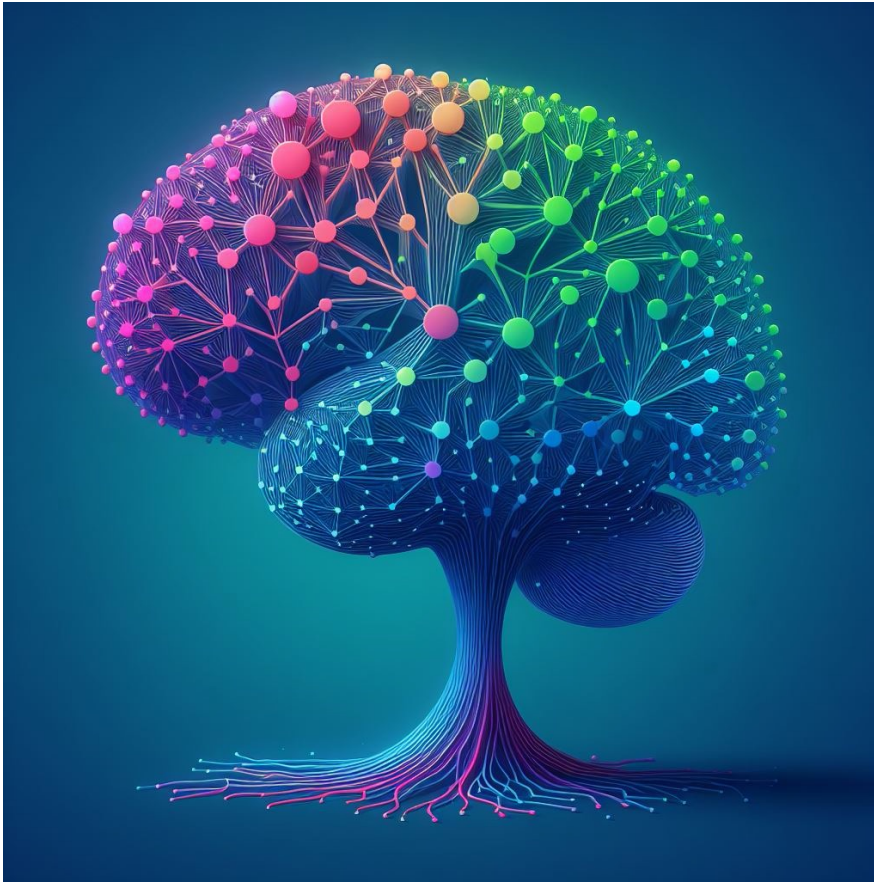




The Consulting Society
EPFL

December 2023



NEURALWORKS

Consulting Presentation

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TCS Incubator



Executive Summary

Part 1: Available EEG hardwares in the market

- Six companies are currently developing EEG hardwares and can be potential clients. Another six companies already have the software but open to collaborations.
- The companies that are developing hardwares without softwares locate in the US, Denmark and Belgium.

Part 2: Potential EEG applications for NeuralWorks

- Recent advancements in EEG devices and machine learning techniques has increased interest in EEG applications.
- Despite the global neurological disorders market (including sleep disorders, epilepsy, etc) projecting a 6% CAGR over the forecast period 2020-2028, 30% is attributed to EEG devices.
- VR, inclusive technology, aging population and the population with disability are the growth are the play roles for BCI in the market. The big investors are in north US.
- The neurofeedback market leaders are mostly located in Europe and produce multi-channel EEG devices with softwares, focused on clinical usage, while there can be a potential application in personal well-being.
- There is a high demand for personalized gaming experiences but offers are lacking.
- Brainwave Authentication and military applications are potentiel future breakthrough applications of EEG.

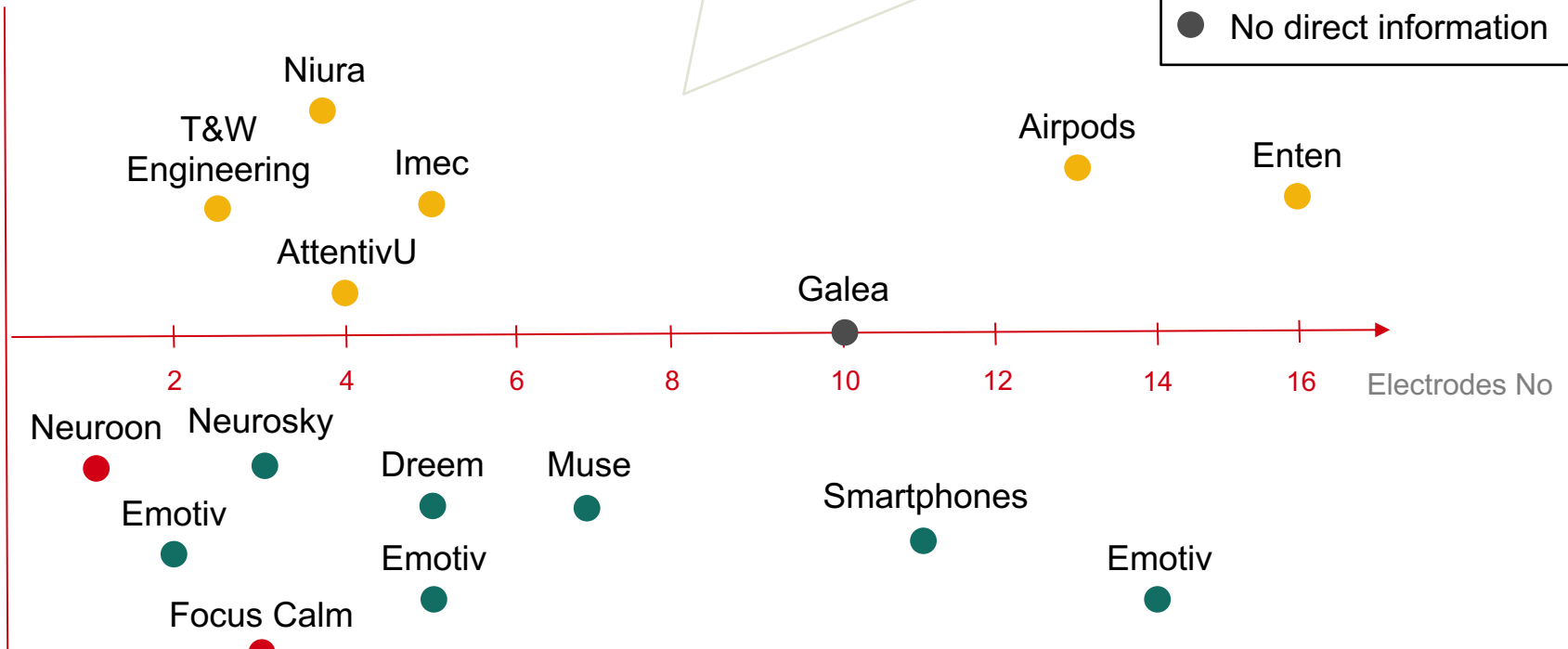


6 companies are currently developing EEG hardwares and can be potential clients. Another 6 companies already have the software but open to collaborations

These devices selected based on the user-friendliness. Within this criteria, the devices like CGX, NIRx, Enobio, and ant neuro are excluded. New OpenBCI devices are becoming more user-friendly, so keep an eye on it!

- Open to collaborations
- Under development
- Unavailable for collaborations
- No direct information

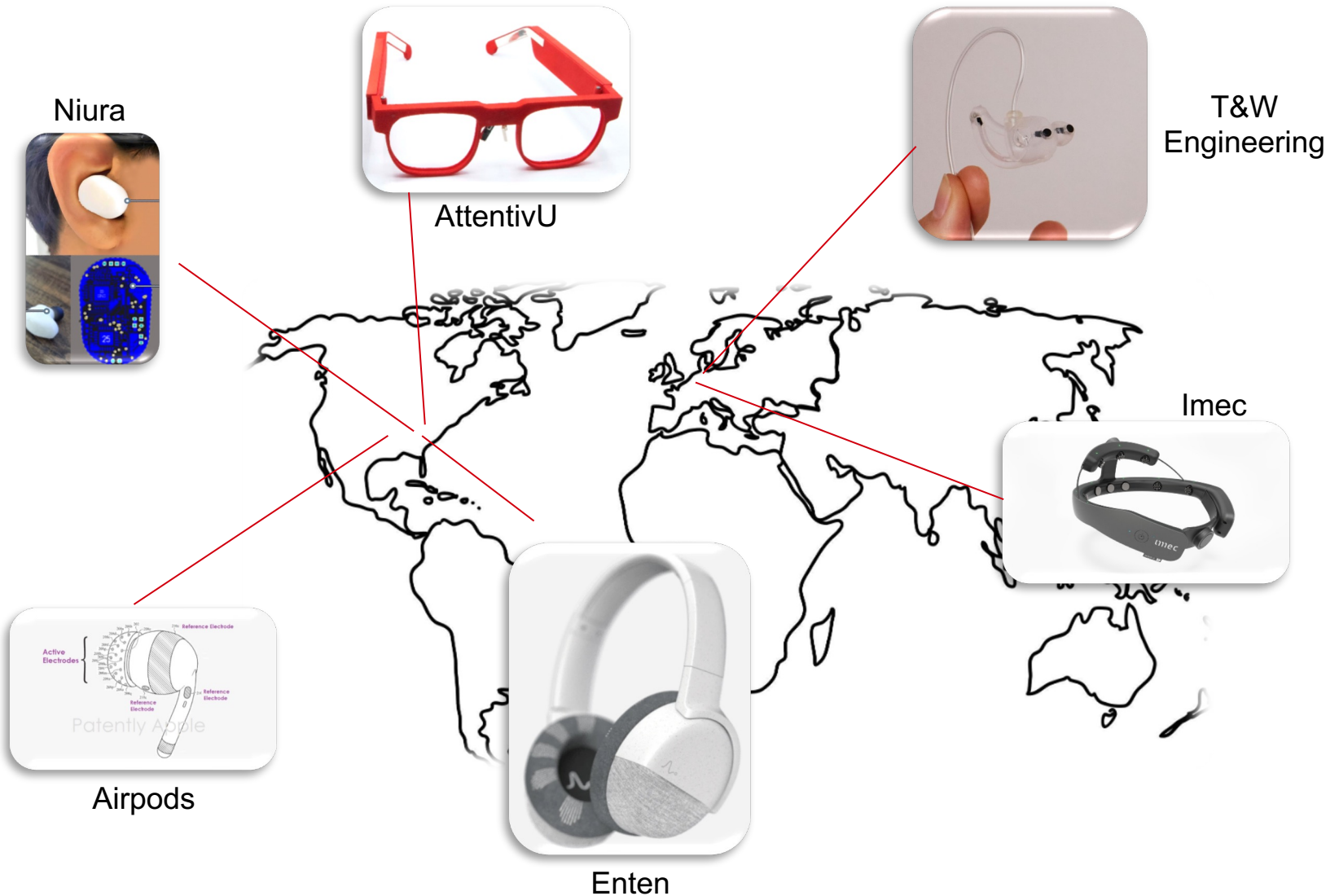
No Software



Have Software

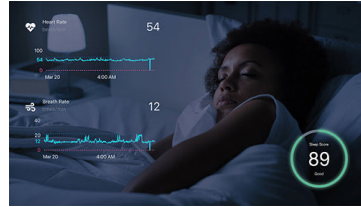


The companies that are developing hardwares without softwares locate in the US, Denmark and Belgium

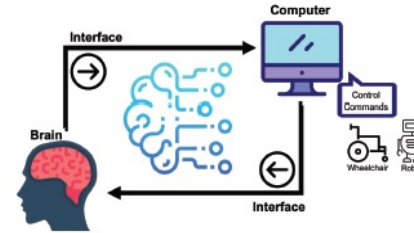




Recent advancements in EEG devices and machine learning techniques has increased interest in EEG applications.



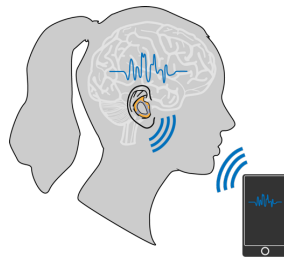
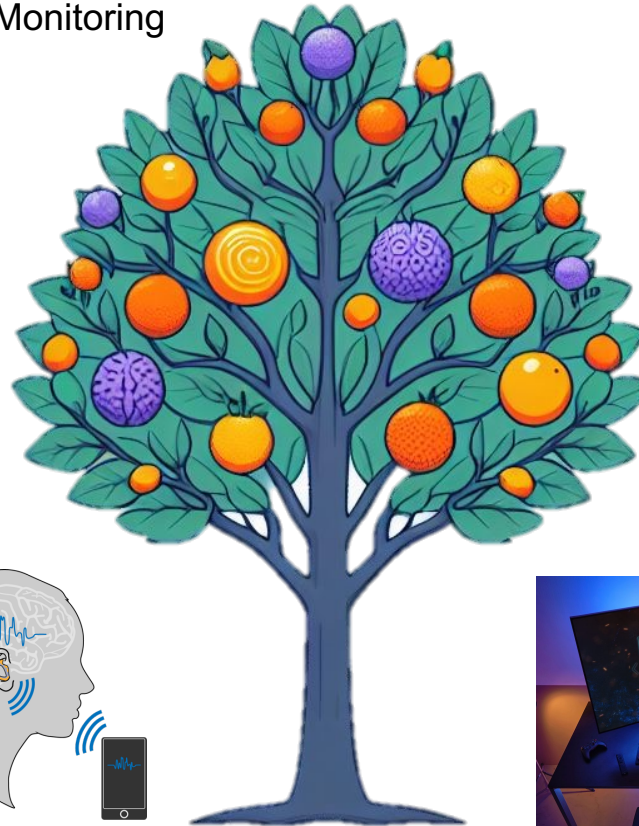
Sleep Monitoring



BCI



Epilepsy Diagnosis



Brain-wave Authentication



Neurofeedback



Gaming

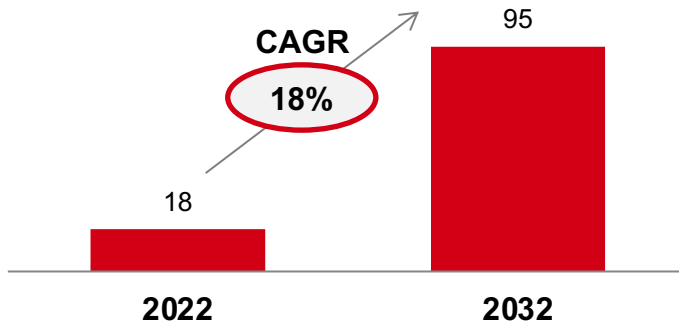


Sleep monitoring ever-evolving market will experience a 18% CAGR over the forecast period 2022-2032

The sleep monitoring market employs non-invasive, wearable devices to track brainwave patterns during sleep, offering insights into sleep quality and aiding in the detection of disorders like insomnia, sleep apnea, and nocturnal seizures.

Sleep monitoring market

Sleep monitoring market is expected to grow at 18% rate during the forecast period (billion U.S. dollars)



Around 20% of the global adult population, which translates to over 2 billion people, grapple with insomnia or sleeping disorders on a regular basis

Market segmentation is divided in 4 categories

Device types (Wearables or Non-wearables)

- Smart watches
- Bands
- Other wearables
- Beds
- Sleep monitors

Application

- Insomnia
- Obstructive sleep apnea
- Narcolepsy
- CPAP ¹
- RLS ²

Distribution channels

- Personal use
- Sleep and fitness centers
- Hypermarkets, Supermarkets
- Pharmacy and retail stores

Other significant categories may include geography or demographic segmentation (gender, age)

1. CPAP = Continuous Positive Air Pressure

2. RLS = Restless Legs Syndrome (RLS)

Source: McKinsey, GmInsights



EEG sleep monitoring latest businesses highlight the market's diversity with its various products

Compumedics Limited offers healthcare solutions encompassing cardiology, neurology, electromyography, and sleep-related issues using a comprehensive range of EEG technologies¹



+130 employees worldwide

\$42.4 U.S. million dollars in 2023
(+12% than prior corresponding year)

\$29 U.S. million dollars market cap
(2023)

Compumedics Limited (founded 1987) has earned prestigious awards, including DesignMark, Top 100 German Innovation Award, and the Frost & Sullivan 2006 Technology Leadership of the Year Award for the European sleep diagnostics market

One of the main competitors of Compumedics Limited is ResMed

Additional sleep monitoring start-ups/ companies active in the EEG sleep market are Zeto Inc, Dymedix Diagnostics, General Sleep Corp, X-trodes, Center for Ear EEG at Aarhus University, Cadwell, Rhythmink International LLC

Study cases in the market

State of Business

Insight



Software and hardware

- *NYX Technologies – Israel, 2016*
- *\$1.5 millions in raising*

- *Uses advanced algorithms and AI in a (EEG) **wearable headband** to tailor the sleep program through its mobile app*



- *Formerly VC-backed– USA, 1998*
- *\$3.2 millions raised*

- *Dymedix Diagnostics manufactures **disposable EEG cap electrodes***



Software and hardware

- *Venture Capital-Backed - Israel, 2019*
- *\$11.2 millions grant funding*

- ***Adhesive EEG electrode patches** for monitoring and analyzing bio-signals (EEG, EOG, EMG, and ECG/EKG)*

1. EEG technologies¹ feature clinical EEG, ambulatory EEG, continuous EEG monitoring, long-term EEG monitoring, lab-based sleep testing, ambulatory sleep testing, and at-home sleep testing

Source: Medical Starttups



Wireless EEG wearables are garnering increasing interest among new businesses in the sleep monitoring market

Natus Medical Incorporated company belongs to the well-established leaders in EEG healthcare solutions today, regarding both its hardware's and software's

natus.

1'420 employees worldwide

\$473.4 U.S million dollars revenues in 2021 (+13.9% from previous year)

\$820 millions valuation, January 2022

Natus Medical Incorporated (founded 1987) offers advanced healthcare solutions for diagnosing and treating neurological and sensory nervous system disorders

Biggest competitors include

- Cyberonics, CTI Molecular Imaging, MicroPort, IDEXX, GE Healthcare

GE Healthcare provide both Hardware's and Software's too

Routine EEG limitations include a low yield of intermittent abnormalities due to short-time sampling. The diagnosis of seizures improves with repeated EEGs, potentially reaching 90% accuracy by the fourth EEG

Study cases in the market

State of Business

Insight

epitel

- Venture Capital-Backed – USA, 2007
- \$12.5 millions in series A funding, 15 investors

- Remote system for seizure detection, **wearable wireless EEG** sensors, including software

empatica

- Start-Up – Italy, 2011
- \$33.7 millions in funding

- Empatica creates AI systems that track human health **miniature, wireless, wearable EEG sensor**

Not direct EEG

ARVELLE THERAPEUTICS

- Company- Switzerland, 2019
- \$221.8 millions raised
- Angelini Pharma and Arvelle Therapeutics finalized a merger, valuing Arvelle at up to \$960 million, 2021

Not direct EEG

1. ILAE = International league against Epilepsy
 2. Series A funding = Early-stage investment for startups to scale operations
 3. Capital-Backed = Financed by investment from venture capital firms
 Source: Medicalstartups

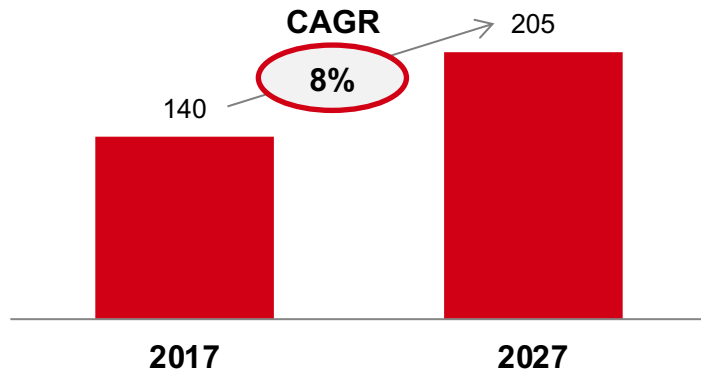


Epilepsy global market is expected to have a 8% CAGR growth over the period 2017-2027 and EEG devices accounted for \$140 U.S. million dollars in 2020

Epilepsy types according to ILAE¹ are focal, generalized, combined focal & generalized, unknown epilepsies

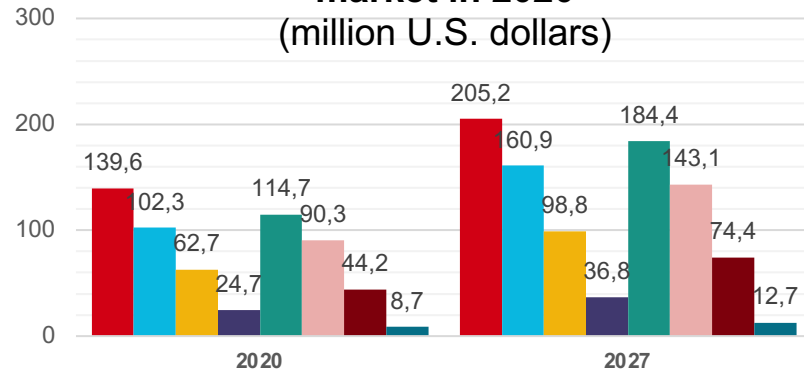
Global epilepsy market

Epilepsy global market is expected to grow at 8% rate (million U.S. dollars)



Increasing prevalence of people affected by epilepsy with constant population growth

EEG represented around \$140 million U.S. dollars of global Epilepsy devices market in 2020



- Electroencephalography (EEG)
- Surface Electromyography (sEMG)
- Electrocardiography (EKG)
- Implanted Advisory Systems
- Intracranial EEG
- Electrodermal Activity (EDA)
- Video Detection Systems
- Others

More than 50 million people suffer from epilepsy globally, approximately 6 million people in Europe

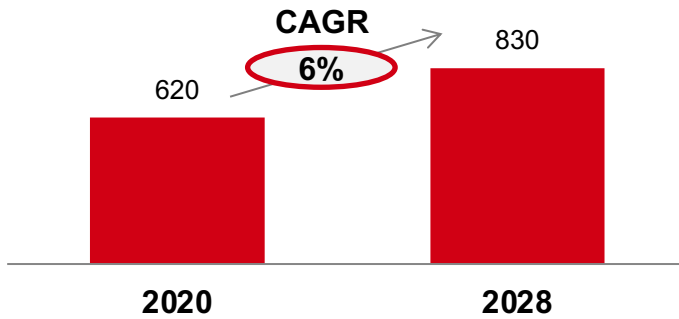
1. CAGR = Compounded Annual Growth Rate
Source: Statista, Arvelle Therapeutics



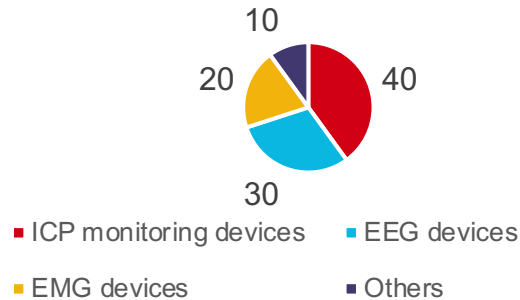
Despite the global neurological disorders market projecting a 6% CAGR over the forecast period 2020-2028, only 30% is attributed to EEG devices

The neurological disorders monitoring market utilizes non-invasive, wearable devices to track and analyze brainwave patterns, playing a crucial role in detecting and monitoring conditions such as epilepsy, migraines, and cognitive disorders

Neurological market is expected to grow at 6% rate during the forecast period (million U.S. dollars)



Device types repartition by market share [%]



Market segmentation is divided in 4 categories

Device types

- ICP monitoring devices
- EEG devcies
- EMG devices

Other significant categories may include geography or demographic segmentation (gender, age)

Application

- migraines
- neurodegenerative diseases
- strokes & brain injuries
- neuromotor diseases

Distribution channels

- Personal use
- Healthcare institutions and hospitals
- Medical equipment suppliers and distributors
- Laboratories

1. ICP monitoring devices = Intracranial Pressure monitoring devices
2. EMG devices = Electromyography devices

Source: Technavio



VR, inclusive technology, aging population and the population with disability are the growth are the play roles for BCI in the market.

Popular basic BCI Applications

**Cursor
Control**

**Communication
Systems**

**Assistive
Technology**

Target Audience and Industries

**Healthcare and
rehabilitation**
Hospitals, clinics, and
home use

**92 million People with
disabilities**

**Tech Enthusiasts and
Early Adopters**
36% of the global
population

Growth Factors

**Virtual reality and
augmented reality**
Demand for intuitive and
hands-free cursor control

Aging population
People over 60 projected
to reach **29.4 % in 2050**

**Increasing focus on
inclusive technology**



Two main contributors in Non-invasive BCI market located in USA with a \$13M revenue.

State of business

In Numbers

Insight



- Corporation
- Location: USA
- Year: 2016

- Revenue: \$115.7M
- 533 Employees
- Investment: \$643M

- **Invasive** Brain implants
- treatment of brain disorders
- enabling web browsing and telepathy



- Corporation
- Location: USA
- Year: 2011

- Revenue: \$12.7M
- 91 Employees

- **Non- Invasive**
- cognitive efficiency
- Real-time feedback



- Corporation
- Location: USA
- Year: 2004

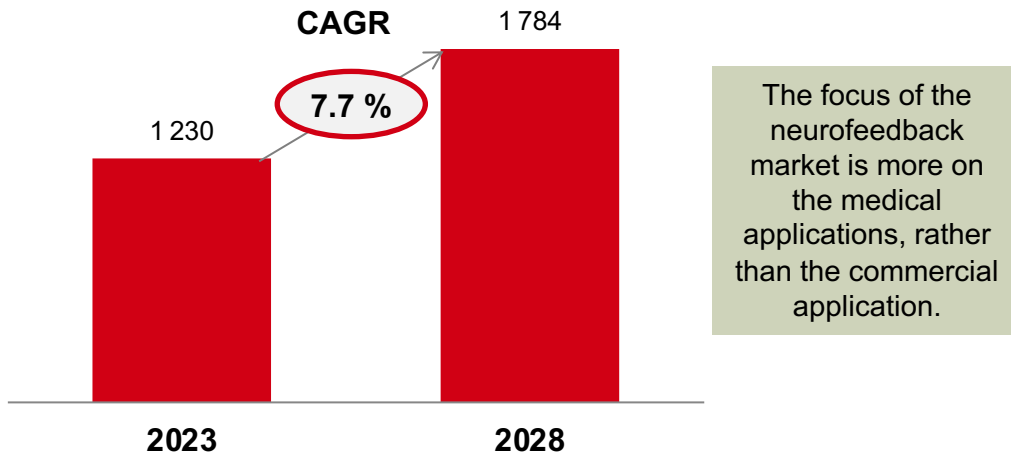
- Revenue: \$13.2M
- 62 Employees

- **Non- Invasive**
- Education
- Mini games
- Meditation
- Research
- Sleep monitoring



The neurofeedback market is expecting a growth of 8% in the next 5 years due to the constant increase of patients with neurological disorders

Neurofeedback market

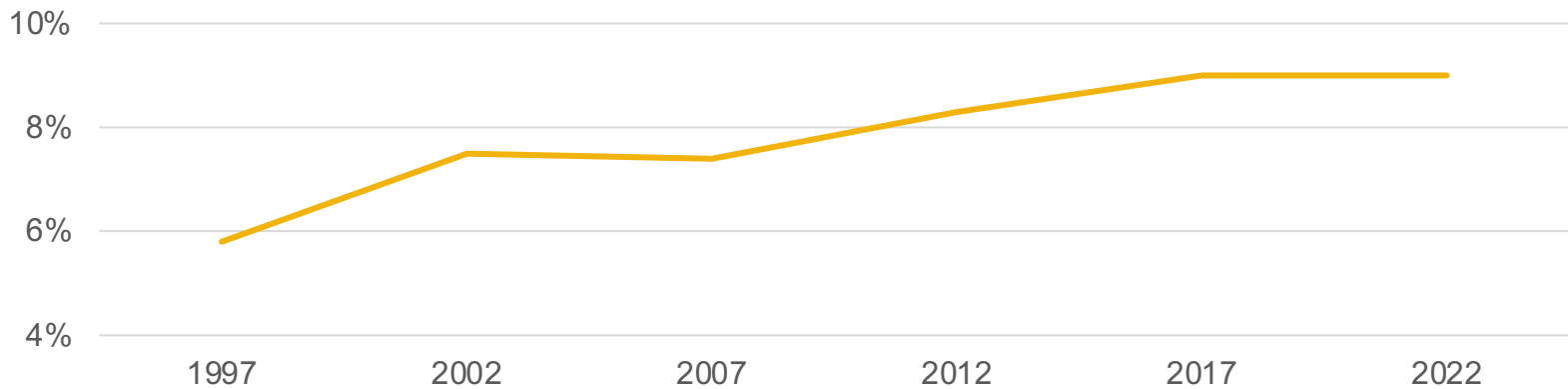


The focus of the neurofeedback market is more on the medical applications, rather than the commercial application.

Neurological disorders contributing into the market growth

- ADHD
- AST
- Stress management
- Post-COVID neurological complications
- Dementia
- Emotional regulation
- Learning difficulties

ADHD diagnostics increase leading to the higher demand on neurofeedback devices



ADHD = Attention Deficit Hyperactivity Disorder
AST = Autism Spectrum Disorders
Source: Mordor Intelligence, Centers for Disease Control and Prevention



The neurofeedback market leaders are mostly located in Europe and produce multi-channel EEG devices with softwares, focused on clinical usage.

State of Business

Insight



- *Company – USA, 1995*

- *Produce of EEG amplifiers, electrodes, caps , and software with feedback mechanisms*
- *Often used in clinical settings and for research*



- *Company – Germany, 2015*
- *About 100 employees, 16 clinics in Australia, Netherlands and US*

- *Produce 22-, 32-, 64-channel EEG systems for clinical uses*
- *Provide neurofeedback sessions with 3-5 electrode devices.*



- *Company - Switzerland, 2005*

- *The information collected is then processed and displayed on a computer screen in the form of visual and auditory feedback.*



- *Company - Netherlands*

- *For neurofeedback produce 21-channel EEG caps and compatible software*



Focus/Meditation target multiple industries and can be a promising market for Neurofeedback applications.

Popular Sub-Applications

Security and Authentication

Panic and anxiety Attacks companion

Brainwave-driven music choice

Target Audience and Industries

High-security environments

Wellness Applications

Entertainment

People with anxiety disorders

25 million people in Europe

People with ADHD

3.3 million in the EU

Growth Factors

Demand for robust security solutions and multi-factor authentication methods

Increasing awareness of mental health issues and the need for personalized, immediate interventions

Growing trend of personalized experiences in entertainment and wellness



Muse and BrainCo are the two leading companies to implement neurofeedback in personal well-being.

State of business

Characteristics

Insight



- Developed by InteraXon
- Location: Canada
- Year: 2014

- Revenue: \$1.1M
- 11 Employees

- Sleep monitoring
- Anxiety control
- Meditation
- Focus
- Real-time feedback



Not direct EEG

- Corporation
- Location: UK
- Year: 2011

- Revenue: \$993.6k
- 16 Employees

- Sleep monitoring
- Anxiety control
- Available only on iOS
- 198 ratings on Appstore



- Harvard University-Backed Startup
- Location: USA
- Year: 2015

- Revenue: \$1.1M
- 11 Employees

- Focus
- Education
- BCI (BMI)
- Real-time feedback



Gaming market has loyal customers and expected to have a 9.3% growth rate until 2027.

Popular Sub-Applications

Cognitive load adjustment

Adaptive storytelling

Focus training mini-games

Target Audience and Industries

Gaming and entertainment industries

Mobile phones' game players

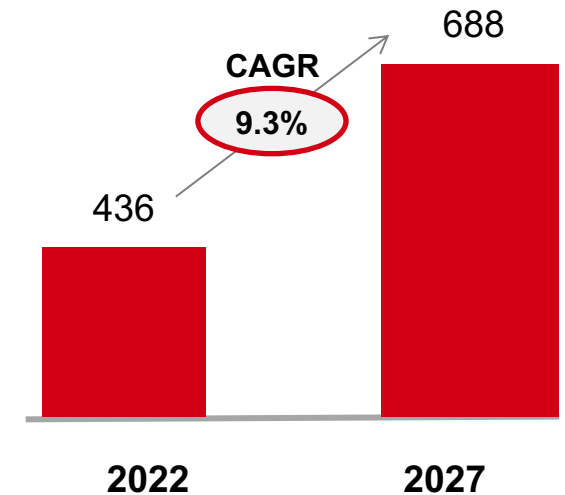
55.6 billion mobile game downloads in 2022

Console players

46.6 million PS5 consoles sold

Growth Factors

Video game revenue is expected to grow at 9.3% rate (billion U.S. dollars)





There is a high demand for personalized gaming experiences but offers are lacking

- There is a potential market for building BCIs in games and gamification.
- The Use of Brain–Computer Interfaces in games might not be ready for the General Public.

	<u>State of business</u>	<u>Characteristics</u>
EMOTIV	<ul style="list-style-type: none">• Corporation• Location: USA• Year: 2011	<ul style="list-style-type: none">• Revenue: \$12.7M• 91 Employees
NeuroSky® Body and Mind. Quantified.	<ul style="list-style-type: none">• Corporation• Location: USA• Year: 2004	<ul style="list-style-type: none">• Revenue: \$13.2M• 62 Employees



Brainwave Authentication and Military applications is a potential future breakthrough application of EEG.



Computers & Security
Volume 129, June 2023, 103198



Brainwave-based authentication using features fusion

Uses a person's unique electrocardiogram (ECG) signal as a biometric identifier

Continuous authentication as long as the user wears the device

Successful improvement in authentication accuracy using EEG data and feature combination



Conclusion

Main outcome

It is crucial to prove and emphasize the effectiveness of NeuralWorks softwares compare to the available softwares in the market.

Key Findings

- **Emotiv** and **Neurosky** seems to be two of potential hardwares to use: open to 3rd parties, well-established, already covering different areas of application. Under-develop hardware companies can be demanding.
- **Neurological disorders**, such as sleep disorders and epilepsy cannot be the low-hanging fruits for NeuralWorks because:
 - EEG is not the only helpful tool (only 30%)
 - Neuralink is the main player (huge investment + invasive)
- There is a gap in **neurofeedback market**. The market is mainly focused on the medical applications. The companies working on the non-medical neurofeedback softwares are few: muse, BrainCo (focusCalm)
- **BCI gaming** has few competitors and expected to have a huge market in near future.
- **Personal well-being**, such as work well-being, stress management at work (EAP), focus, meditation, etc is a recent interest. If NeuralWork can prove its added value by the effectiveness of its softwares, it is possible to lead the market.

Future perspective

- Brain-wave authentication
- Military applications



Backup slides



SOURCES

Sleep Monitoring

- **Market** - <https://finance.yahoo.com/news/sleep-tech-market-report-2023-114700181.htm>
- **CAGR, segmentation, competitors** - <https://finance.yahoo.com/news/sleep-tech-market-projected-grow-095900714.html>
- **Compumedics** - <https://www.compumedics.com.au/en/product-category/solutions-sleep-diagnostics/>
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Epilepsy

- **Devices segmentation** – <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8917432/>
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- Nymi company – <https://www.nymi.com/nymi-band>

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- WHO – <https://www.who.int/news-room/fact-sheets/detail/mental-health-strengthening-our-response>



SOURCES

BCI

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- **GDW –** <https://www.gwi.com/reports/tech-enthusiasts>
- **European Commission for statistics –** https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Ageing_Europe_-_statistics_on_population_developments
- **Growjo marketing agency –** <https://growjo.com/company/Neuralink>



List of criteria for finding a low-hanging fruit applications

- precise of measurement with earbuds
- competitiveness of the market
- ease of reachability of the customers (medical applications are out)
- market trends

Complementary “keywords” which can be considered for NeuralWorks:

- Neuromarketing
- Employee Assistant Program (EAP): burnout, cognitive load, focus
- Mental health
- Applications based on low-resolution EEG, Ear-EEG
- Audio Visual Entrainment (AVE)