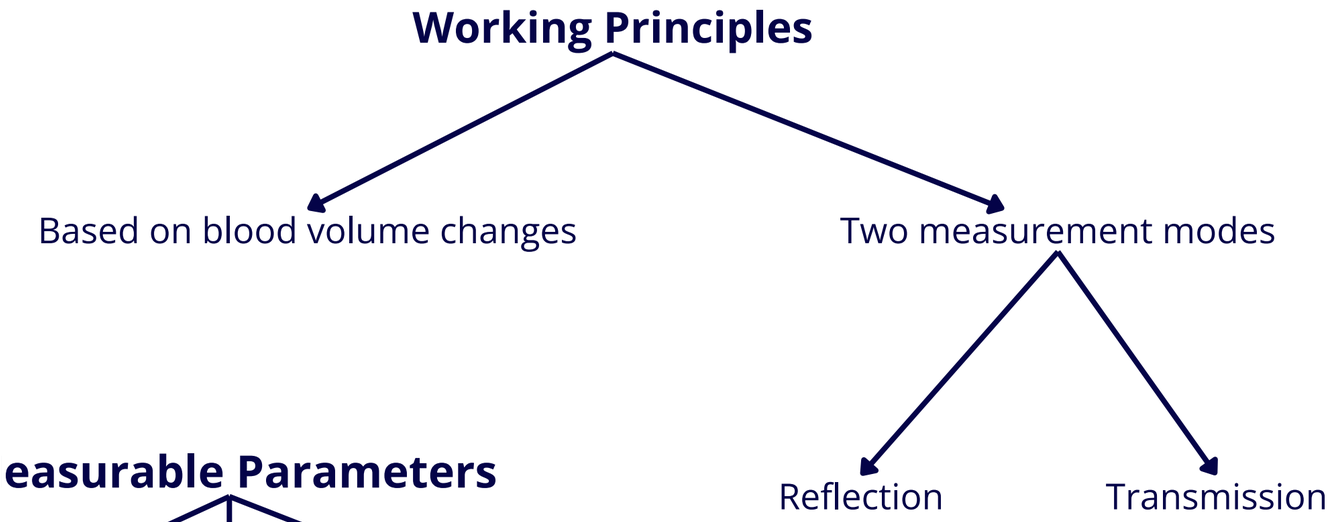
Key points:

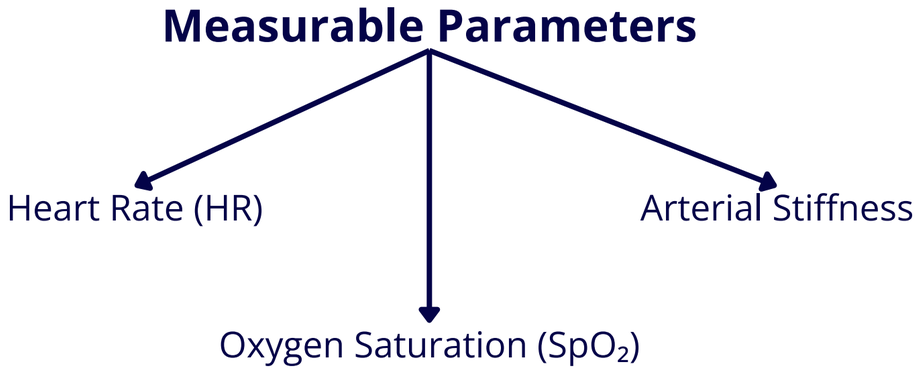
- **Better agreement** on wake onset time (smaller variability and a median closer to zero);
- The **higher dispersion** of sleep onset data (wider interquartile range) can be explained by the concept of **sleep latency;**
- On average, a healthy person takes between 10 and 20 minutes to fall asleep.

WHY PHOTOPLETHYSMOGRAPHY (PPG) ?

Determines and registers the variations in blood volume in the body which occurs with each heartbeat

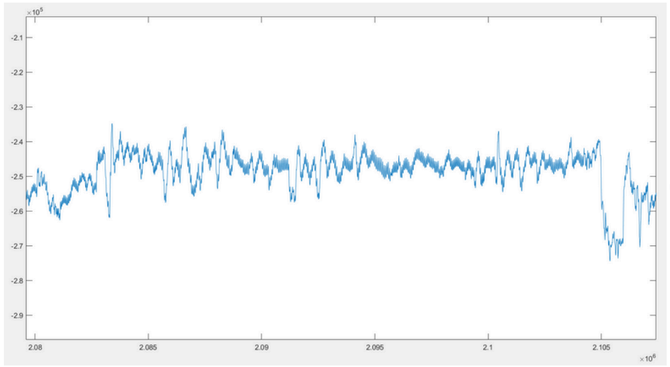






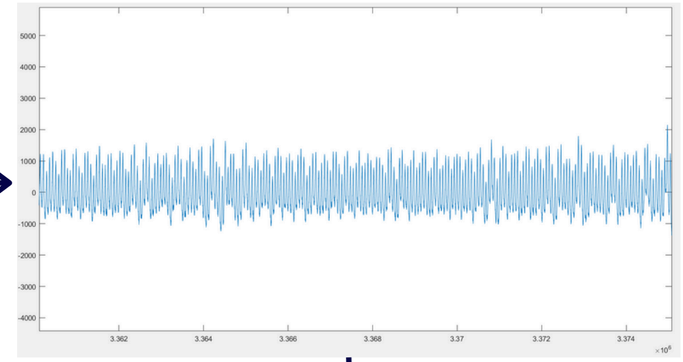
PPG SIGNAL FILTERING

ppg_raw

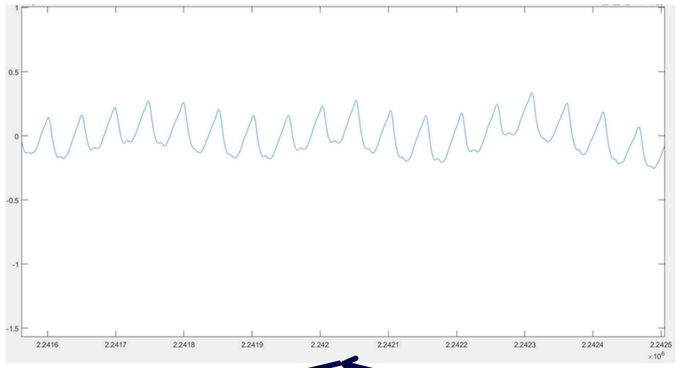


highpass(ppg_raw,fs,0.15,0.1);

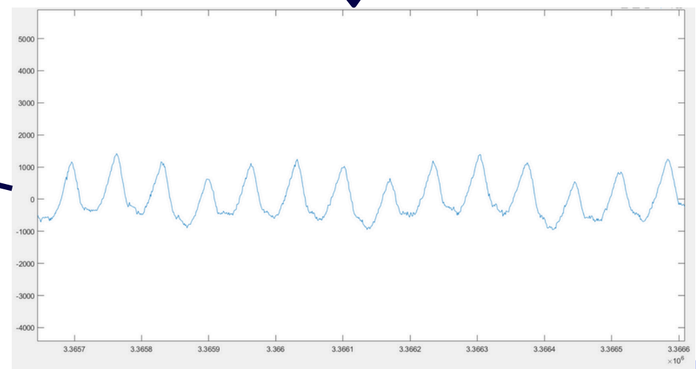
ppg_highpass



ppg_lowpass

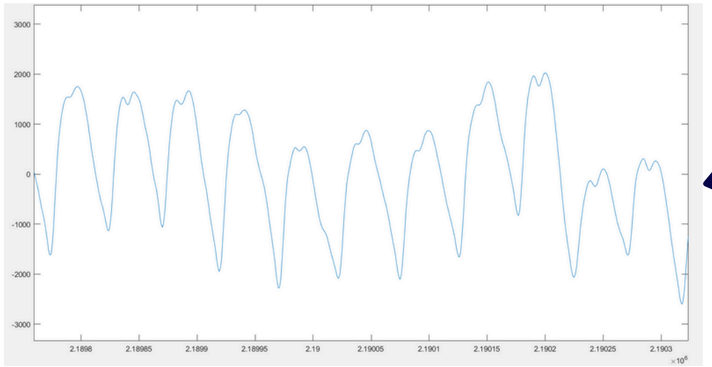


zoom in



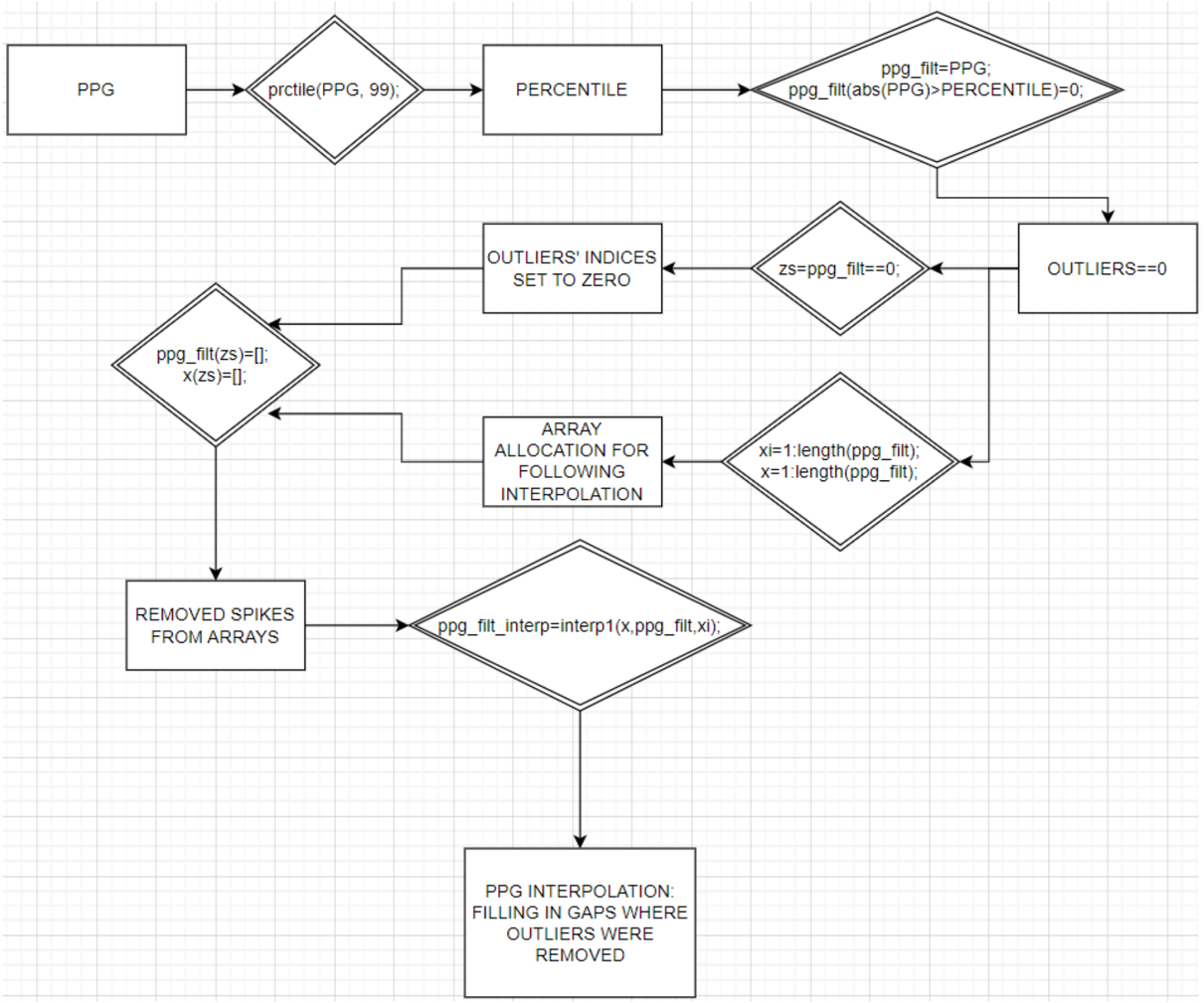
lowpass(ppg_highpass,fs,7.5,8);

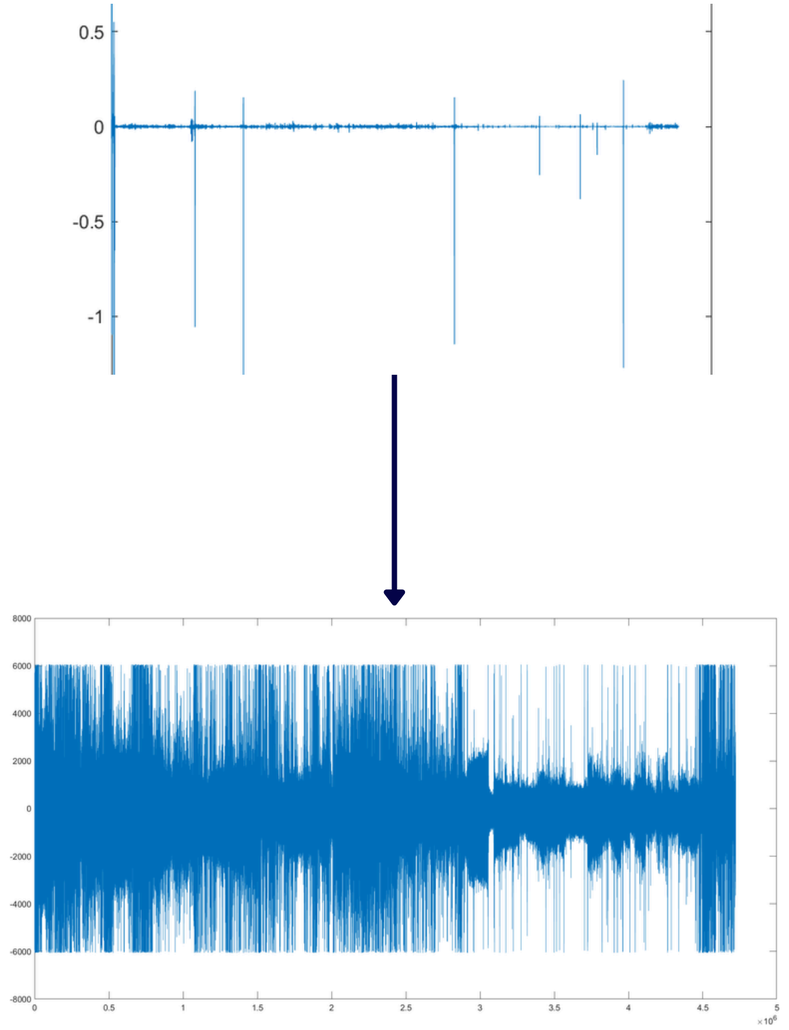
PPG=-ppg_lowpass



Sweet Dreams

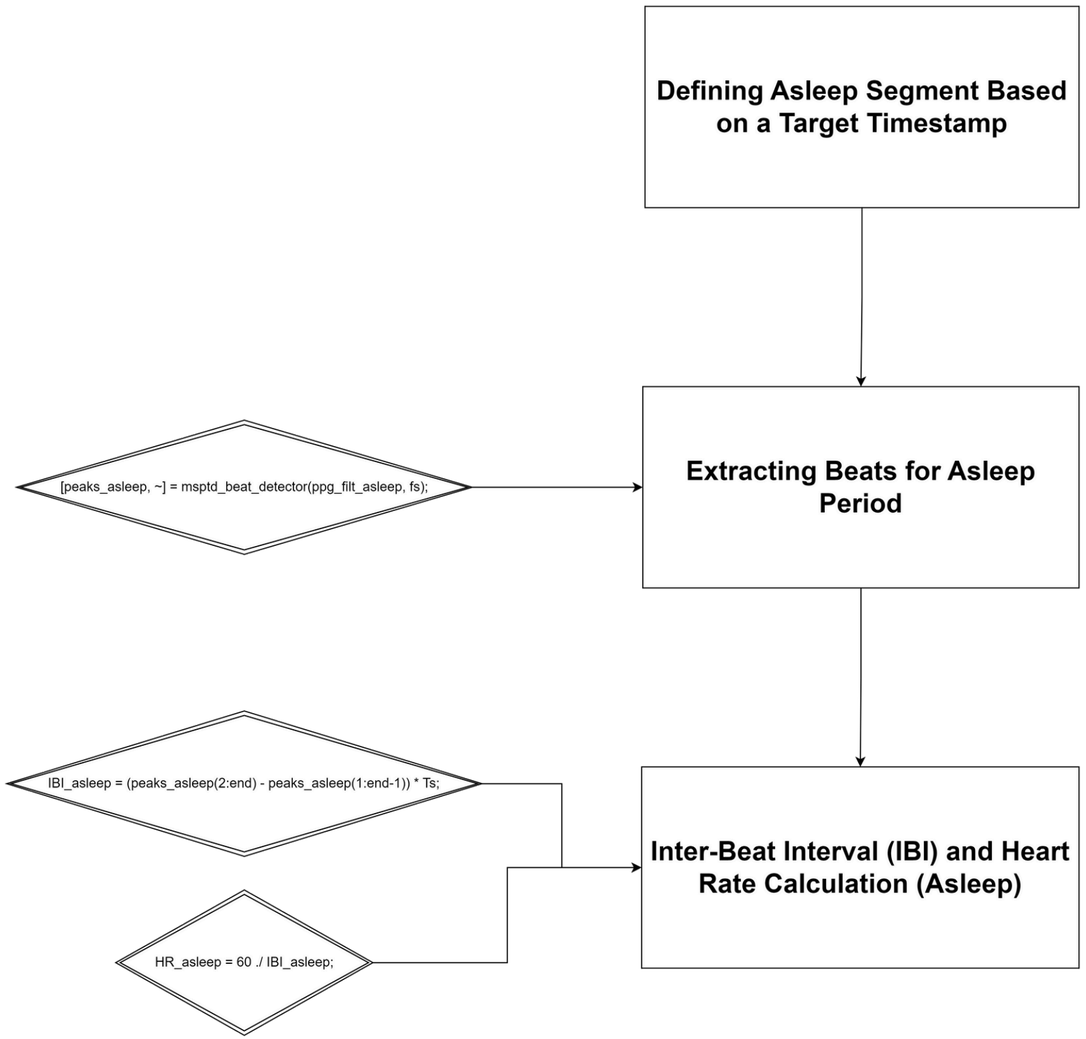
SPIKES REMOVAL & INTERPOLATION





Sweet Dreams

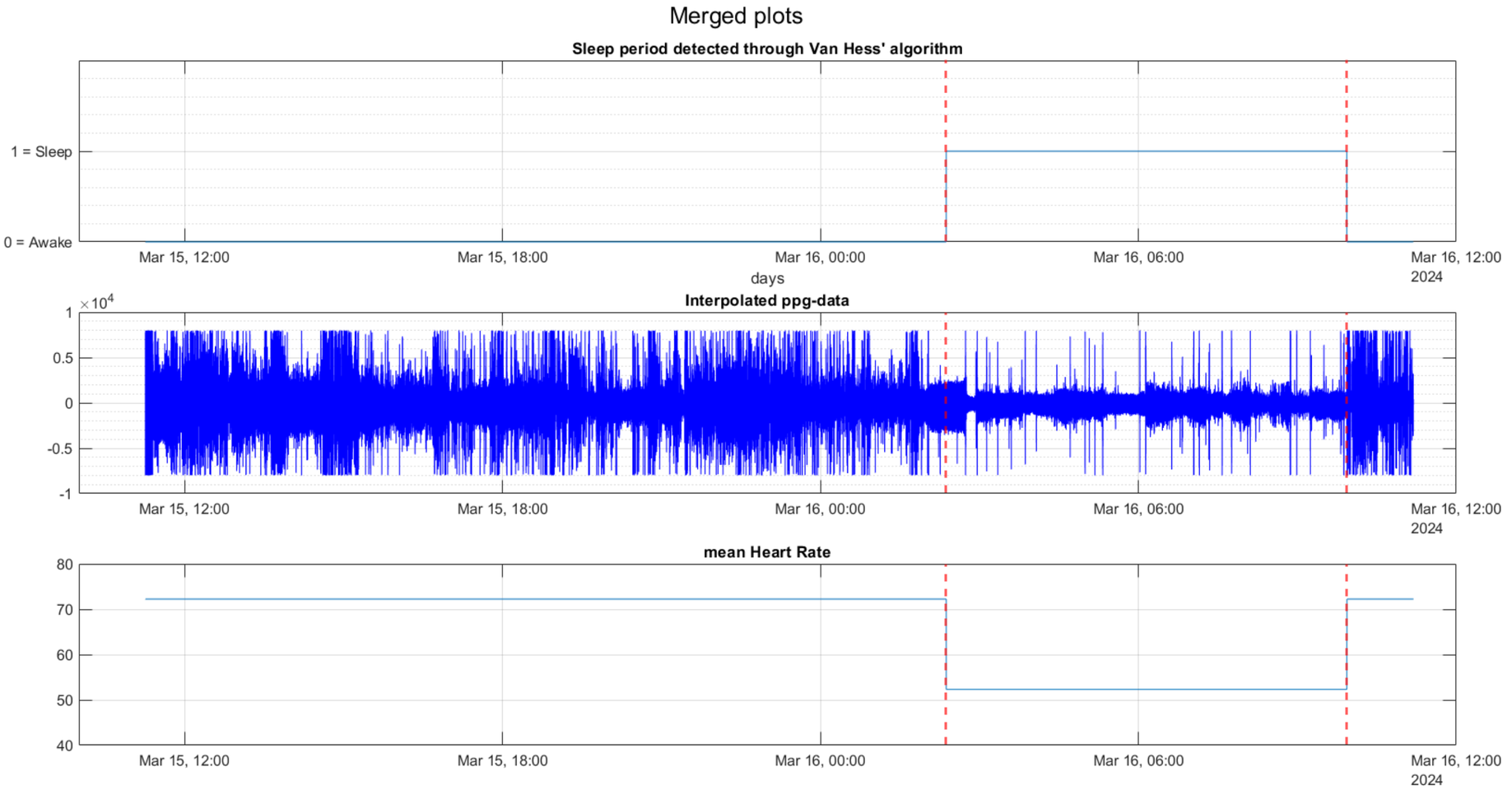
HEART-RATE EXTRACTION (AWAKE VS ASLEEP)



REFERENCE

S. M. Bishop and A. Ercole, 'Multi-scale peak and trough detection optimised for periodic and quasi-periodic neuroscience data,' in Intracranial Pressure and Neuromonitoring XVI. Acta Neurochirurgica Supplement, T. Heldt, Ed. Springer, 2018

PPG: a “double-check” for the wake vs sleep period



APP DESIGN

PATIENT:

- Keeping track of sleep quality.
- Direct access for clinical consultation.
- Real-time update of sleep score.

DOCTOR:

- Keeping track of the patient's status.
- Real-time intervention by providing feedback.
- Real-time chat with the patients.

PATIENT'S LAYOUT

CLICK ON IT...

Enter your account credentials and view the main-page of the app with all your data.

CLICK ON IT....

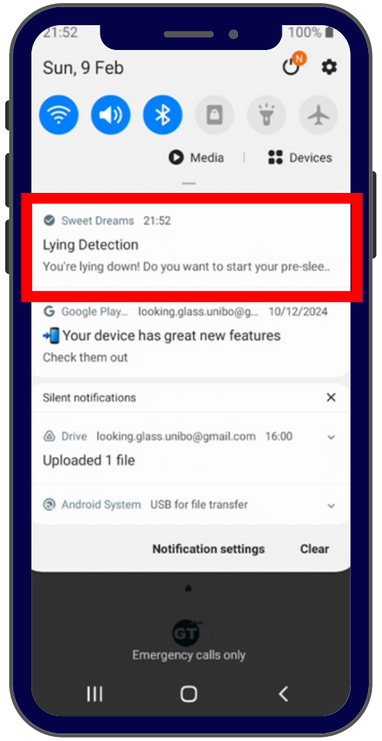
Start the connection with the *Polar device* and complete the registration on the appropriate page.

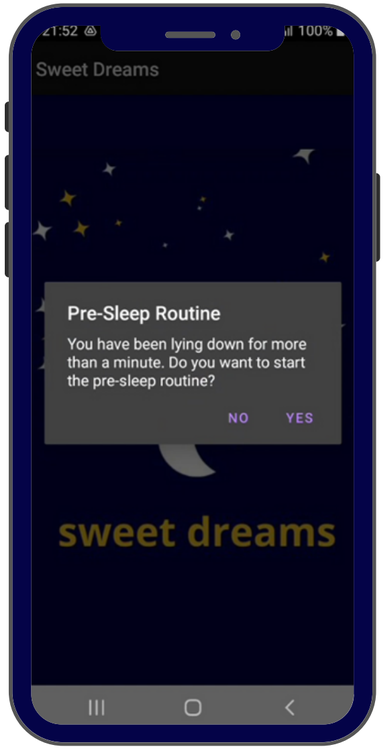
POLAR

Firebase

ARE YOU SLEEPING?

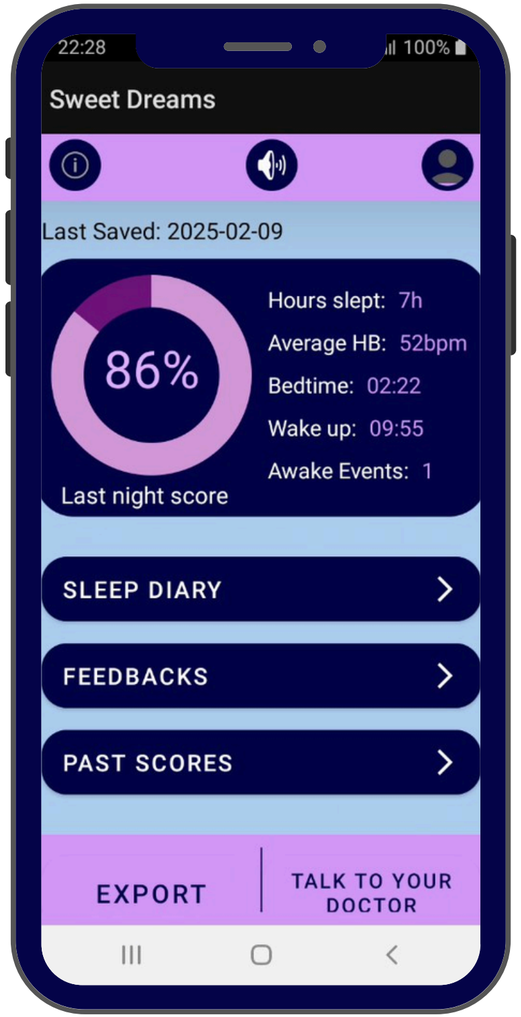
POP-UP notification to choose whether to start pre-sleep routine or not, having been lying down for more than 5 minutes. The patient can in real time accept it or not.





PATIENT'S MAIN-PAGE

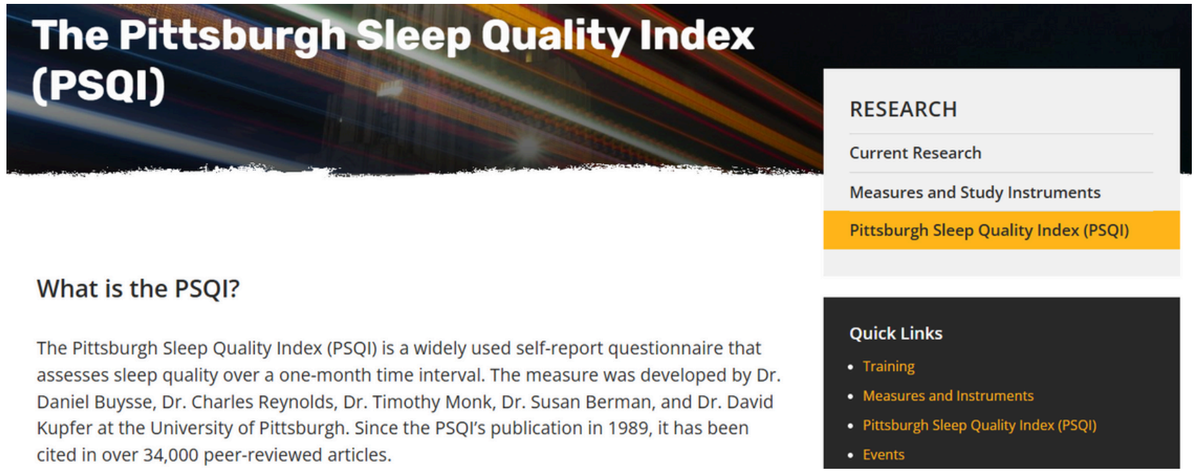
Firebase

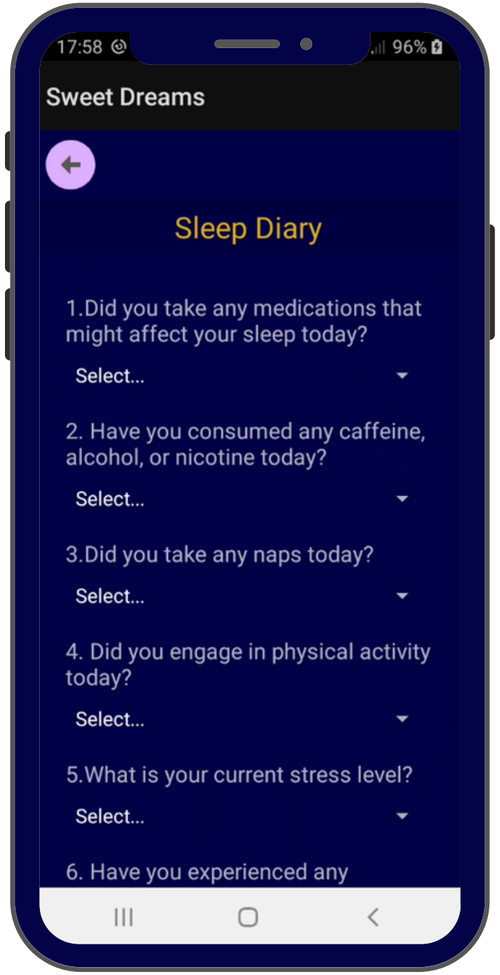


The main screen provides an intuitive summary of sleep quality through a percentage score and key parameters.

Score obtained with an algorithm similar to **PSQI**.

University of Pittsburgh

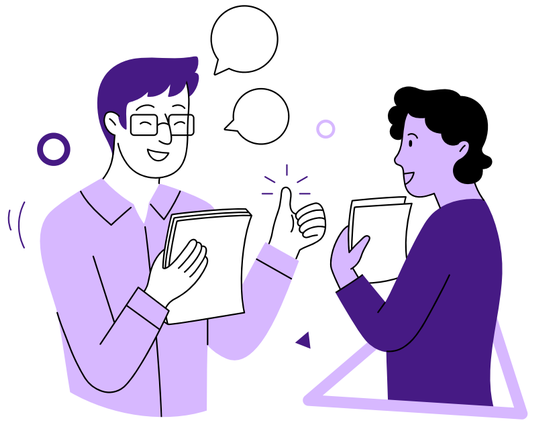


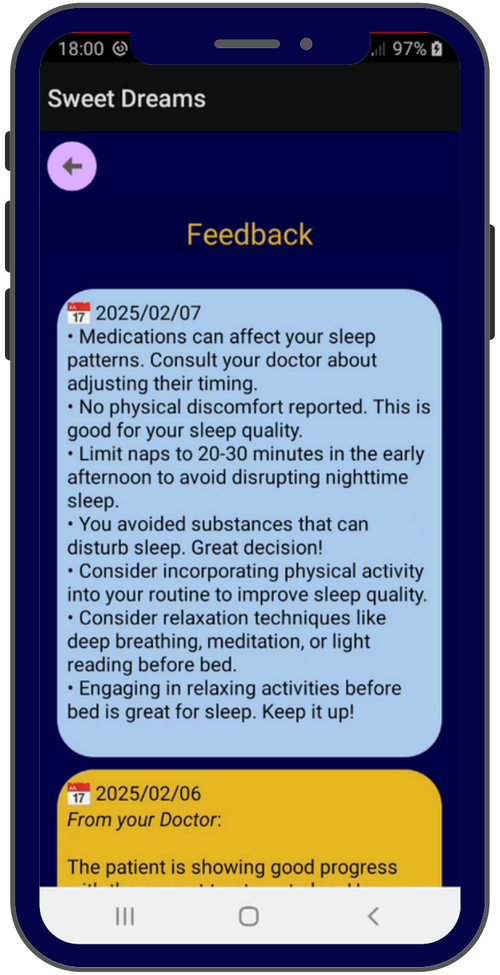


1. SLEEP DIARY

A daily questionnarie needs to be filled by the user to evaluate the following night sleep.

Starting from it, the most suitable feedbacks for the specific situations are outlined .

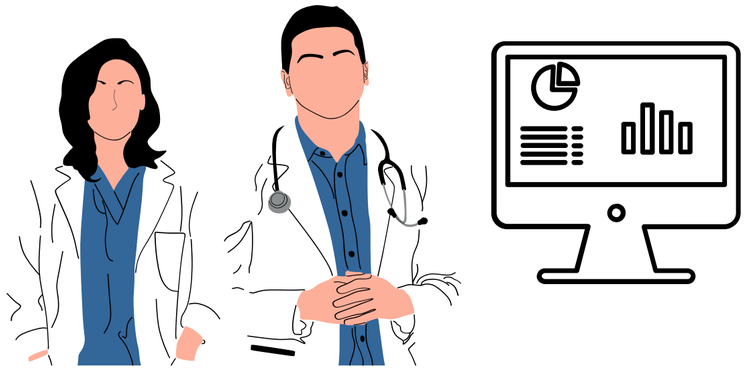


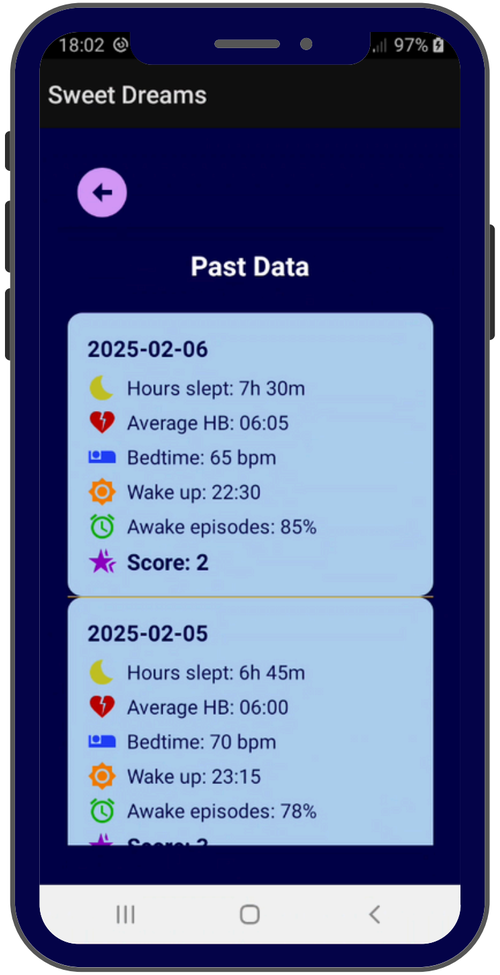


2. FEEDBACKS

Daily feedbacks are shown, so they can supply advices to increase sleep quality.

Everything is enriched by a direct link with the doctor, who visualizes the results and, if needed, gives real-time advices.

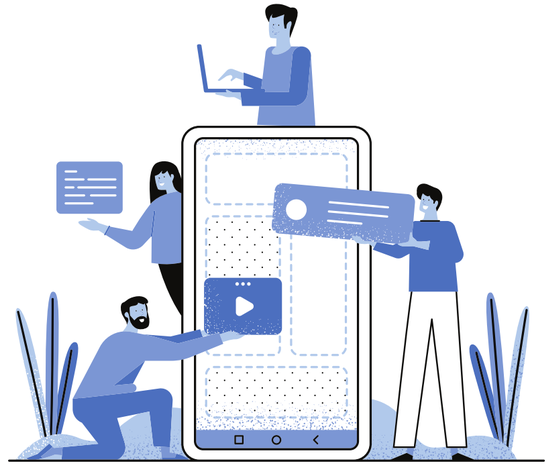




3. PAST SCORES

It is present a collection of data of the patient from the previous days to have a general idea of the trend of the parameters.

In this way the patient has clear signals of his/her improvement or not observing a straightforward and simple interface.



OTHER FUNCTIONALITIES

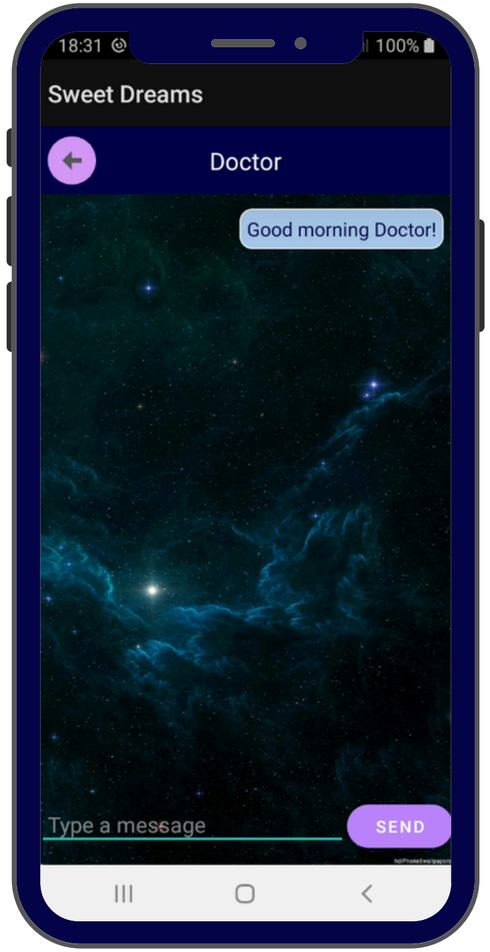
An info button is shown so the patient is able to read again the instructions if needed.

To make the experience more inclusive, there is a button for visually impaired users to describe out loud each button.

It is present also a user botton to read the recap of the inserted data during the registration. It is also possible to modify the answers given at the beginning.

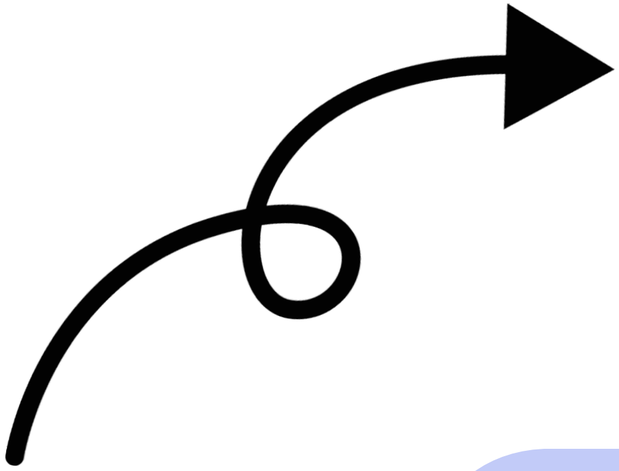
CLINICAL CONNECTION

EXPORT | TALK TO YOUR DOCTOR



The analysis of the data can be shared through PDF using Bluetooth connection or through third parts.

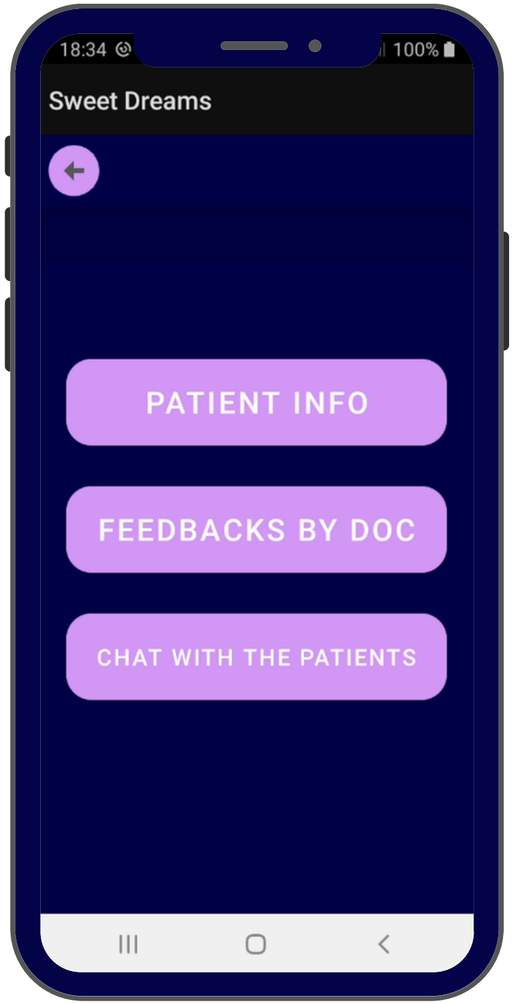
Furthemore it is possible to directly talk with your doctor through a specific chat.

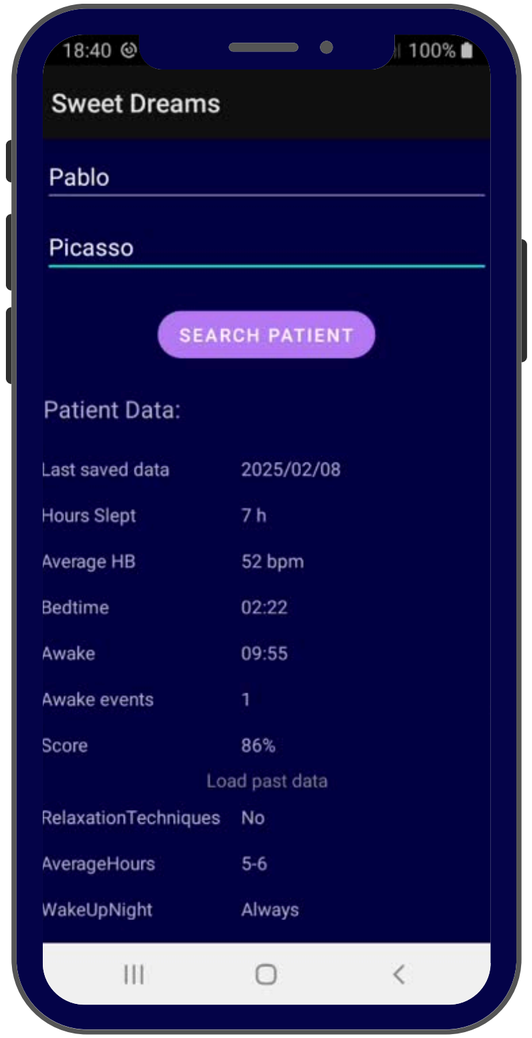


DOCTOR’S LAYOUT

It is possible to access the doctor button only if given permission from the agency for that specific device.

The doctor layout is divided in 3 main buttons.

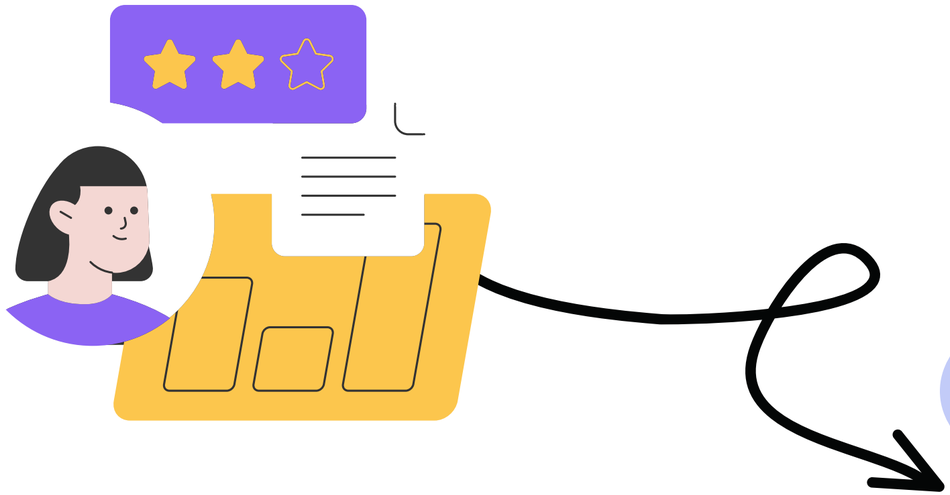


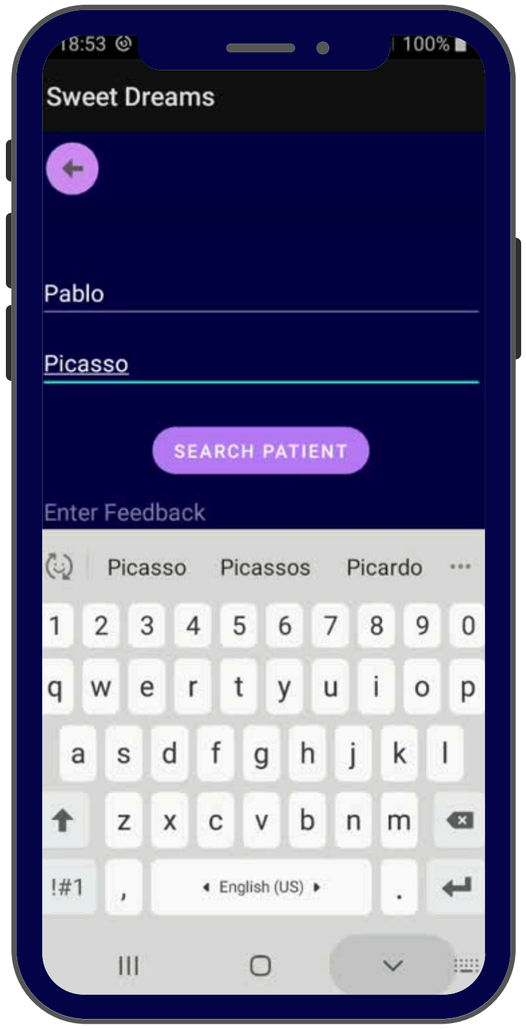


1. PATIENT INFO

The relative patients of registered doctors are recorded into the app by the agency.

The doctor can search a spefic patient and look at his/her general information and sleep data.

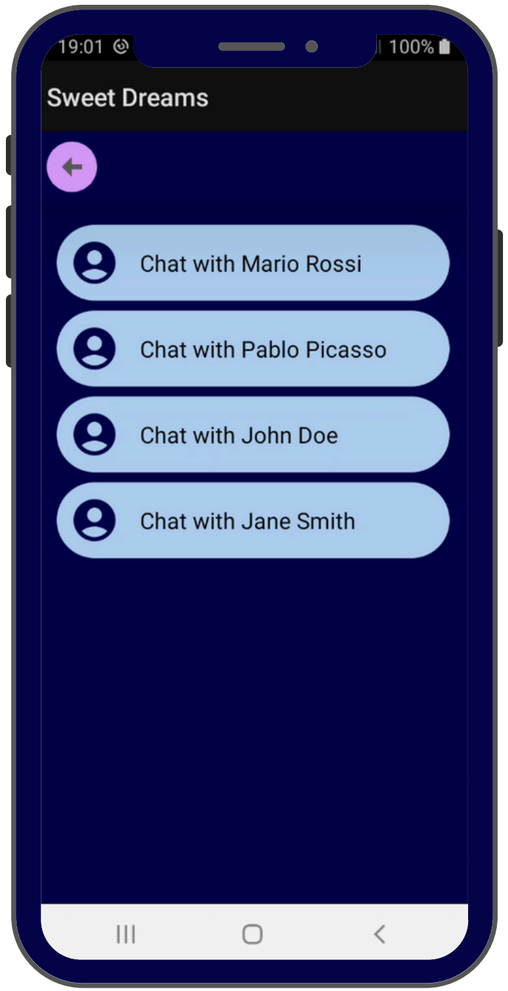




2. FEEDBACKS BY DOC

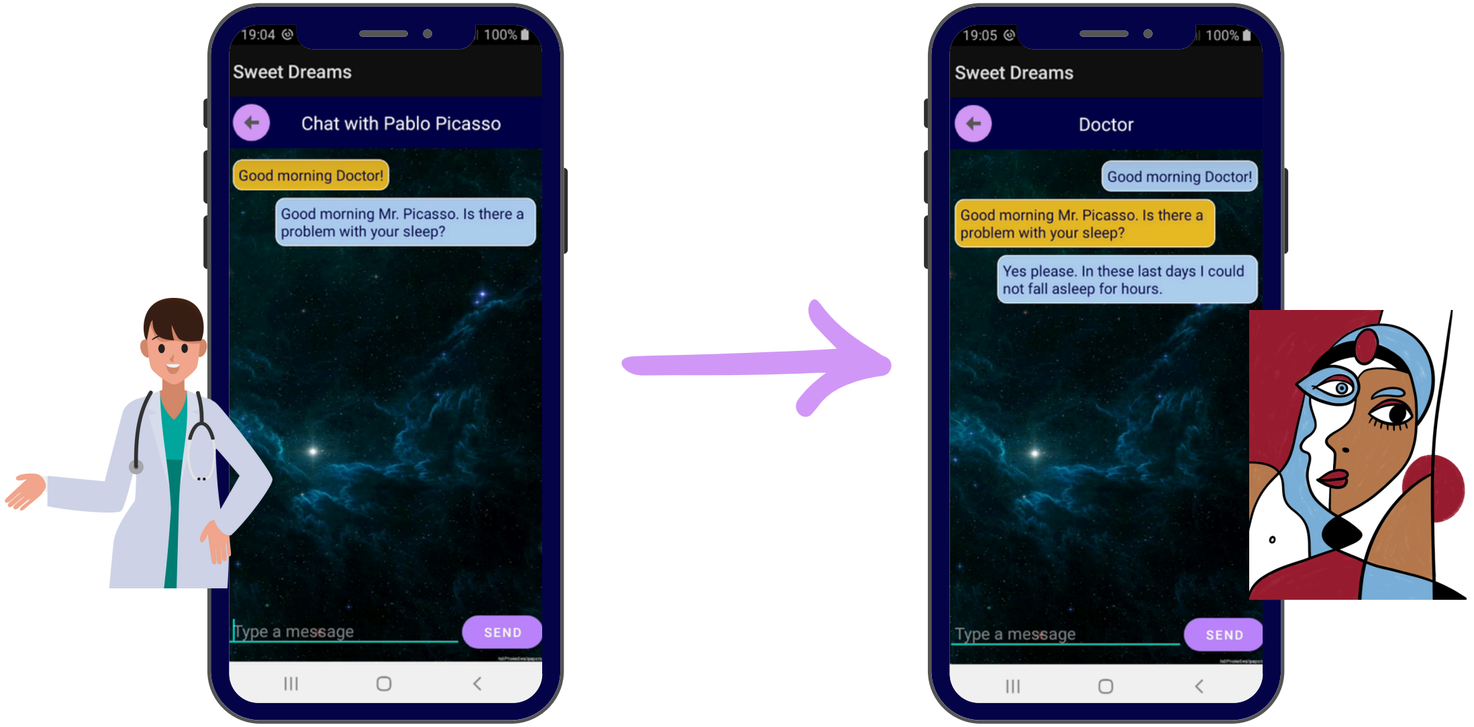
The doctor can search also for the feedbacks given to each patient.

The physician is also able to write new feedbacks that will appear in the patient side.

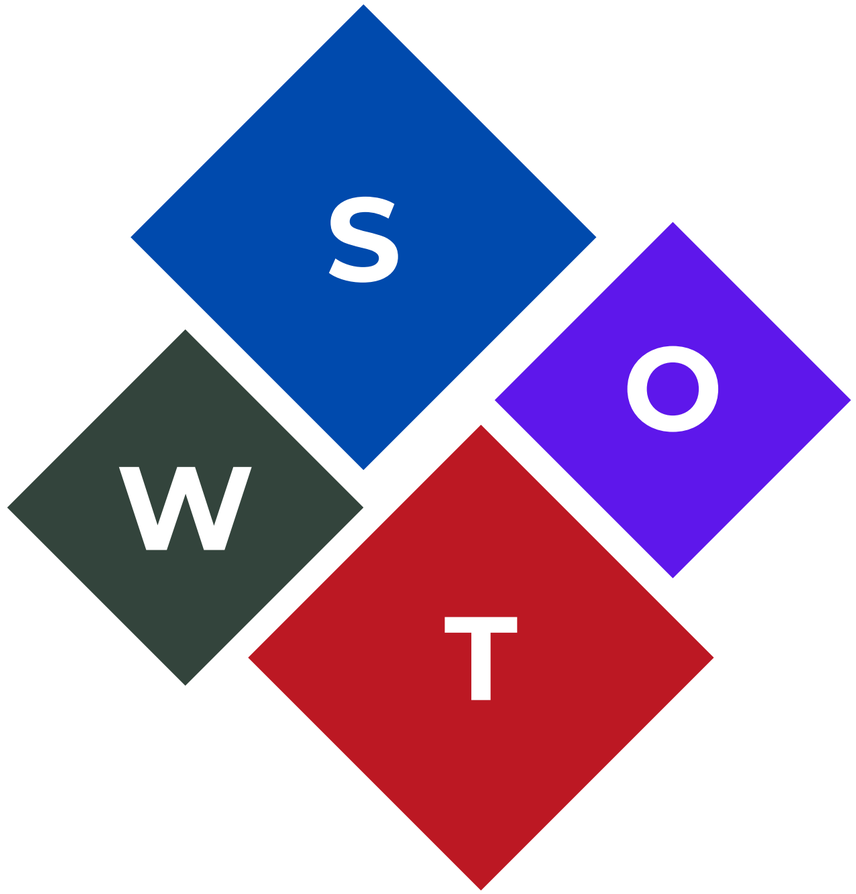


3. CHAT WITH PATIENTS

A correspondent chat is also present in the doctor layout.



SWOT ANALYSIS: AT THE BEGINNING



Strengths

- Main ideas
- Our skills
- Availability of sensors

Weaknesses

- Width of target
- App development stage
- Limited access to data sets

.

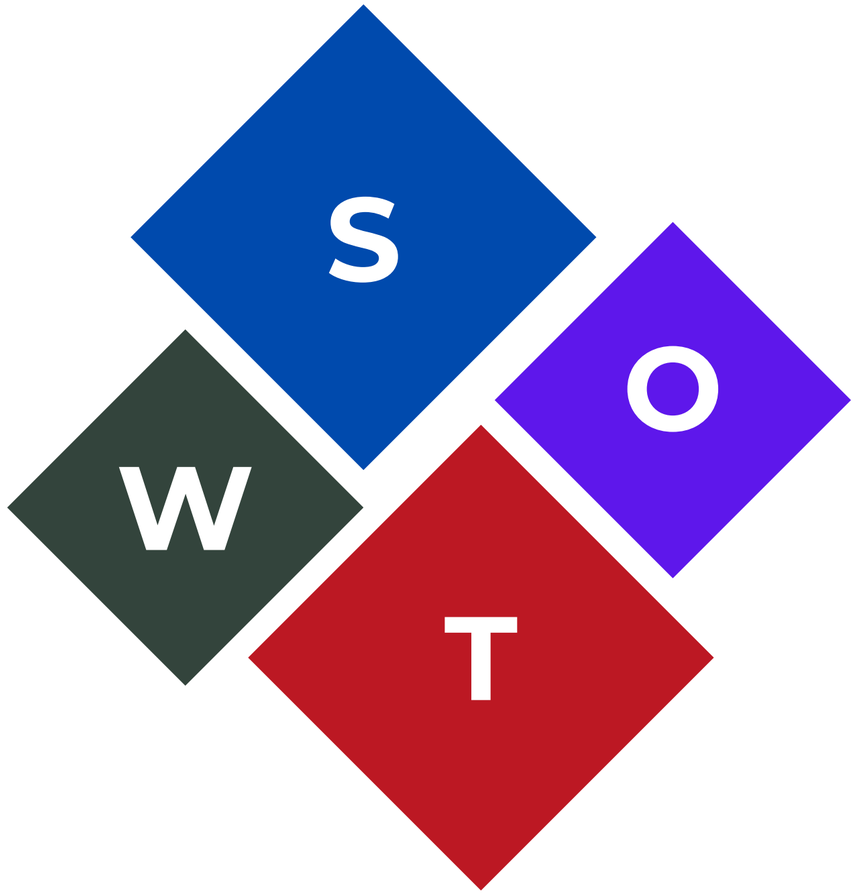
Opportunities

- Emerging need
- Telemedicine
- Link with “Cartella Clinica”

Threats

- Competitors for healthy patients target
- Short-time term

SWOT ANALYSIS: TODAY



Strengths

- Teamwork
- Tools Knowledge
- Creativity
- Problem solving
- Telemedicine

Weaknesses

- Availability of data
- Android studio
- Database
- Lack of time for complete validation

Opportunities

- Build everything inside one app
- Emergin need in the oncological field
- Future developments

Threats

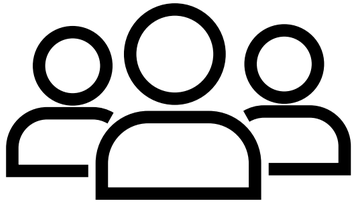
- Competitors
- Cooperations with clinician

FUTURE DEVELOPMENTS

- **Algorithms part:**
  - More subjects and data are required to validate.
  - Analysis on temporal windows that last 24h.
  - Improvement of statistical results.
  - Combine everything in the app.

- **App part:**
  - Implement AI - based feedback.
  - IOT - automating and improving the sleep quality assessment
  - Develop a software available on smartwatches

- **Target:**
  - Deeper focus on each different cancer’s type.
  - Patients with neurological disease.



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- DOI:10.1371/journal.pone.0142533 A Novel, Open Access Method to Assess Sleep Duration Using a Wrist-Worn Accelerometer.
- DOI:10.1038/s41598-018-31266-z Estimating sleep parameters using an accelerometer without sleep diary.
- DOI: 10.1038/s41598-022-11792-7 Detecting sleep outside the clinic using wearable heart rate devices.
- https://www.sleepfoundation.org/how-sleep-works/sleep-latency

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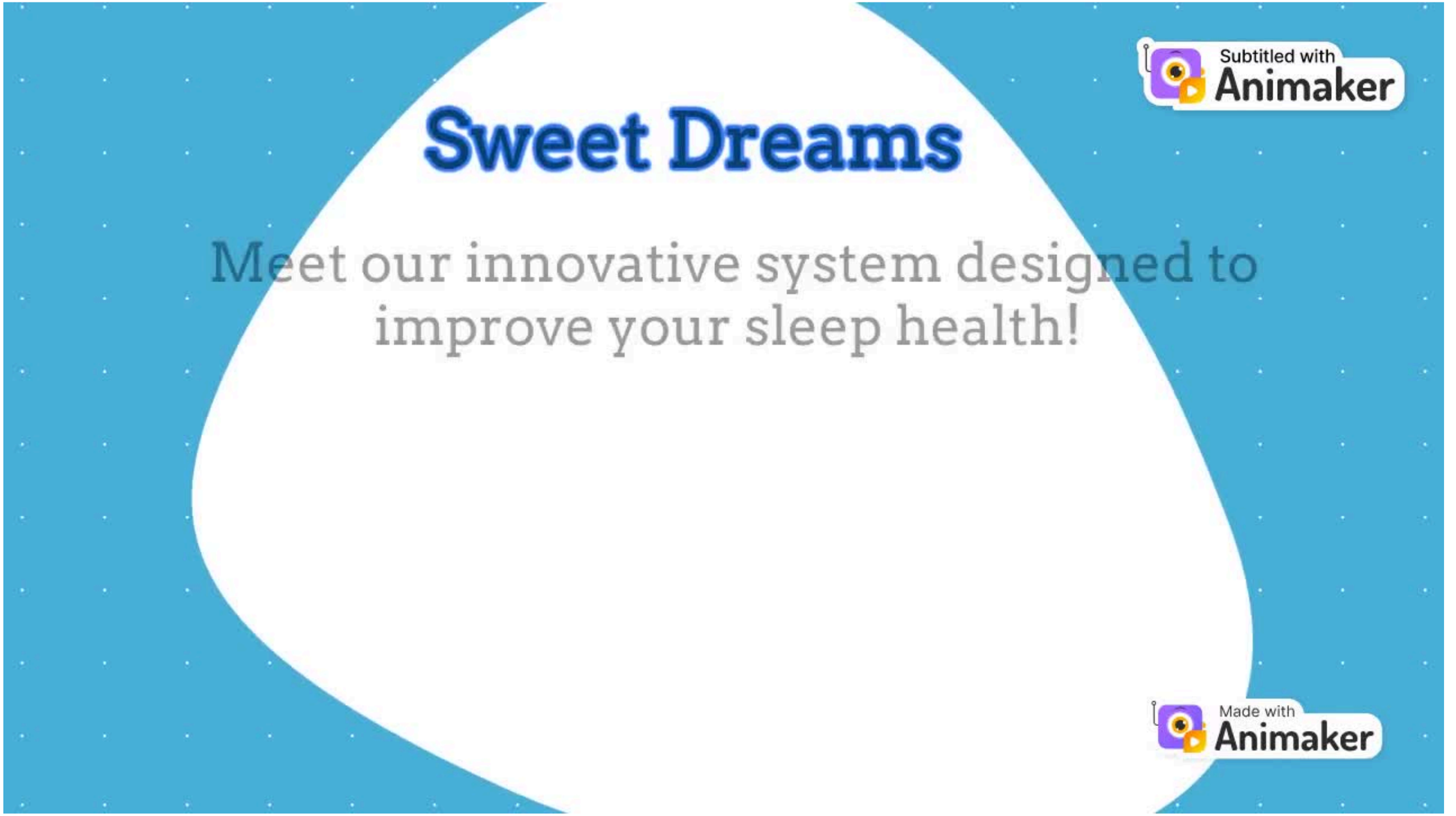
THANKS FOR YOUR ATTENTION

Ageing and rehabilitation engineering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Sweet Dreams
Meet our innovative system designed to improve your sleep health!
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