



# Neurofeedback AI Music (NAIM)

EXPLORE Phase

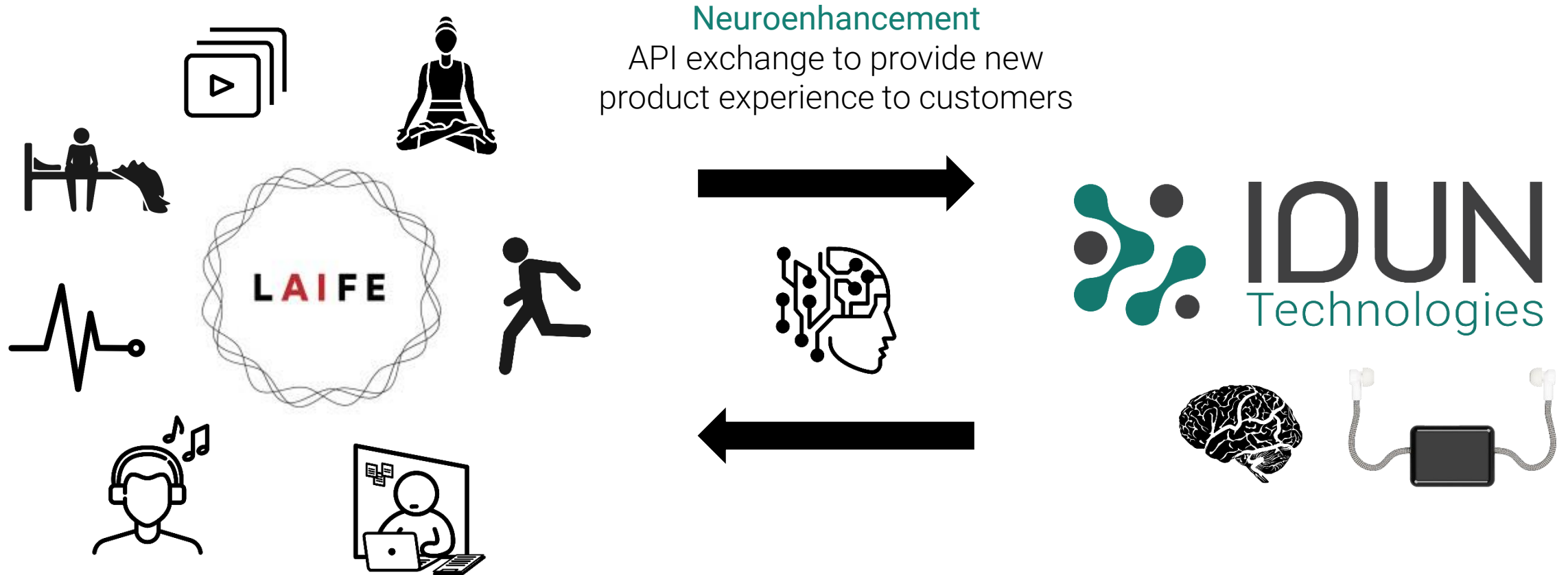
25. Mai 2021

Mark Melnykowycz

mark@iduntechnologies.ch

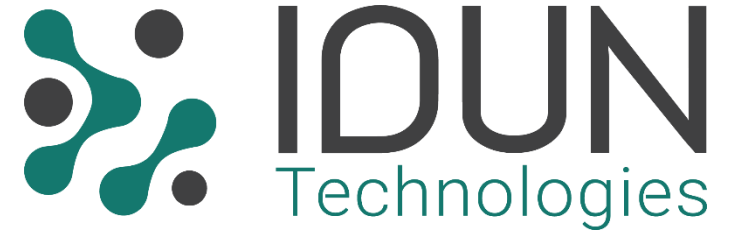
[www.iduntechnologies.ch](http://www.iduntechnologies.ch) | [contact@iduntechnologies.ch](mailto:contact@iduntechnologies.ch) | +41 44 552 05 65

# Neurofeedback AI Music



## Neuroenhancement

API exchange to provide new product experience to customers

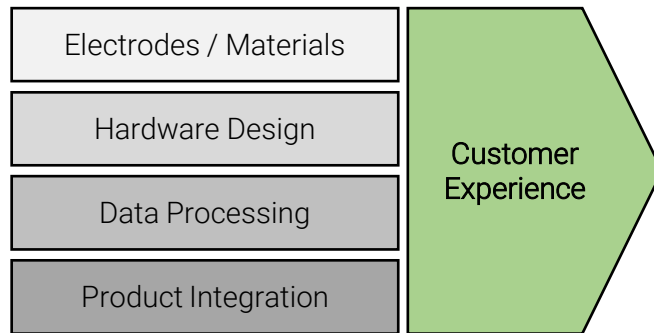


# IDUN - Connecting Emotion to digital life

## Neurofeedback Value Chain

IDUN brings neuroscience into every-day product designs from electrode materials to final product design

Brain Activity



Emotional Score



IDUN API

## Product Integration

IDUN technologies enable products to understand customer emotional needs and provide a happier customer experience



# Neurofeedback AI Music: Project Planning

Neurofeedback AI Music NAIM Project Lead - IDUN Technologies AG		2021								EXPLORE (PHASE 1 – Idea Validation) EXPERIMENT (PHASE 2 – Product realization) EVOLVE (PHASE 3 – Market launch and investment search)
		Reach Incubator Phases								
		EXPLORE		EXPERIMENT			EVOLVE			
Work Package	Description	4	5	6	7	8	9	10	11	Outcomes
<b>WP1</b>	<b>AI Classifier Design</b>									Music classifier design Brain activity classifier integration
Task 1	Music feature model design									
Task 2	Integration to brain activity model									
Task 3	Neurofeedback system design									
<b>WP2</b>	<b>System Development</b>									Refined music and brain models AI music generator Integration with IDUN product platform
Task 1	Neurofeedback system development									
Task 2	Integration with IDUN cloud platform									
Task 3	Collect brain activity data									
Task 4	User testing									
<b>WP3</b>	<b>Launch</b>									Outreach to existing investors Published demo videos and outreach
Task 1	Investor outreach									
Task 2	Video produciton									

April

28.4 - IWC  
Pitch

May

25/26.05  
Datathon

Explore Phase

Foundations

Build

ML Classifiers

Classifier PoC

DL Architecture

System Outline

System Design

Offline Prototype

Product Mockup

Sleep Biomarkers

Sleep Data Collection

Data Analysis

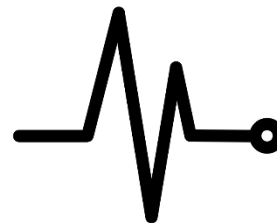
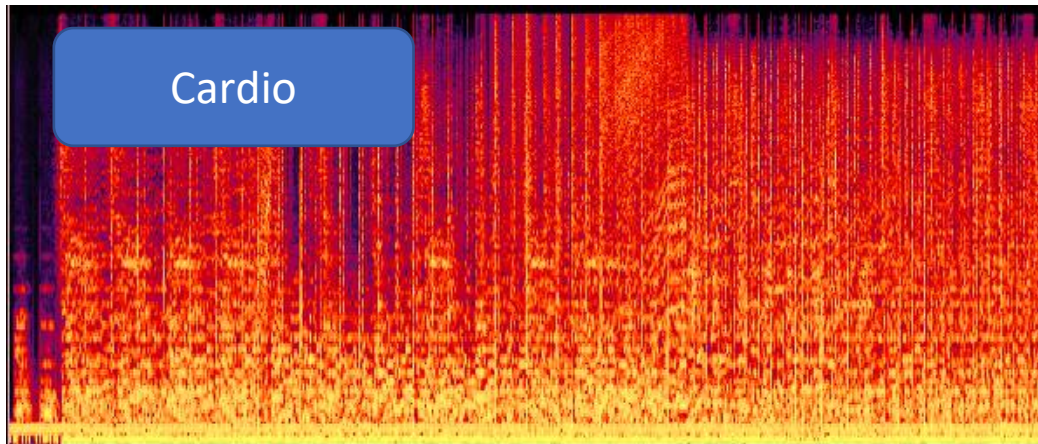
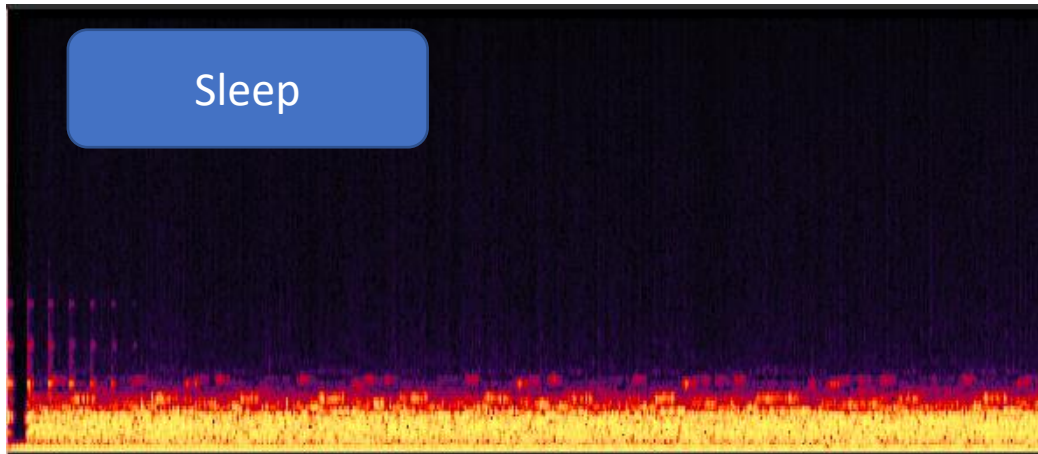
Sleep Journey

Sleep Market Story

Data Value Chain

Pitch Design

# LAIFE Music Types



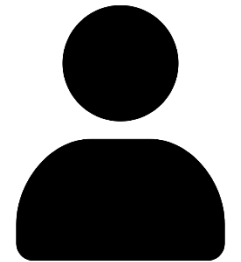
## Neurofeedback System

How can we move from singular music pieces that generalize over the population to unique pieces for individual users?

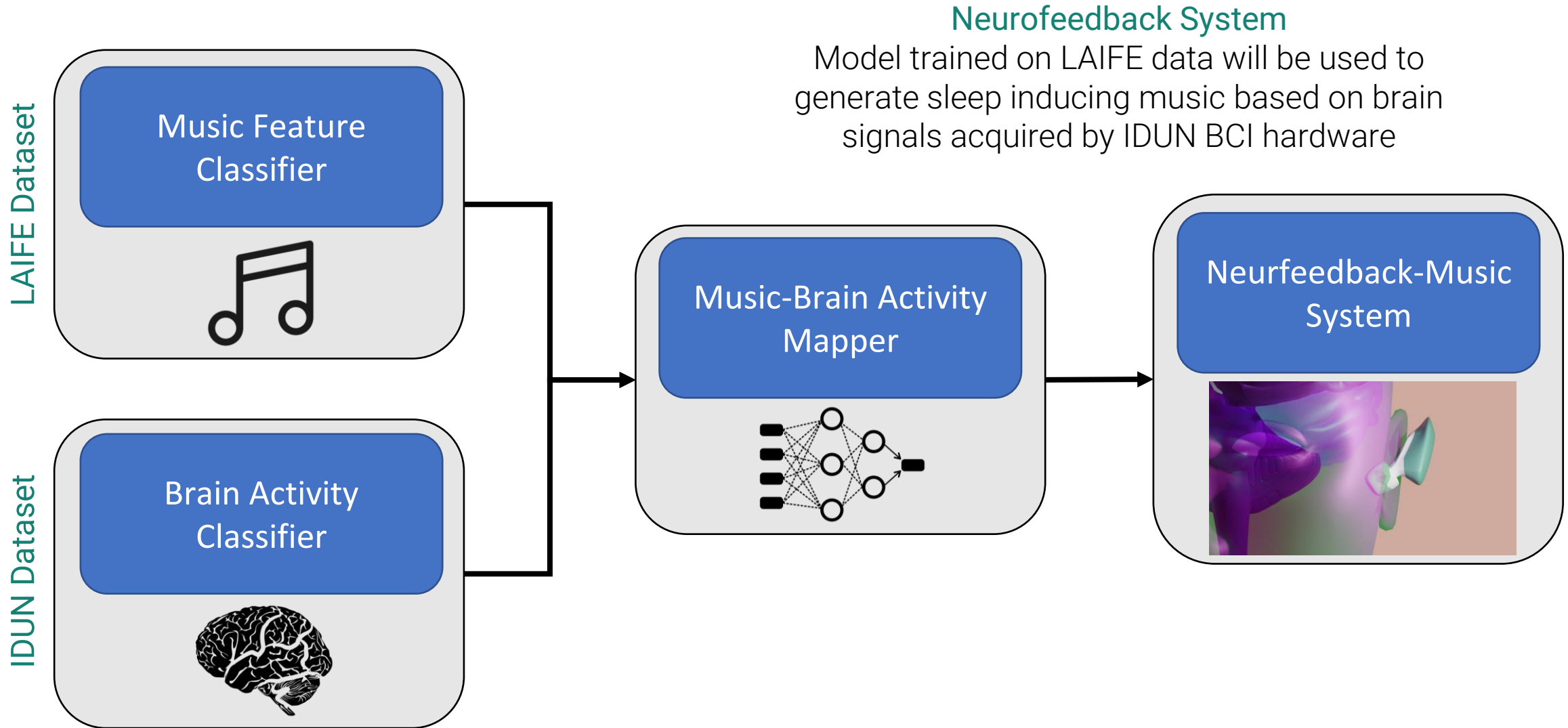
Data Features

Meta-data

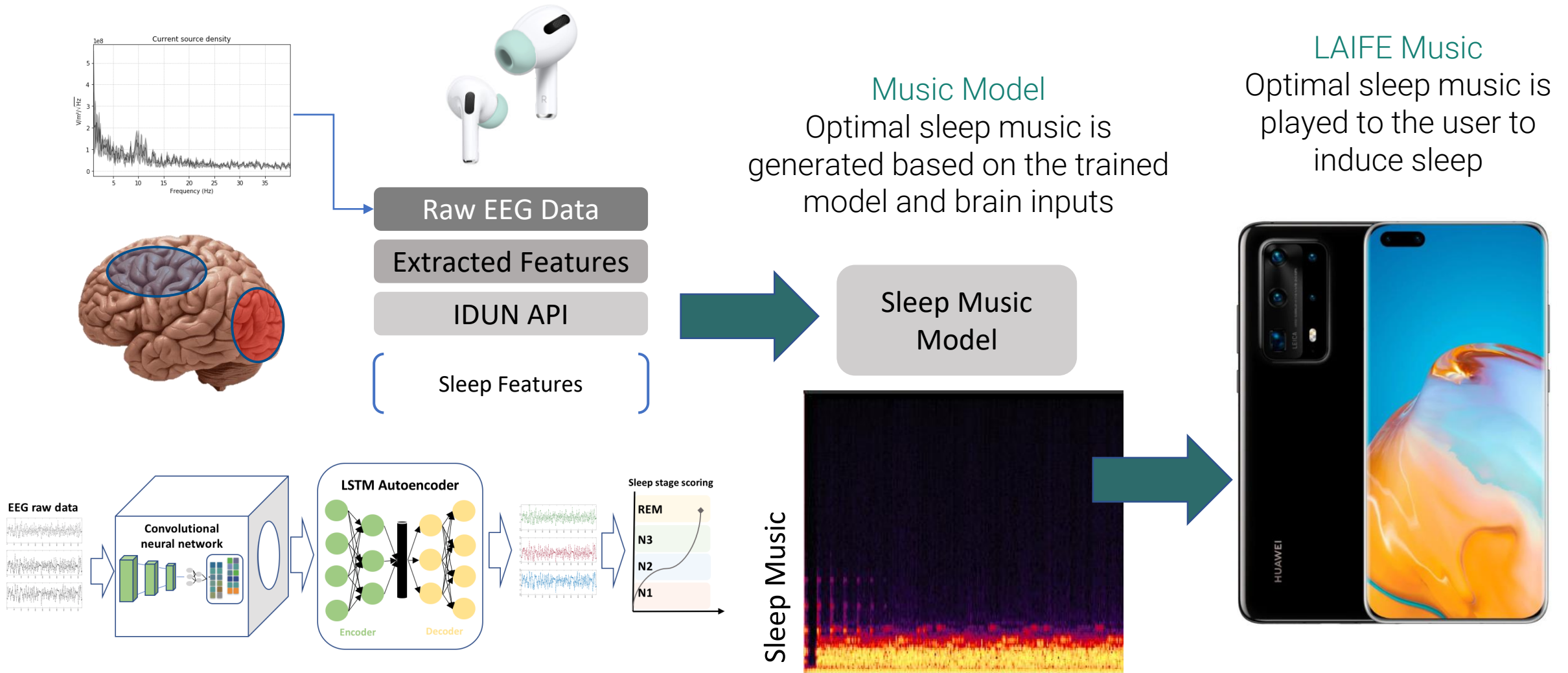
Personalization



# Architecture Overview: Raw data to features



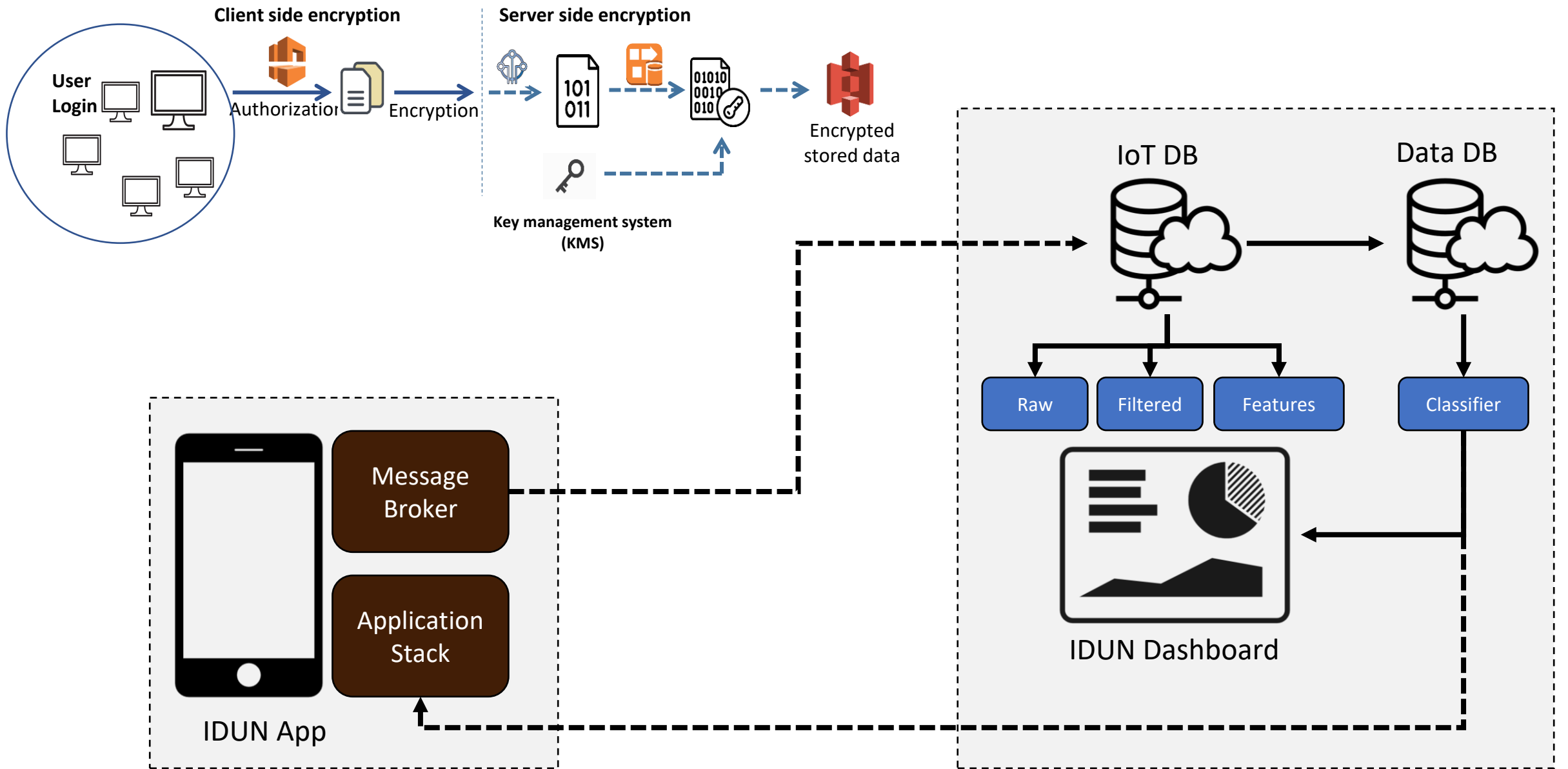
# Neurofeedback Music – Sleep Journey Enhancement





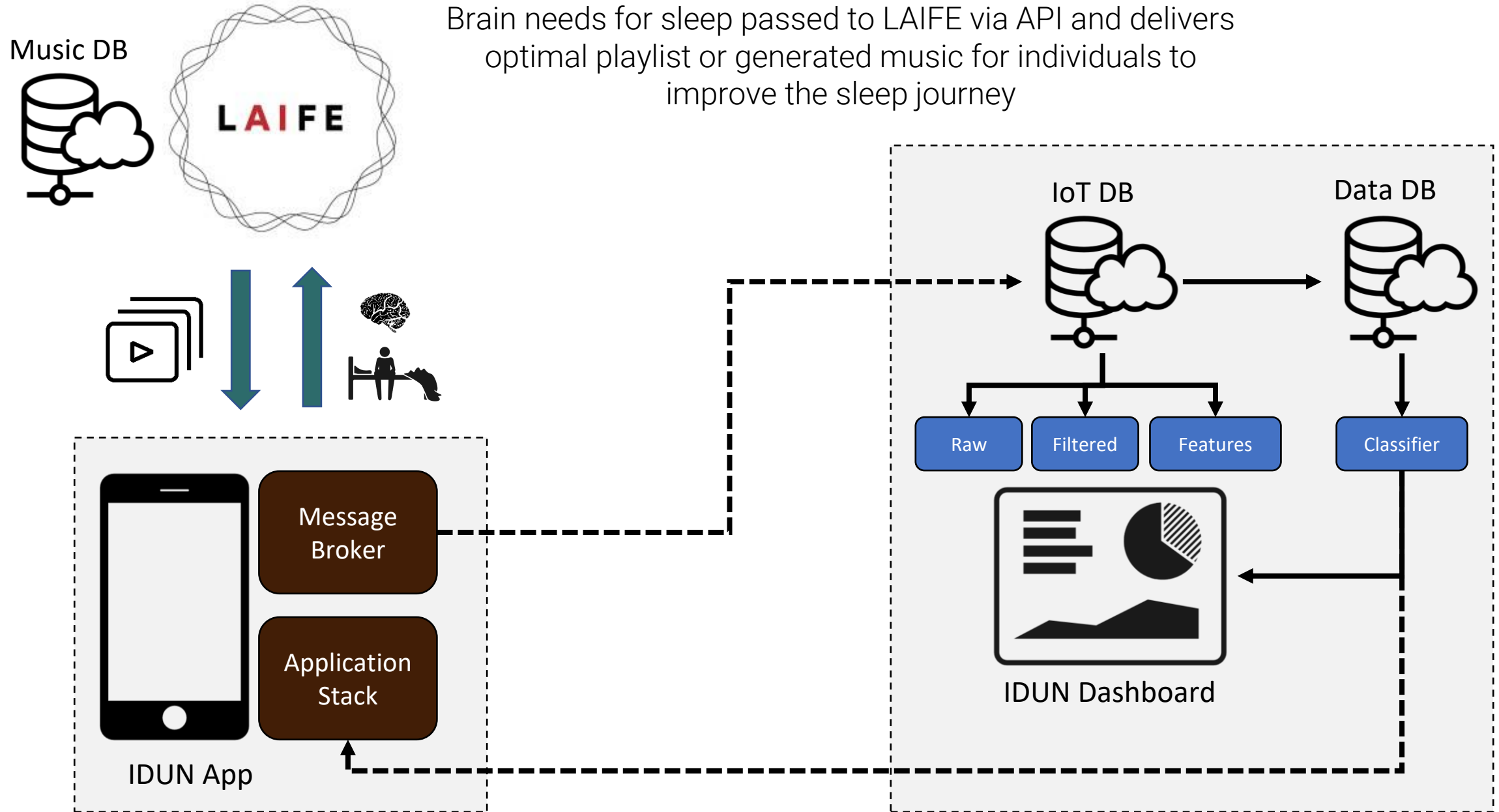
# Neurofeedback AI Music: Mobile Experience





## Application Architecture

Brain needs for sleep passed to LAIFE via API and delivers optimal playlist or generated music for individuals to improve the sleep journey



# Real-time IoT Dashboard Device Data



☰ IDUN Dashboard SIGN OUT

### Review

Using the dropdown menu below, please select the data recorded in the Research page that you would like to review or download.

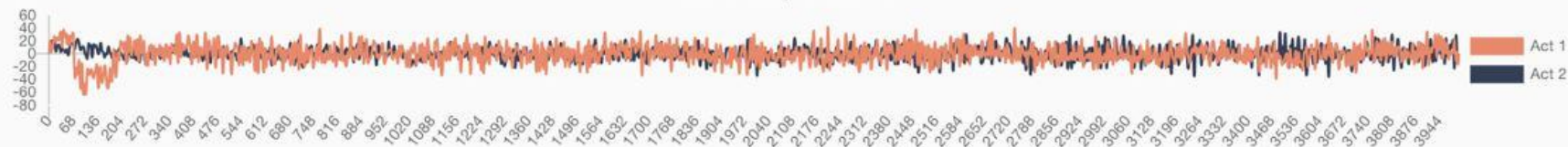
28b1e9c9-0850-410b-9460-af457cc0e270  
▼

dgs-00001

REFRESH DROPDOWN LIST

The raw data presented below is the data recorded over the entire experiment. This data needs to undergo considerable preprocessing before metrics should be calculated. Seeing spontaneous and large spikes in the data is completely normal, however if you see many large spikes in the data exceeding a range of 200 microVolts then it is recommended to disregard the data and to instead clean both your ears and the earpieces and to record another session.

#### Raw Data, Channel 1



DOWNLOAD RAW DATA

#### PSD Data, Channel 1

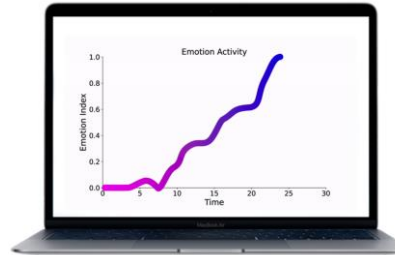


DOWNLOAD PROCESSED PSD DATA

# Webapp Feature Release Roadmap

## Recording Dashboard

- Visualization of raw EEG data stream
- Time and frequency domain
- Channel settings



## Emotion activity index

- Recording of brain response over time
- e.g. during visual or auditory input
- Export reports



## Emotional score

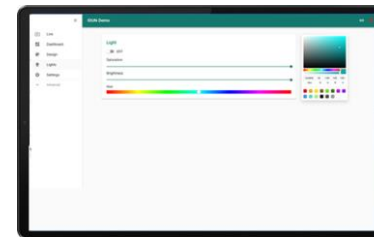
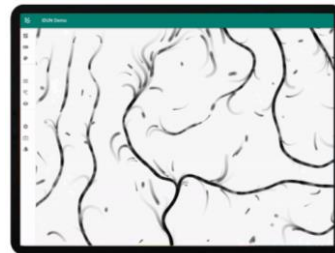
- Personalized emotional scores for immersive app experiences
- Third-party access to through IDUN API

EXPLORE

EXPERIMENT

## Neurofeedback

- Generative design to conceptualize brain states
  - Can be used for neurofeedback training



## BCI applications

- Controlling smart devices
- IoT interface

# Data protection regulation (EU)



## GDPR compliance

### Responsibilities (Shared by Controller and Processor):

- Pseudonymisation and encryption of personal data
- Ability to restore and access personal data
- Ensure confidentiality, integrity, resilience of processing systems and services
- Establish processes for continuous testing and evaluation of technical and organisational measures



**Controller**

Platform, Application, IAM

OS, Network, Firewall configuration

Client/Server side encryption

Network traffic protection



**Processor**

Networking

Storage

Compute

Database

# Sleep Journey Characterization

Going to Bed

Falling Asleep

Sleeping

...

Sleep Latency

Sleep Staging

Waking Up

sleep outcome

mediating States

Biomarkers

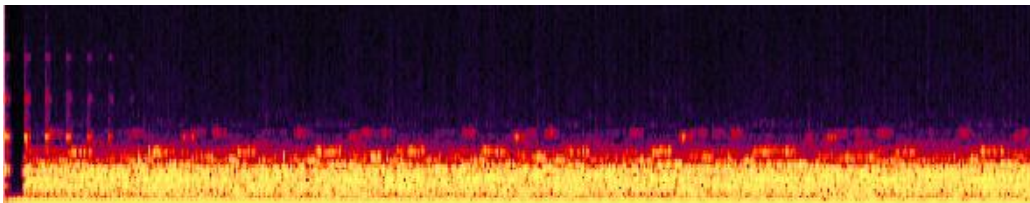


State of relaxation, stress, maybe goes beyond EEG:  
Heart rate, breathing

Sleep cycles between light and deep sleep during the night

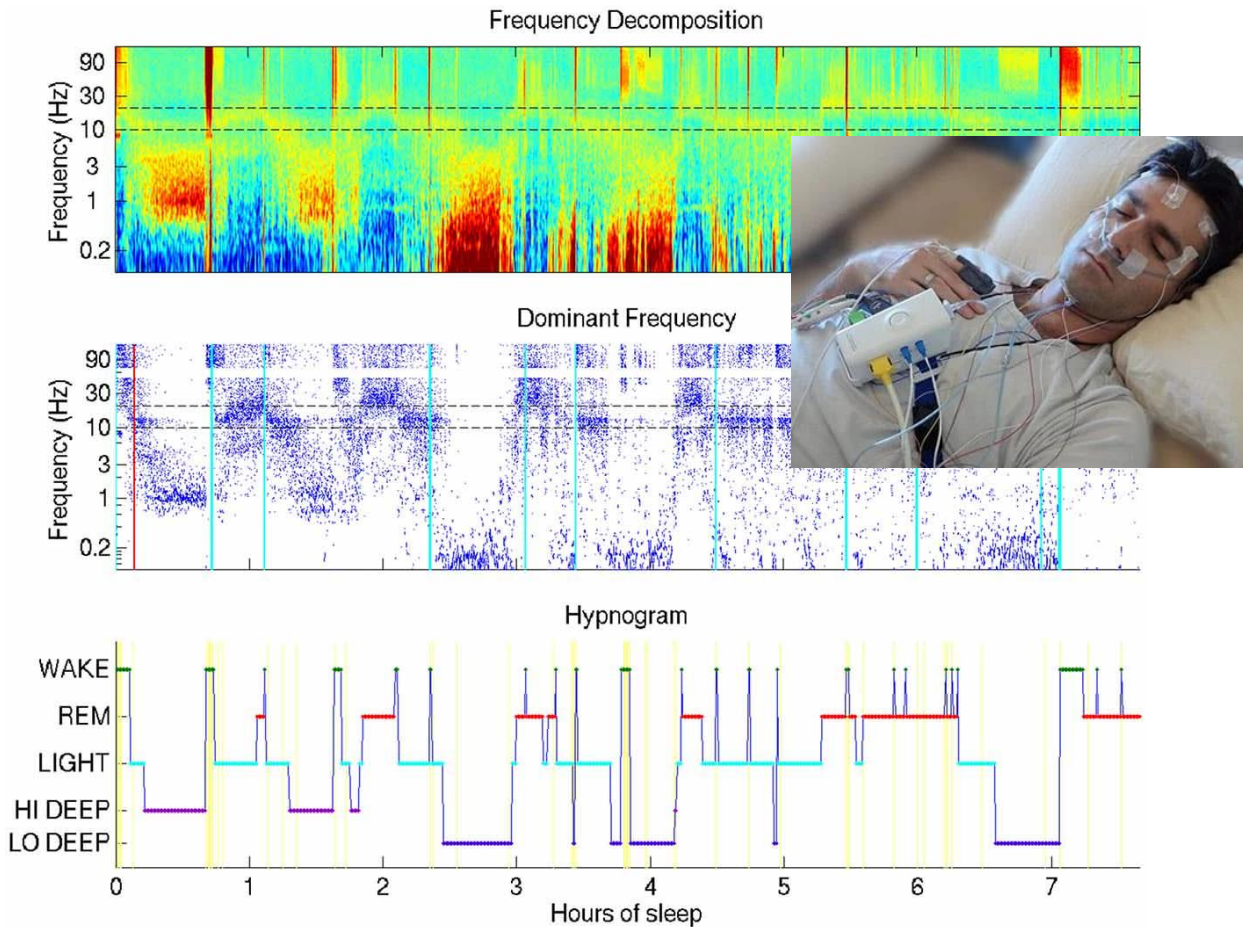
Waking up at the right time in the sleep cycle

Wakefulness (lights out):	Alpha activity	REM	eye movements
		N1	Theta activity (or Sleep Spindles and K-complex together with "Arousal" HR increase)
Falling asleep	one of the sleep stages	N2	Sleep Spindles and K-complex
		N3	Slow wave sleep, Delta Waves >80%





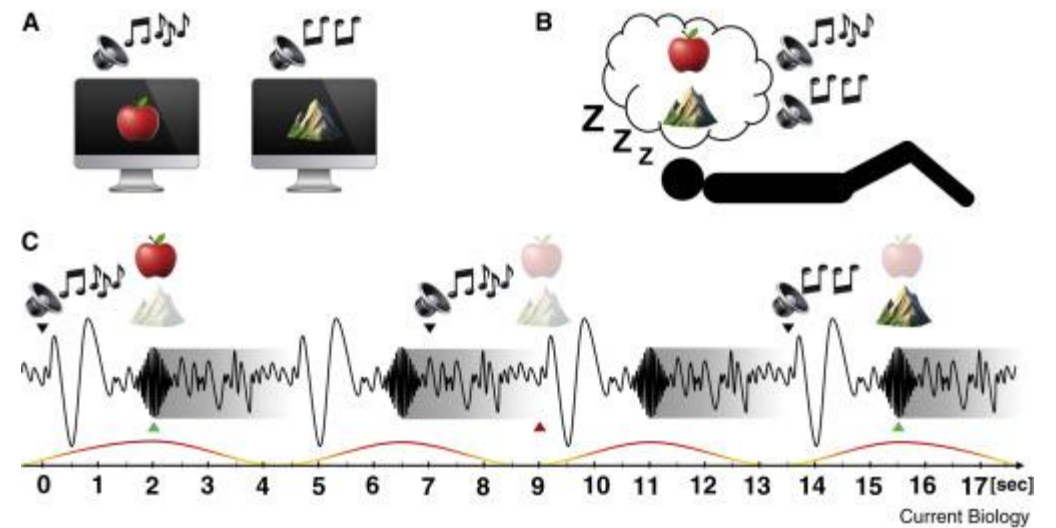
# Brain Activity and Sleep



Visualization of Whole-Night Sleep EEG From 2-Channel Mobile Recording Device Reveals Distinct Deep Sleep Stages with Differential Electrodermal Activity  
<https://www.frontiersin.org/articles/10.3389/fnhum.2016.00605/full>

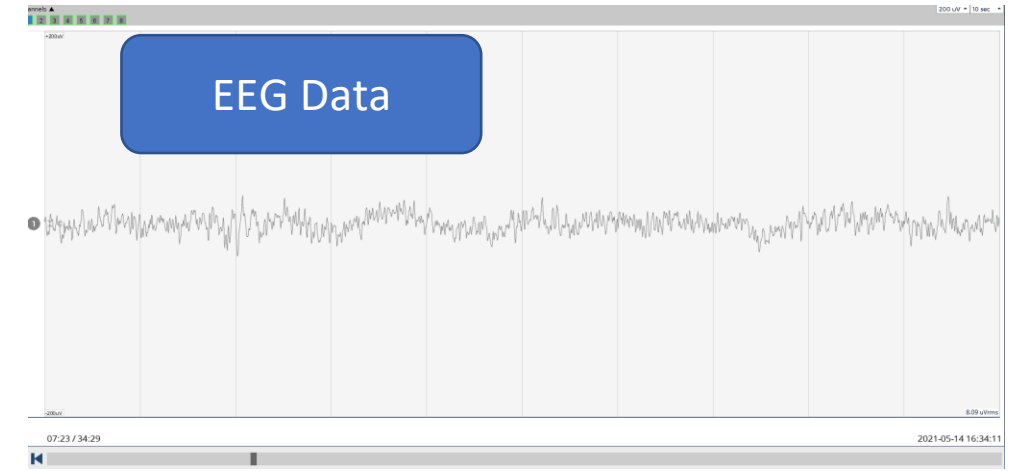
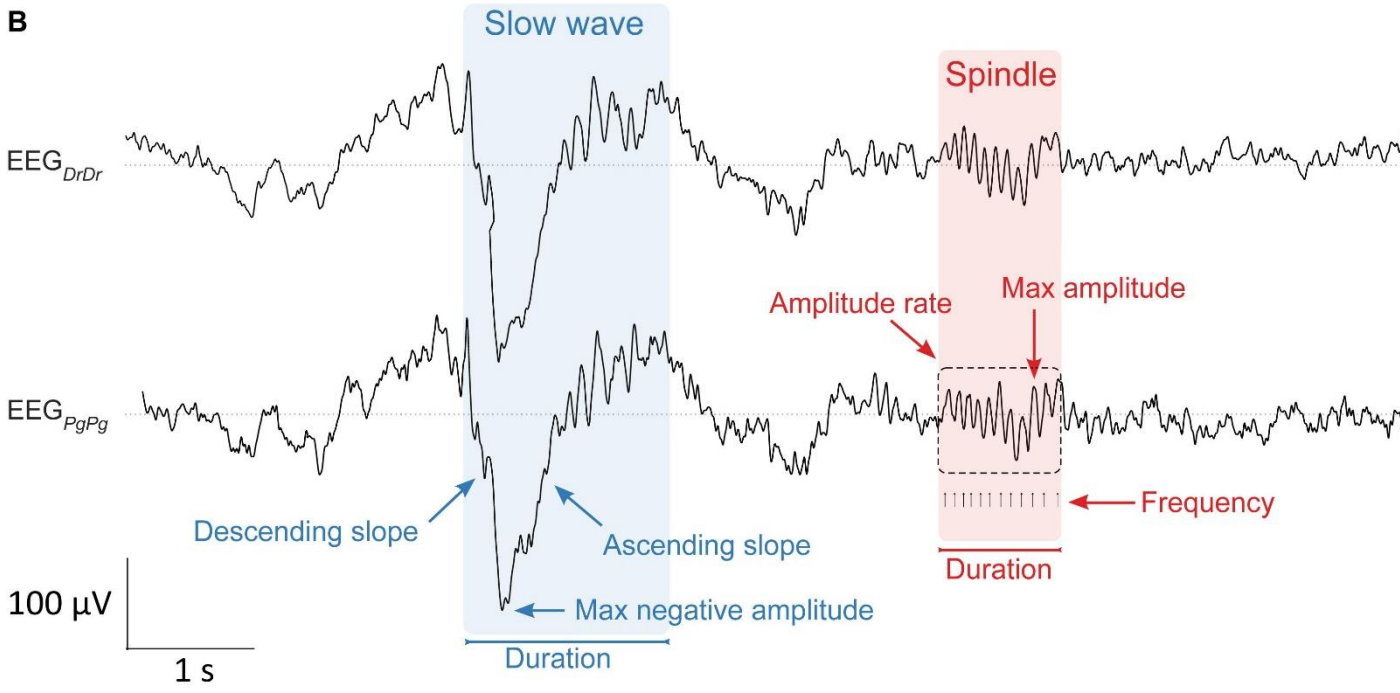
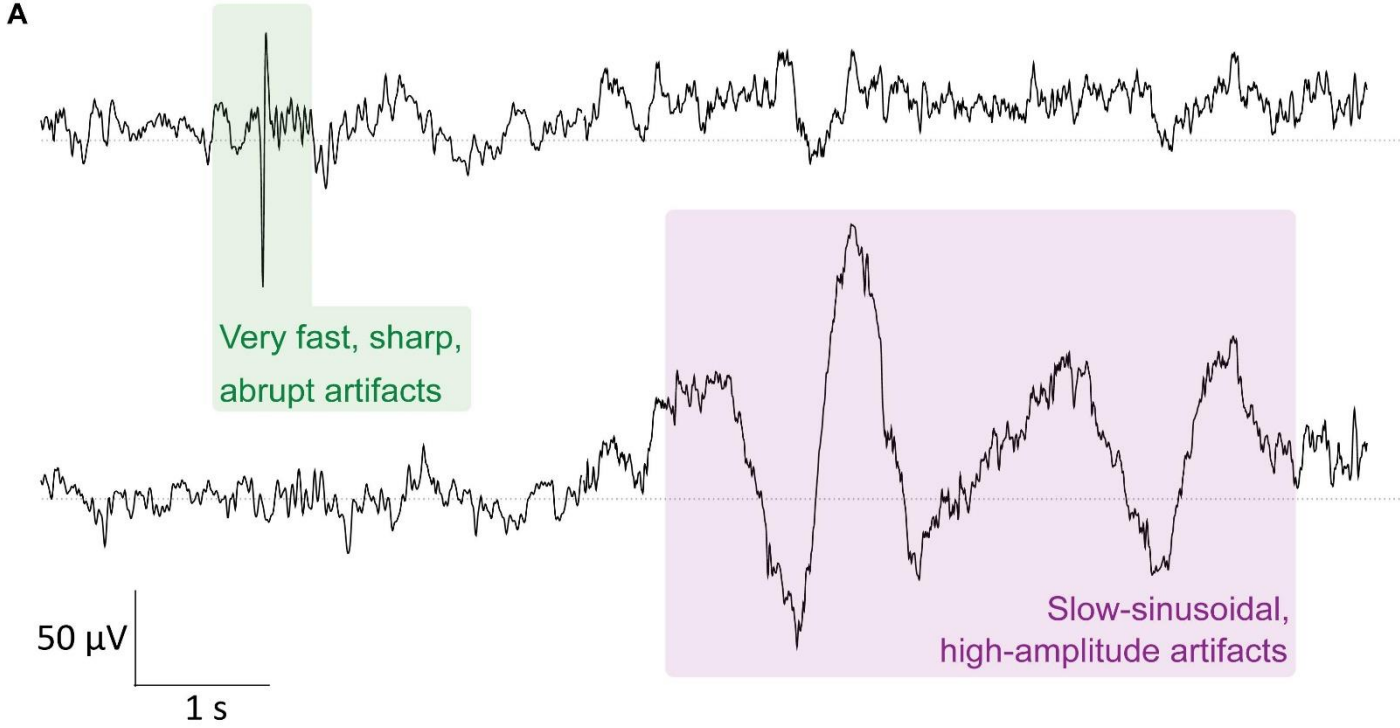
## Neurofeedback System

Goal is to use music stimulation to improve the sleep journey and personalize LAIFE music to individual users using mobile EEG system, bringing neuroenhancement to LAIFE dataset



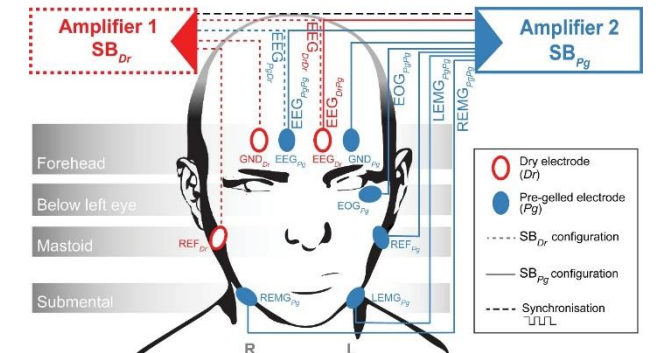
<https://www.sciencedirect.com/science/article/pii/S0960982218303750>





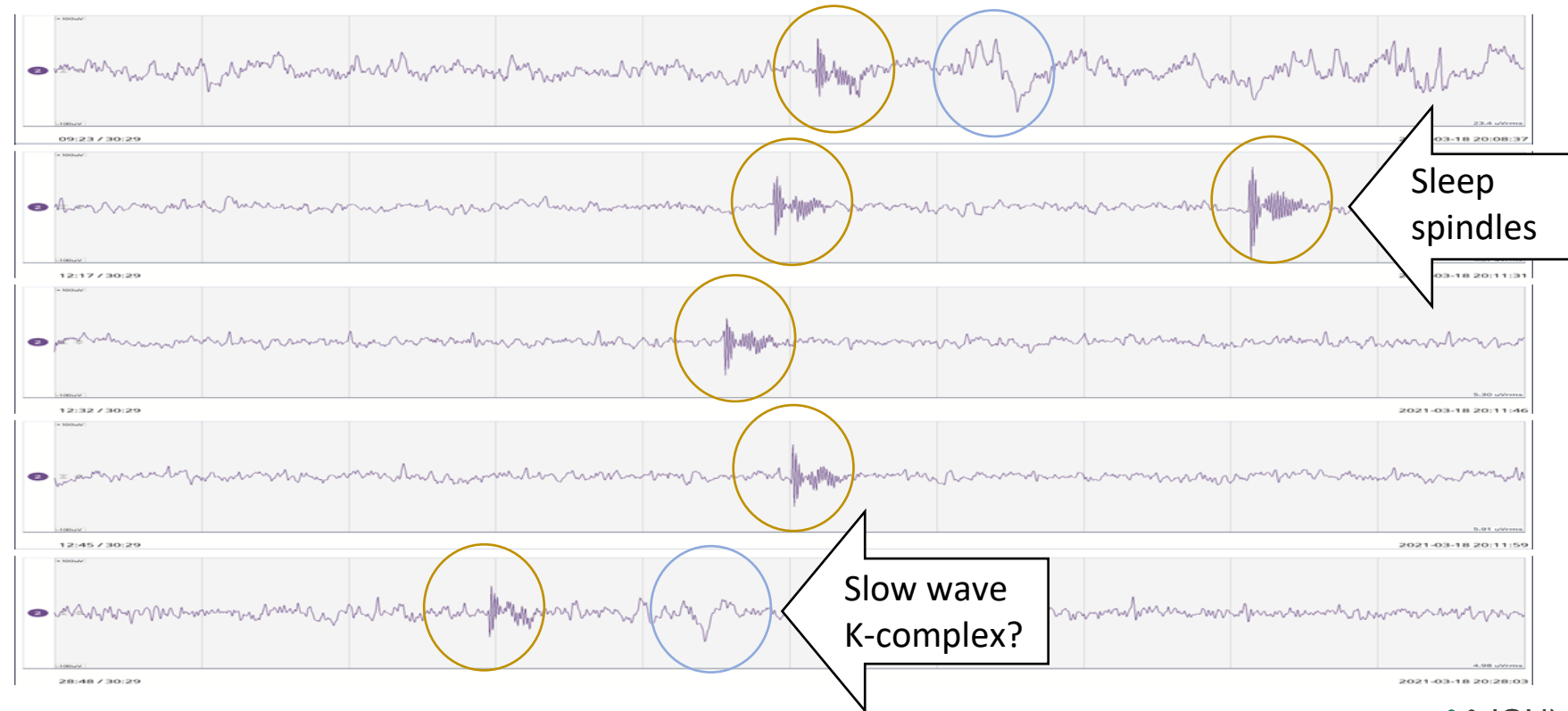
## A Protocol for Comparing Dry and Wet EEG Electrodes During Sleep

[Frontiers | A Protocol for Comparing Dry and Wet EEG Electrodes During Sleep | Neuroscience \(frontiersin.org\)](https://www.frontiersin.org/journal/10.3389/fnins.2021.681111)



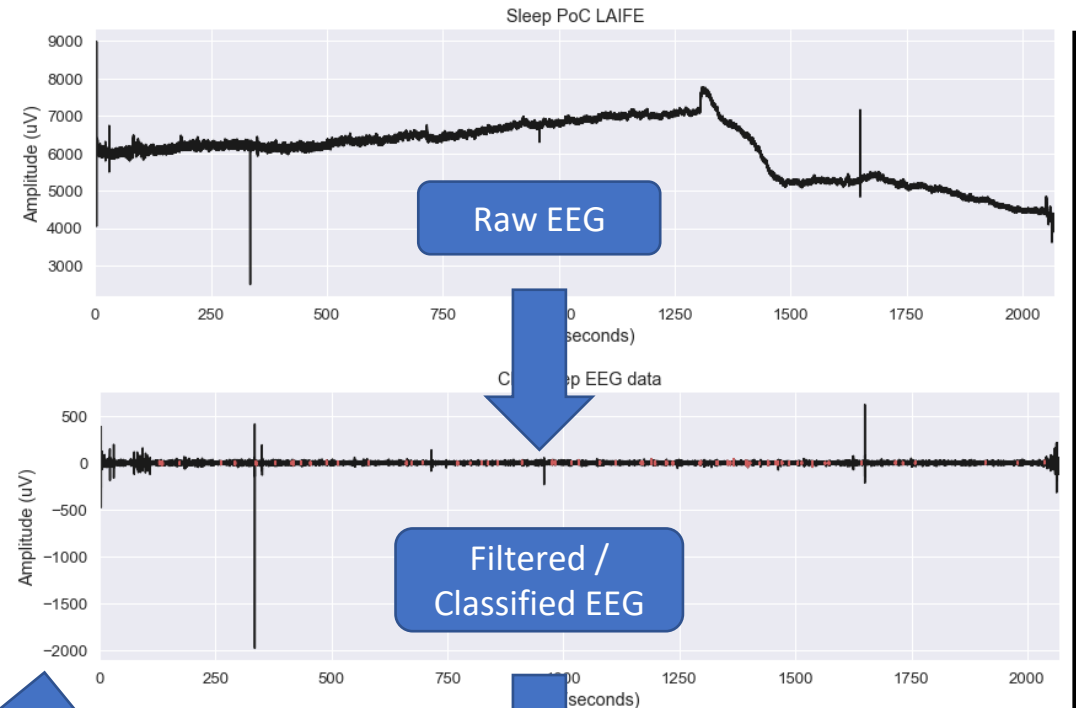
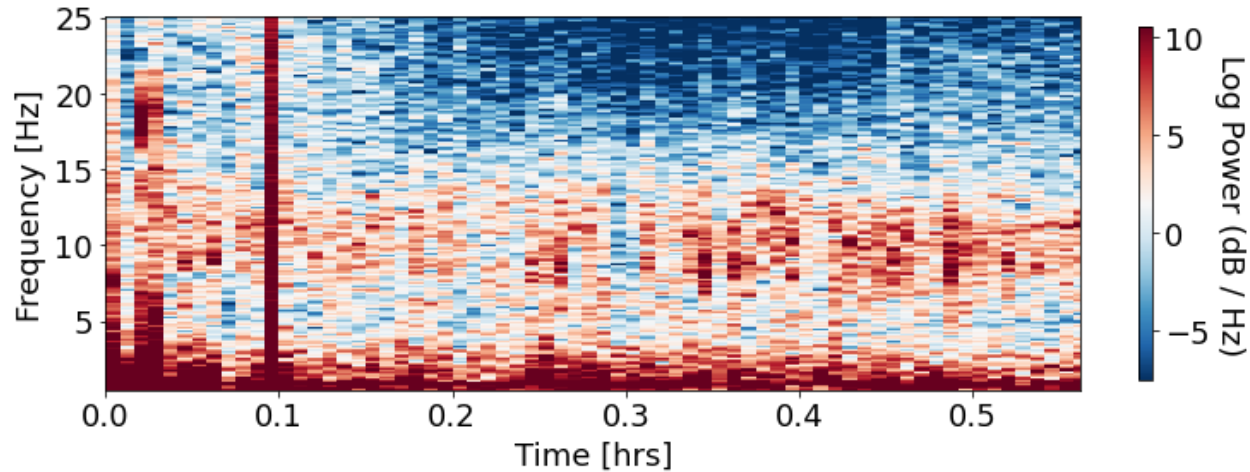
# Sleep Test – Foam/Stratex Electrodes

- Sleep recording confirmed sensitivity of our hardware for typical sleep microstructures with 30 min recording



# Brain Activity – Data Processing and Feature Extraction

- Ear EEG data is processed to remove environmental interference, then sleep features are extracted using the *A7 Detector* algorithm\*.
- Spectrogram translates data into frequency-time and intensity domain, to visualize the sleep features and compare alongside features from LAIFE data.



	Start	Peak	End	Duration	Amplitude	RMS	Ab	RelPower	Frequency	Oscillations	Symmetry	Channel	IdxChannel
0	128.868	129.188	129.440	0.572	39.796798	9.360757	1.0	0.245101	12.823158	7.0	0.555556	CHAN000	0
1	134.036	134.196	134.544	0.508	44.106229	9.670616	1.0	0.327318	12.828887	7.0	0.312500	CHAN000	0
2	135.948	136.276	136.580	0.632	34.827190	7.783869	1.60	0.325470	12.986701	8.0	0.515723	CHAN000	0
3	172.248	172.668	172.880	0.632	29.087631	6.285302	1.374752	0.248352	13.833794	8.0	0.660377	CHAN000	0
4	261.660	261.880	262.604	0.944	36.23					11.0	0.232088	CHAN000	0
...	...	...	...	...	...					...	...	...	...
63	1731.308	1731.644	1732.096	0.788	33.33					9.0	0.424242	CHAN000	0
64	1757.984	1758.472	1759.044	1.060	26.56					13.0	0.458647	CHAN000	0
65	1909.404	1909.976	1910.128	0.724	31.418039	6.371793	1.570315	0.313030	13.169620	7.0	0.785714	CHAN000	0
66	1978.664	1979.020	1979.700	1.036	23.517294	4.622139	1.425561	0.341893	13.169737	12.0	0.342308	CHAN000	0
67	2037.084	2037.200	2037.600	0.516	40.027803	7.319685	1.654093	0.290683	12.619006	7.0	0.223077	CHAN000	0

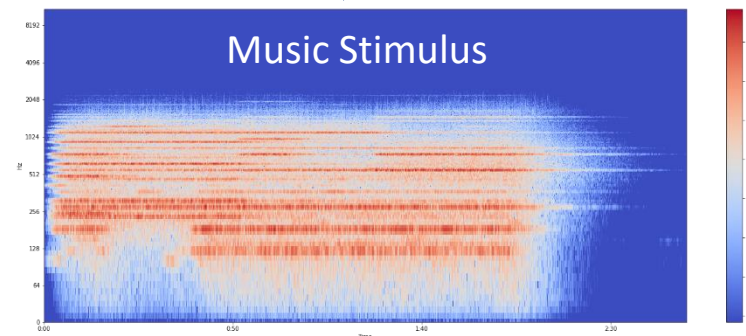
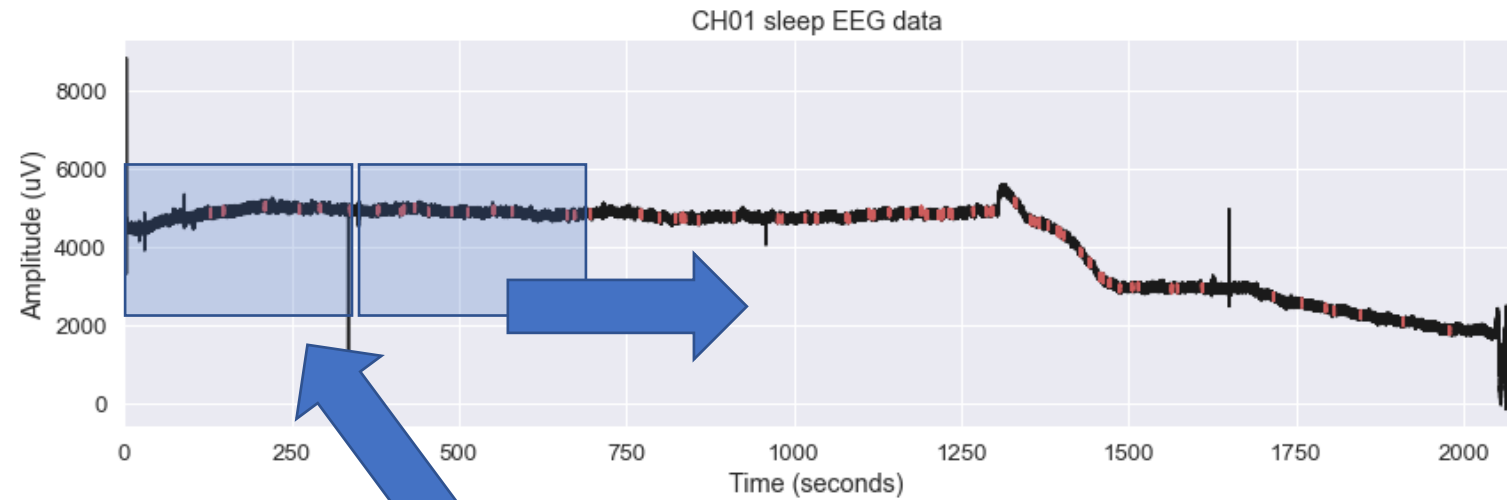
68 rows x 13 columns

\*A sleep spindle detection algorithm that emulates human expert spindle scoring

<https://doi.org/10.1016/j.jneumeth.2018.08.014>

# Sleep Test – Guardian Electrodes

- Ear EEG recorded over 30 min session
- LAIFE music played during the entire session, 250 sec loop
- Subject experienced sleep onset in conjunction with music features



- Music stimulation used to influence the sleep journey

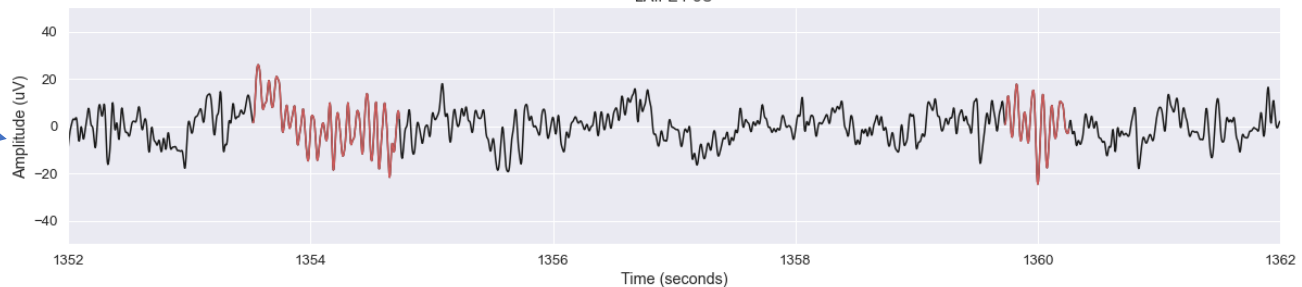
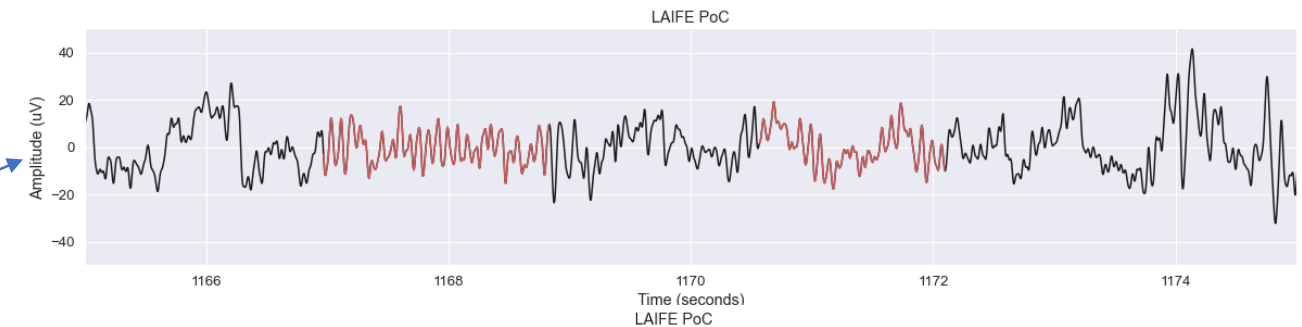
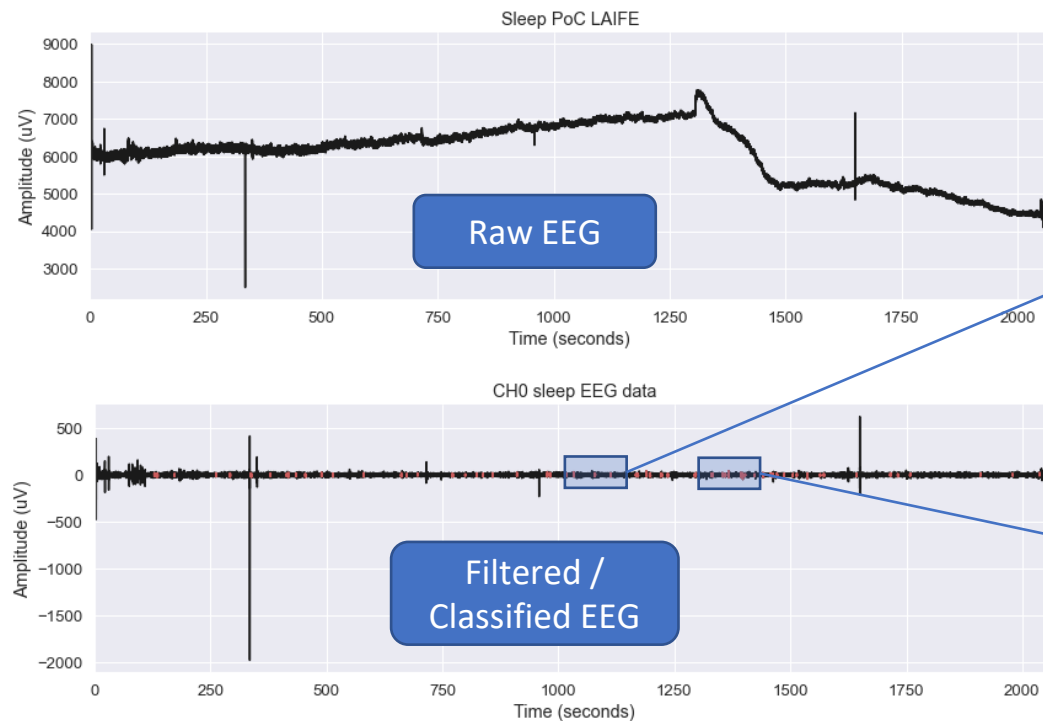


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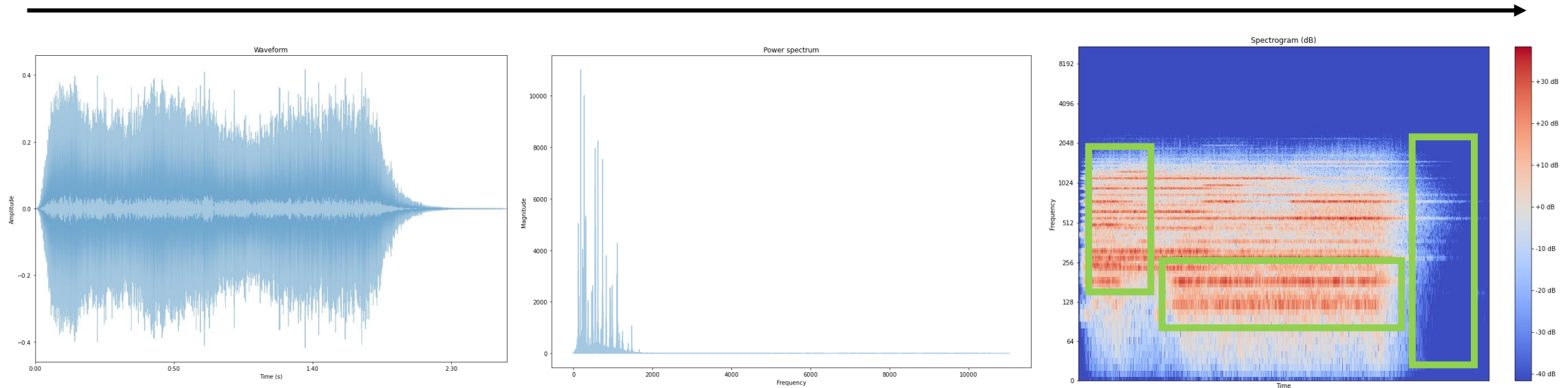
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...	...	...	...	...	...	...	...	...	...	...	...	...	...
63	1731.308	1731.644	1732.096	0.788	33.339855	6.687679	1.407654	0.230038	13.029521	9.0	0.424242	CHAN000	0
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68 rows x 13 columns

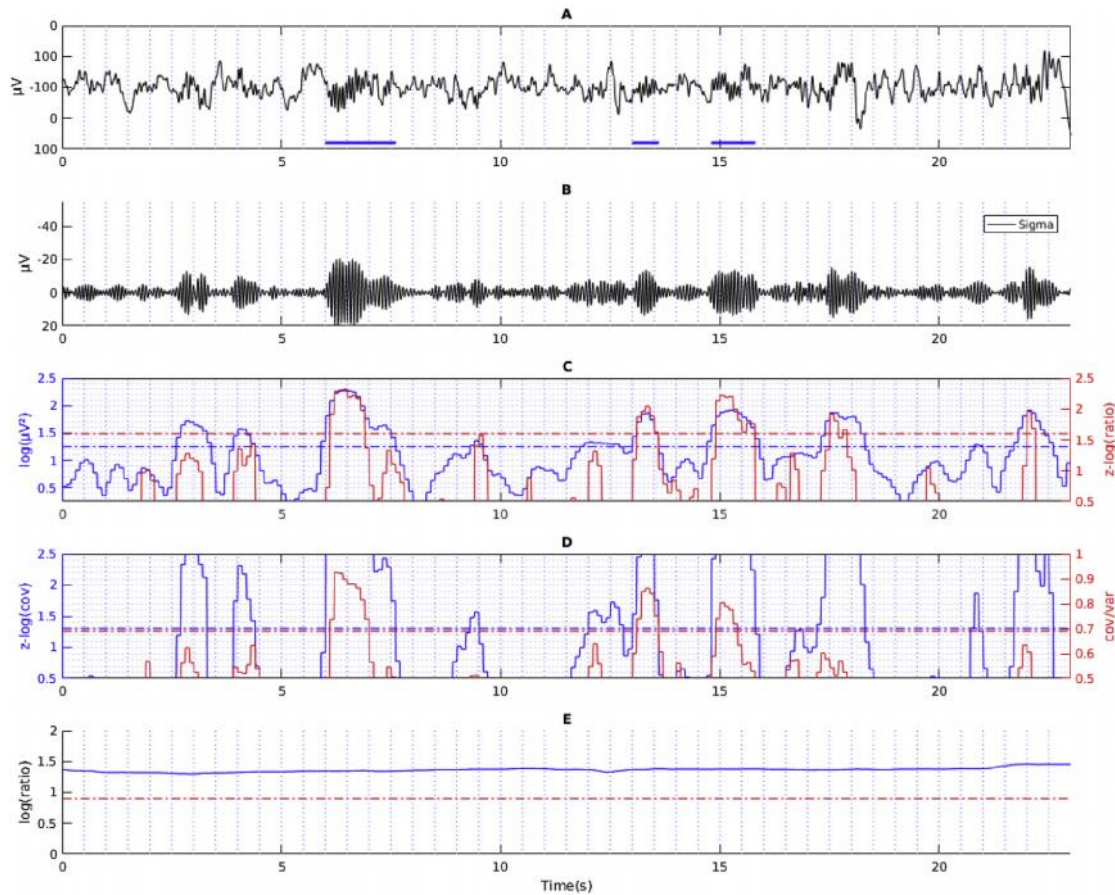


# LAIFE Data – Feature Processing

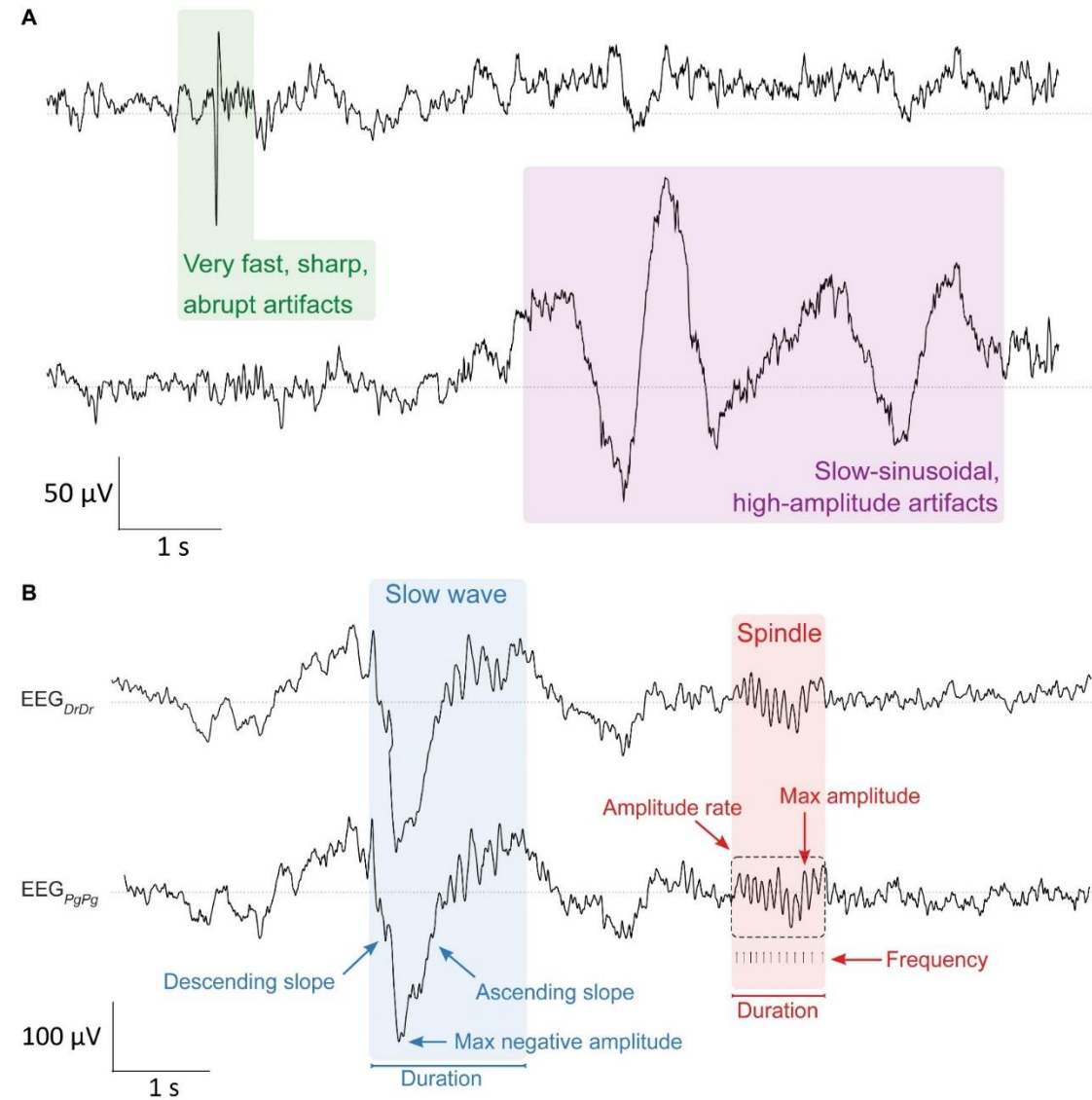
- Raw audio waveform decomposed into power spectrum and spectrogram to visualize features needed for training pipeline.
- Lower frequencies act as sleep inducing stimuli for the brain and form the basis for neurofeedback stimulation pipeline.



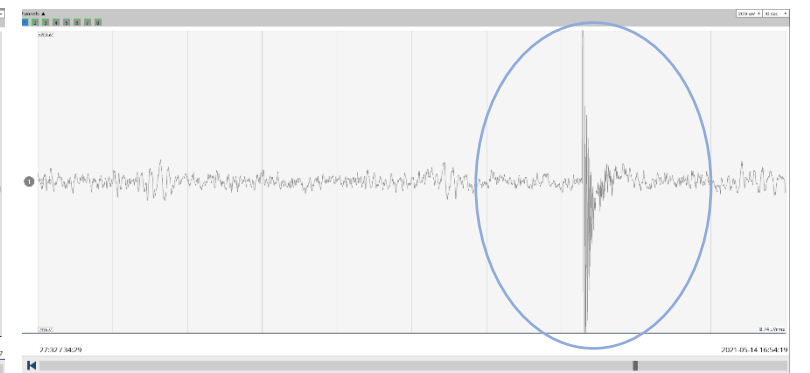
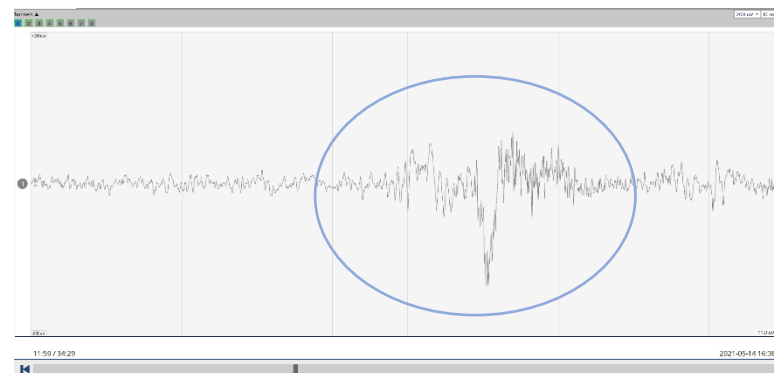
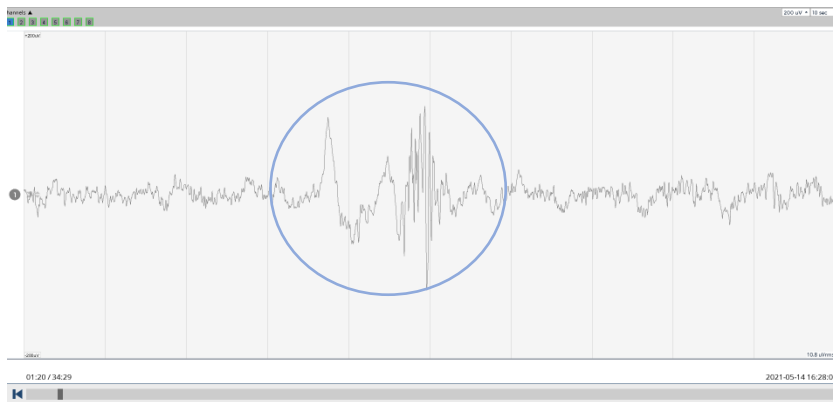
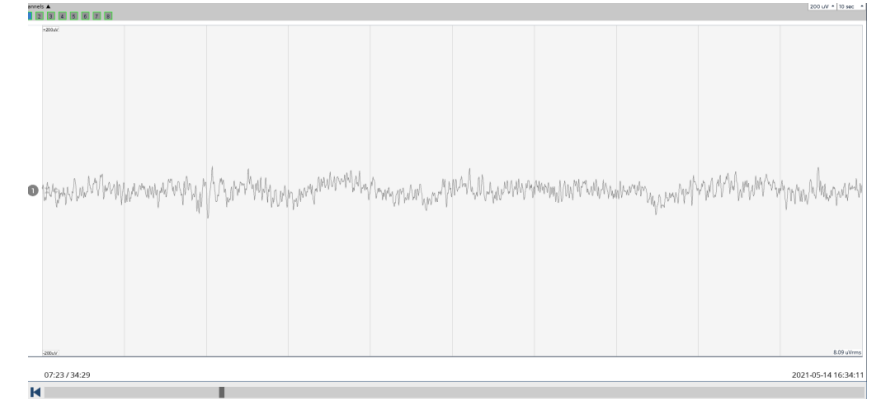
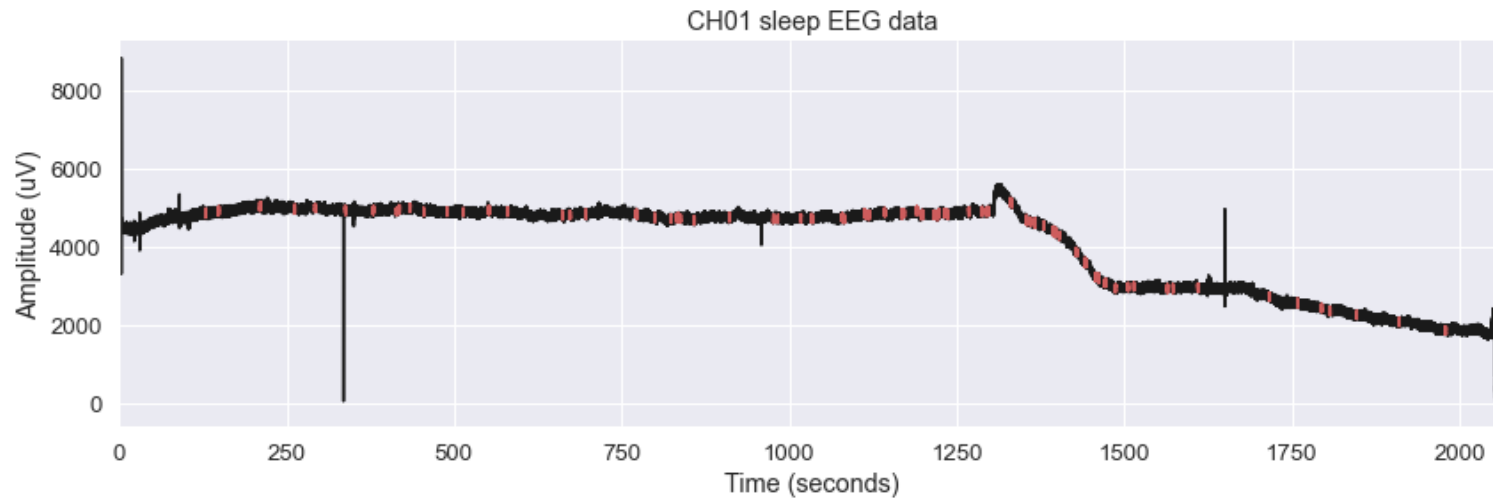
# Sleep Spindle Extraction



**Fig. 1.** The four A7 parameters: “A7absSigPow, A7relSigPow, A7sigmaCov and A7sigmaCorr” extracted from 25 s of EEG signal band-pass filtered 0.3–30 Hz (*EEGbf*). (A) *EEGbf* with three detected spindles marked in blue; (B) *EEGbf* band-pass filtered in the sigma band 11–16 Hz (black); (C) A7absSigPow in blue and A7relSigPow in red with their respective thresholds in dash lines; (D) A7sigmaCov in blue and A7sigmaCorr in red with their respective thresholds in dash lines. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).



# Sleep Spindles – Extraction From Brain Activity





# Music Classifier Raw data to brain features

## Music Mapping Model

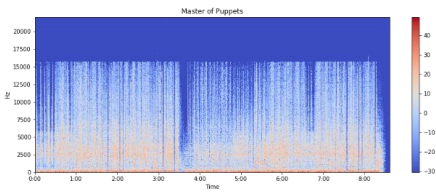
Different approaches will be tested to best characterize LAIFE music inputs

## Brain Mapping Model

IDUN brain feature classification model used to process brain signals

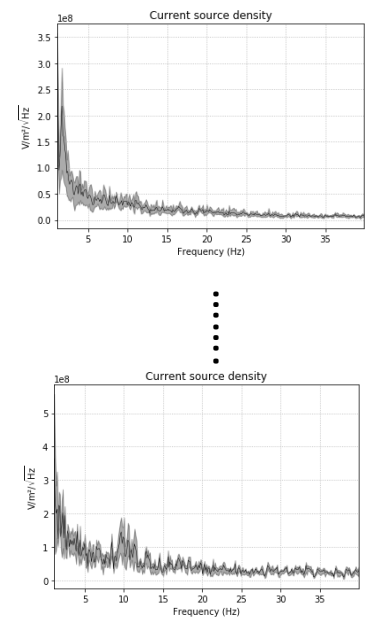
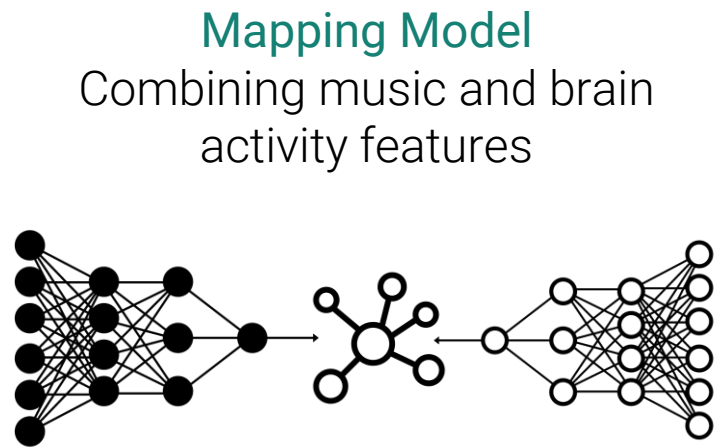
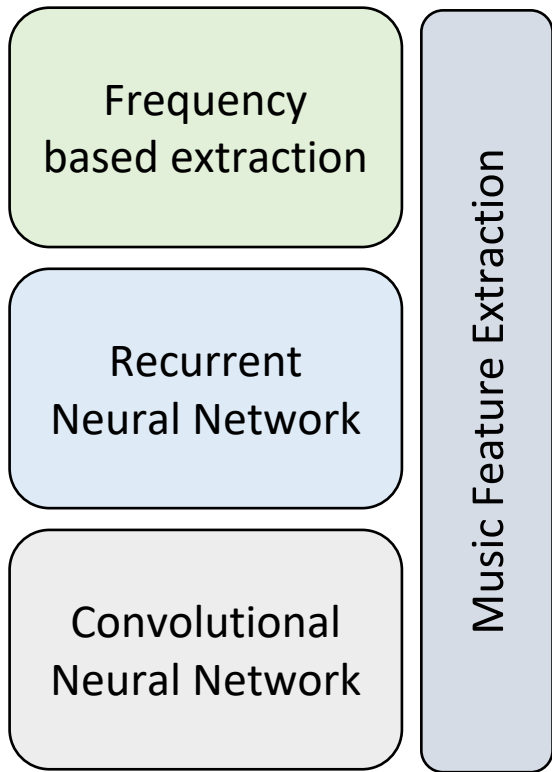
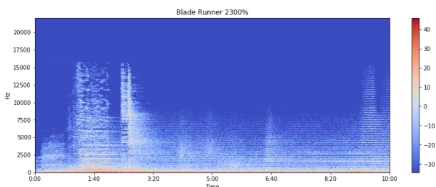
Music Types

### High Energy Music



.....

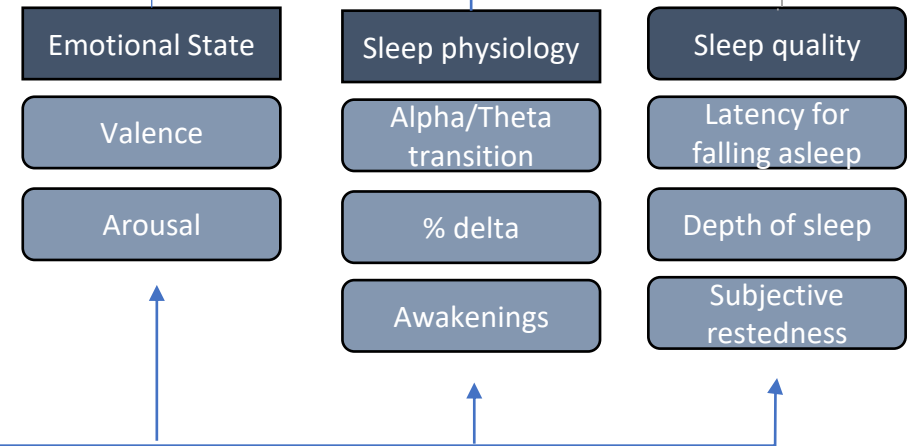
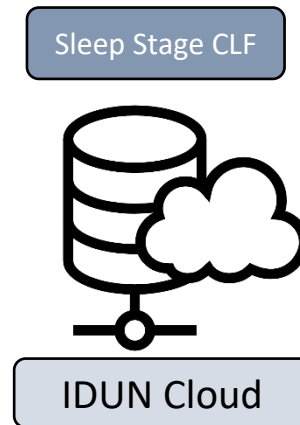
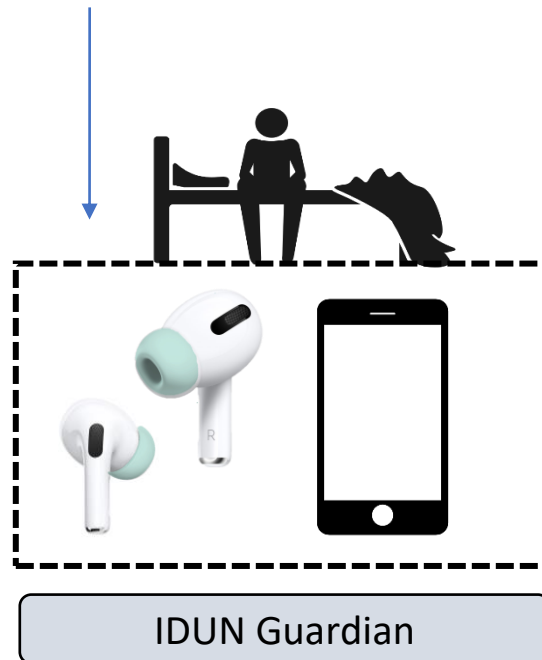
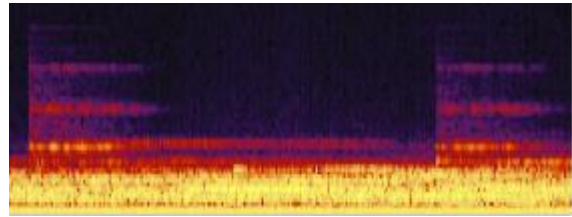
### Low Energy Music



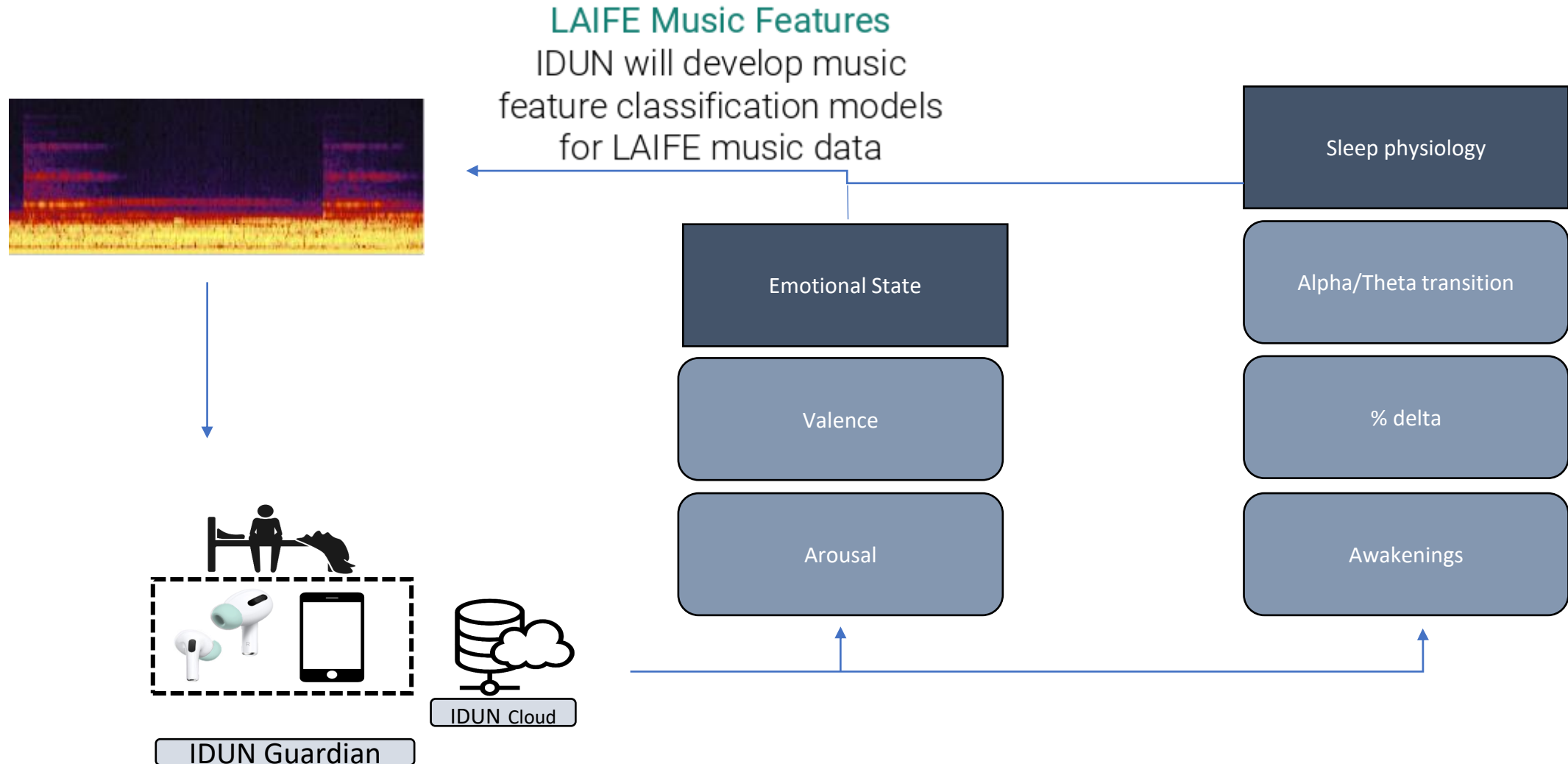
Brain Activity Data

# Music – Sleep Journey Support

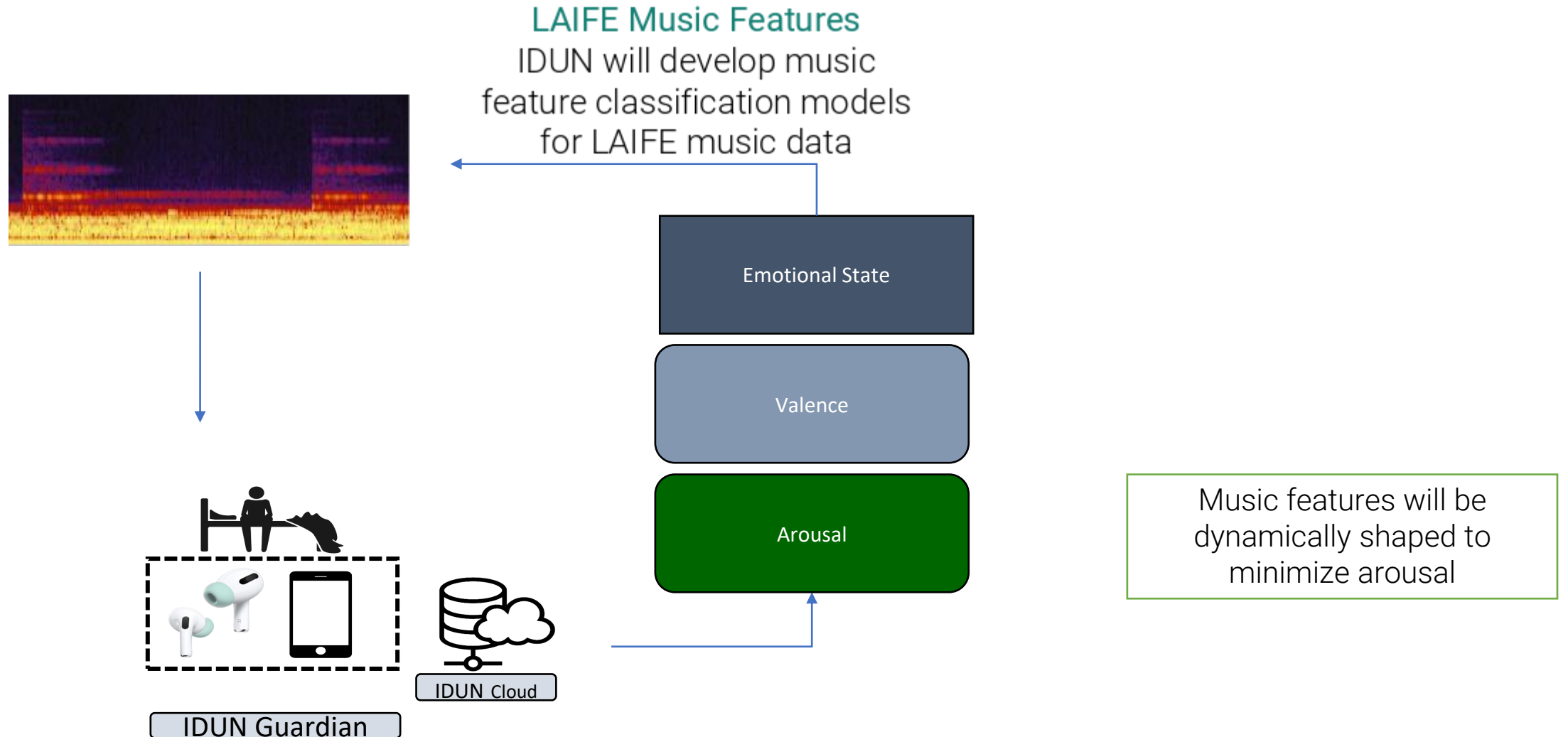
**LAIFE Music Features**  
IDUN will develop music  
feature classification models  
for LAIFE music data



# Music – Sleep Journey Support



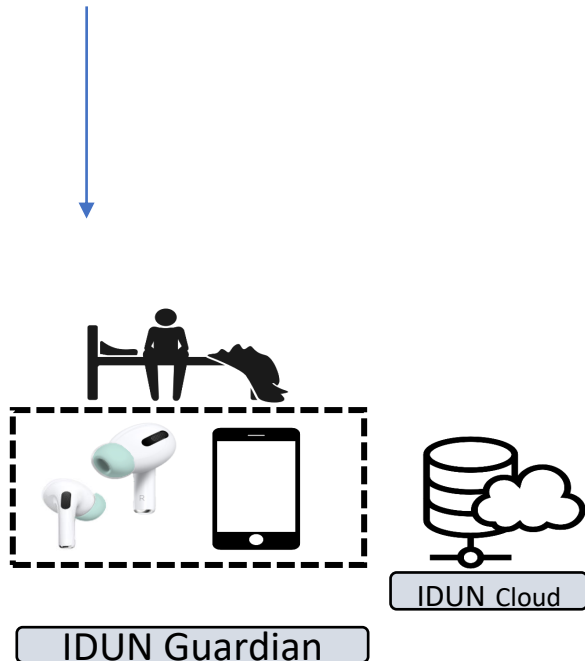
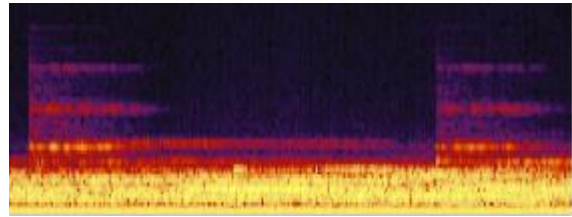
# Music – Sleep Journey Support



# Music – Sleep Journey Support

## LAIFE Music Features

IDUN will develop music feature classification models for LAIFE music data



### Primary outcome:

Achieve a quick transition from alpha to theta EEG

→ Experimentally compare different versions of music w.r.t their effect on time to alpha/theta transition

→ repetitive assessment of naps (e.g., after lunch) in the same individual (t ≥ 6 sessions per music condition, n ≥ 5 Ss)

Sleep physiology

Alpha/Theta transition

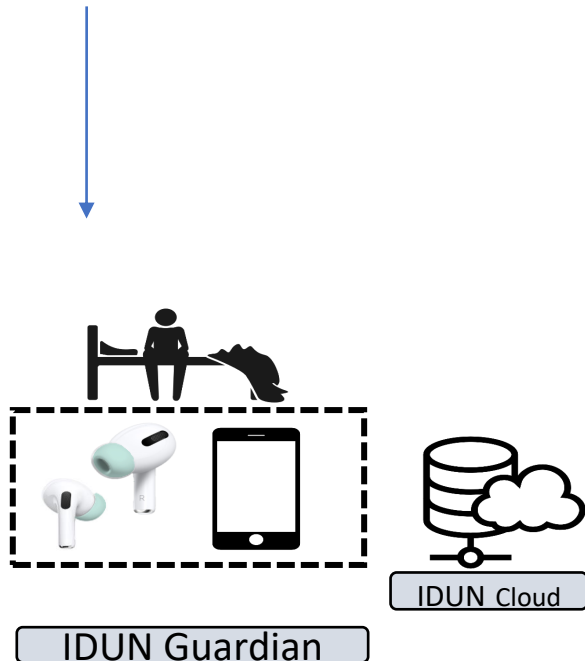
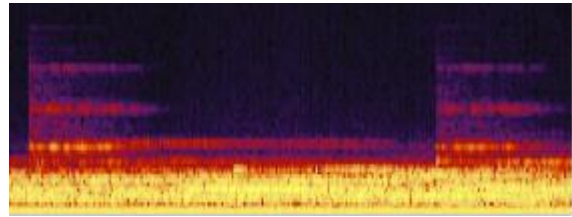
% delta

Awakenings

# Music – Sleep Journey Support

## LAIFE Music Features

IDUN will develop music feature classification models for LAIFE music data

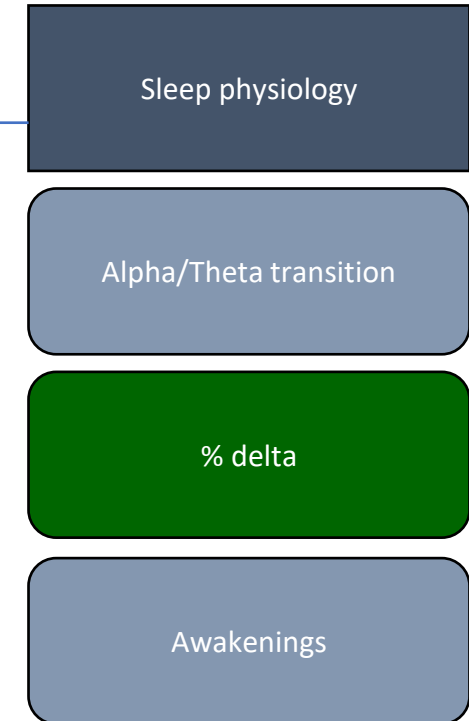


### Secondary outcome:

increase the percentage of delta sleep over a night

→ Experimentally compare different versions of music w.r.t their effect on % delta

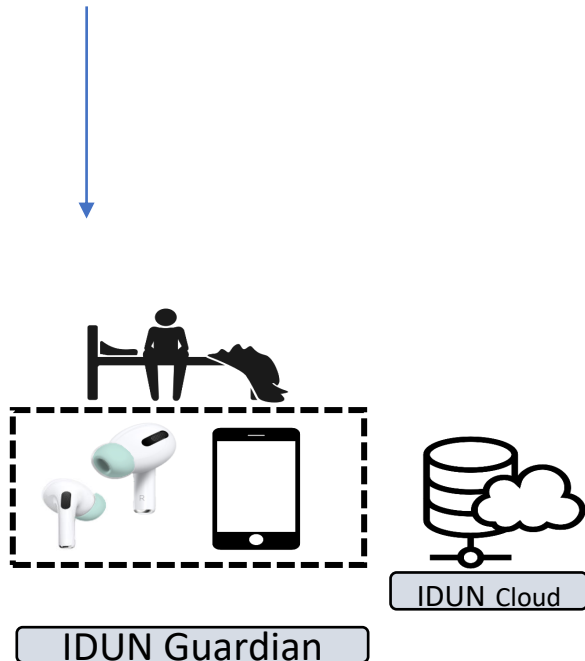
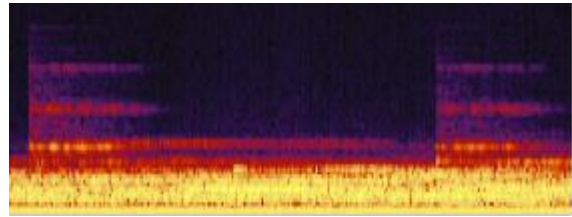
→ repetitive assessment of whole night sleep in the same individual (t>=6 sessions per music condition, n>=5 Ss)



# Music – Sleep Journey Support

## LAIFE Music Features

IDUN will develop music feature classification models for LAIFE music data

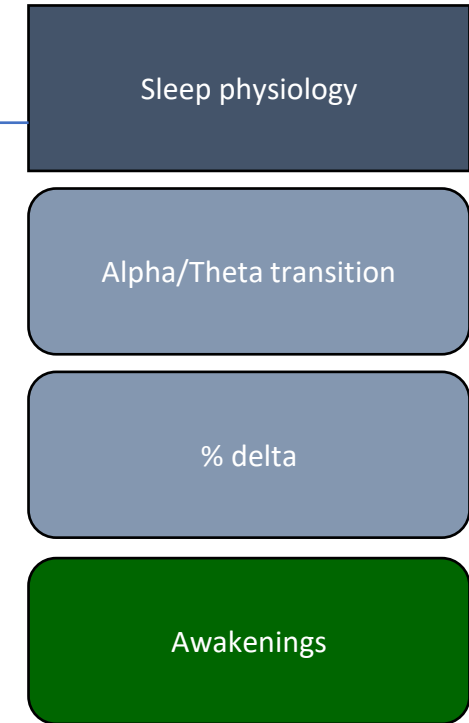


### Secondary outcome:

decrease the number of awakenings over a night

→ Experimentally compare different versions of music w.r.t their effect on number of awakenings

→ repetitive assessment of whole night sleep in the same individual (t ≥ 6 sessions per music condition, n ≥ 5 Ss)



# Neurofeedback AI Music: Project Planning

Neurofeedback AI Music NAIM Project Lead - IDUN Technologies AG		2021								EXPLORE (PHASE 1 – Idea Validation) EXPERIMENT (PHASE 2 – Product realization) EVOLVE (PHASE 3 – Market launch and investment search)
		Reach Incubator Phases								
		EXPLORE		EXPERIMENT			EVOLVE			
Work Package	Description	4	5	6	7	8	9	10	11	Outcomes
<b>WP1</b>	<b>AI Classifier Design</b>									Music classifier design Brain activity classifier integration
Task 1	Music feature model design									
Task 2	Integration to brain activity model									
Task 3	Neurofeedback system design									
<b>WP2</b>	<b>System Development</b>									Refined music and brain models AI music generator Integration with IDUN product platform
Task 1	Neurofeedback system development									
Task 2	Integration with IDUN cloud platform									
Task 3	Collect brain activity data									
Task 4	User testing									
<b>WP3</b>	<b>Launch</b>									Outreach to existing investors Published demo videos and outreach
Task 1	Investor outreach									
Task 2	Video produciton									