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PALU.DISA

Abstract

Mental well-being is essential for both individuals and society. According to the World Health Organization (WHO) one in five people will encounter a depression at least once in their lifetime. Moreover, the Lancet reported that due to depressive mood and anxiety disorder the global economy lost staggering 1 trillion US$ annually in 2020. Additionally, accessing therapy for depression can often be a lengthy and stressful process, with months of waiting. [1, 2]

In the team PaLu.DiSa four students from diverse technical backgrounds have united forces with inno. space of the esteemed Mannheim University of Applied Sciences to help achieve the United Nations' Sustainable Development Goal No.3: "Good Health and Well-being." Through the CBI A^3 (Challenge Based Innovation) project, they aim to streamline the process for therapy treatment and offer vital support to those in need with the assistance of an AI-based system. [3, 4]

The system MINT – Mental health INTelligence – utilises an AI avatar to engage in therapeutic conversations with patients, while using several sensors and technologies to gather essential information. While it cannot diagnose mental health conditions, it can provide a mental health evaluation, schedule appointments automatically, prioritise high-risk cases, and develop a mental health plan in collaboration with the therapist and patient. Powered by the cutting-edge CERN technologies ROOT and REMUS, MINT will transform the way we approach mental health by providing optimal treatment recommendations to patients.

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1 CBI A^3 Program

Have you ever come across the CBI A^3 program? Are you curious to know its connection to the UN SDGs and the involvement of CERN in this context?

In 2015, the UN adopted the 2030 Agenda for Sustainable Development Goals, which are a blueprint for peace and prosperity for both people and the planet. All member countries of the UN are committed to working towards achieving the 17 goals, each with its own tasks.

In the Challenge Base Innovation (CBI) student teams from diverse backgrounds around the world aim to develop a prototype which could help to solve one of the targets in the near future of 2030. The team collaborate and leverage deep technologies from CERN and Attract, following a user-centred design thinking approach. CERN, although famous for its Large Hydron Collider, is not limited to particle physics research. Several technologies like the world wide web and touchscreens were first invented here. They support research groups and student teams to use their technology to achieve a better future for mankind.

This year teams from Swinburne University of technology, Mannheim University of applied science and technology (Germany), Pace University (USA), Pratt Institute (USA) and Warsaw University of applied sciences have combined deep technologies with design thinking to devise innovative solutions for the UN SDG 3 “Good Health and Well-being”. [4, 5]

CBI A^3

Program partners

Current 2022-23 Projects

Figure 1: Logos of CBI A^3, partners and universities

2 Societal Challenge

This year's CBI A^3 challenge is dedicated to tackling one of society's most pressing issues: UN Sustainable Development Goal 3 – Good Health and Well-being. In general, it goals to ensure healthy lives and promote well-being for all individuals, regardless of age. Our team, PaLu.DiSa, specifically focuses on target number four, which aims to reduce premature mortality from non-communicable diseases by one third through prevention and treatment and promote mental health and well-being by 2030. [5, 6]

Figure 2: Visualisation of the 17 UN SDGs [5]

BUT WHAT IS MENTAL HEALTH?

Mental health is not a luxury, but a fundamental human right and indispensable for every individual. A healthy state of mental well-being enables us to learn and work effectively, manage stress, cope with challenges, and contribute to society. Several factors protect or undermine our mental well-being like emotional skills, substance use, genetics as well as economic, social, geopolitical, and environmental aspects. Although mental health is experienced differently from person to person, it is well known that poor mental well-being can lead to a variety of physical health problems. Unfortunately, in our society, the significance of mental health and the struggles of individuals are often dismissed. As a result of this trivialisation, affected feel isolated, lost, and vulnerable. [7]

AND WHAT ARE THE STATISTICS SAYING?

The statistics surrounding mental health are alarming. Suicide mortality rate in general serves as a sobering indicator of the mental well-being of a society. In Germany alone, the number of suicide attempts reached a sad figure of 9.215 people in 2021, leading to more than 25 tragic deaths daily. But the issue runs much deeper than these heart-breaking statistics suggest. Research over three years, uncovered a shocking 34,000 psychiatric emergency admissions, including over 5,000 suicide

attempts - a mere fraction of the 21 million emergency patients Germany sees annually. Additionally, the World Health Organizations reveals that at least one in five people will suffer from a depressive mood disorder at least once in their lifetime. These numbers are just a glimpse into the larger crisis our society is facing. [8, 9]

It is not only the individuals affected by mental health disorders who suffer; society bears the burden. The economic impact is profound, with the global economy losing a staggering 1 trillion US$ due to the productivity losses caused by the two most prevalent mental disorders, depression and anxiety disorders, according to the Lancet (2020). This figure is estimated to reach 6 trillion US$ by 2030 if we don't take decisive action. [2]

WHAT IS THE ISSUE WITH OUR CURRENT SITUATION?

The increasing stress and social pressures in Germany, but also worldwide, amplified by crises like the pandemic and conflicts such as the war in Ukraine, are fuelling a mental health crisis. In addition, the constant connectivity demanded by smartphones and social media intensify the pressure to perform not only at work but also in social life.

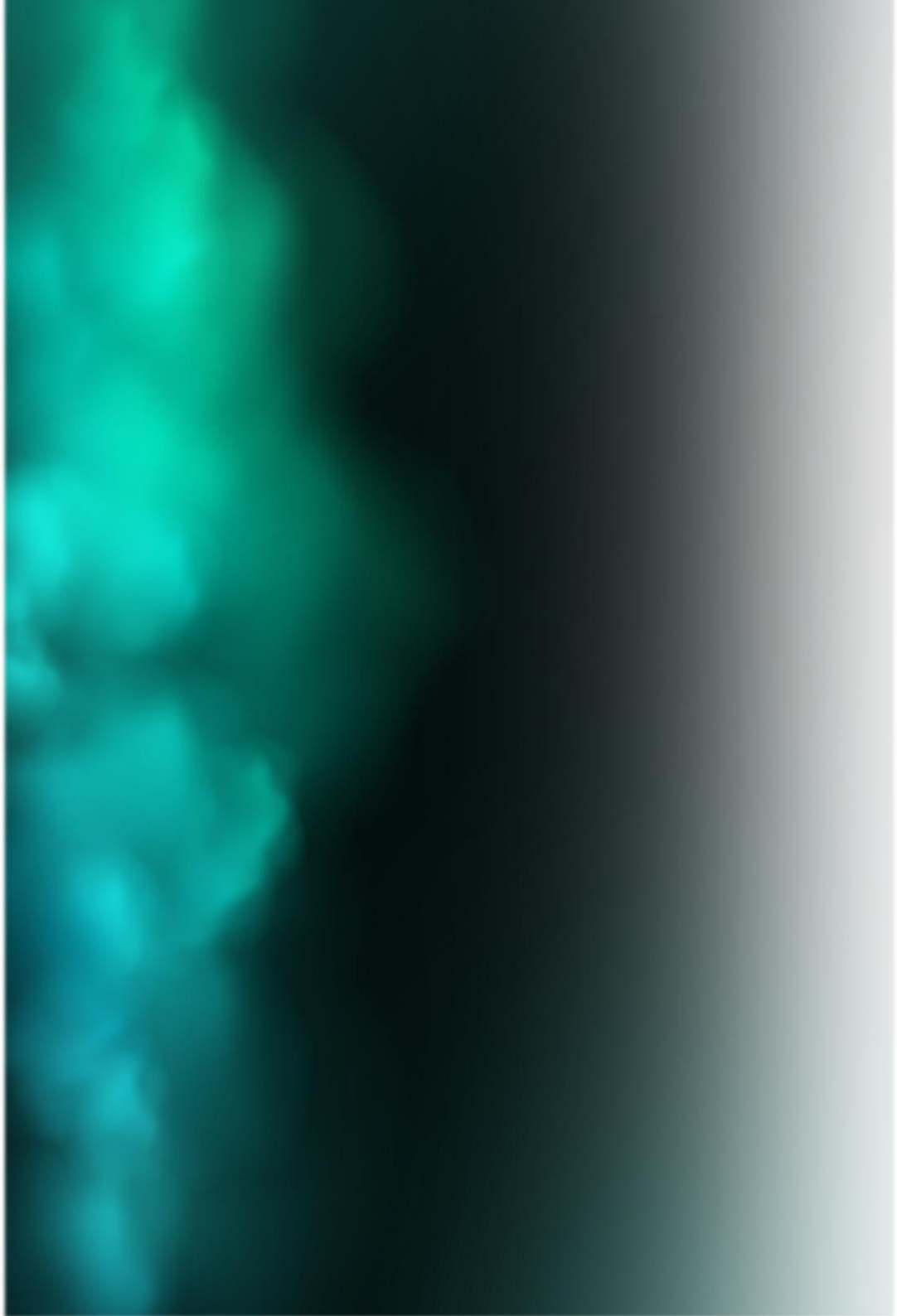
And how are we handling these increasing numbers? Well, not very good. Access to mental health treatment is a significant challenging for individuals. Long waiting times for therapy appointments, often lasting several months, prevent affected from getting the support they desperately need. In Germany, the average wait for a treatment place can be up to 20 weeks, and shockingly, 20% of patients wait a whole year for therapy. These delays can have devastating consequences, as they exacerbate suffering and prolong the recovery process. [10]

WHAT NOW?

We cannot afford to postpone this urgent issue any longer. Mental health is intimately linked to our overall well-being, and it is time, it received the attention it deserves. We can create a society that truly support individuals in their mental well-being by tackling stigma, breaking down barriers and improving access to timely and affordable mental health care.

In our pursuit to enhance mental well-being, we focused particularly on the treatment process and framed the issue in the following leading question:

How might we ease and accelerate the treatment process for (potentially) depressive patients in an easily accessible & comfortable manner?



3 Future of 2030

Imagine a future in the year 2030:
With significant advancements in technology and artificial intelligence we have transformed our cities into modern, connected hubs of prosperity.

In this chapter, we will explore the seven **STEEPLE** aspects – Social, Technological, Economic, Environmental, Political, Legal, and Ethical – that shape the environment of this future scenario, providing a brief overview of the changes and challenges we envision.

Social

By 2030, society has become hyper-connected through the internet, fostering an unprecedented level of information exchange. However, the constant influx of information has led to decreased productivity and increased performance pressure. The digital realm and the emergence of the metaverse have further eroded privacy, as almost every aspect of life can now be shared with the world. [11–13]

Technological

Technological progress has significantly reduced accidents, with advancements in medicine leading to preventive and personalized treatments. Innovations such as bio-printed organs and remote medical interventions have revolutionized healthcare, improving the overall well-being of individuals. [14]

Economic

Craft industries continue to decline, but the overall economy is experiencing a period of prosperity. The rise of technology-driven sectors and new forms of business models have contributed to this economic boom, creating new opportunities, and driving innovation.

Environmental

Despite technological advancements, the environment faces significant challenges. Air and water pollution have increased, posing threats to ecosystems and human health. However, new methods for cleaning the oceans have been discovered, offering hope for addressing these environmental concerns.

Political

In this future scenario, a few global powers hold sway over international affairs. Democracy has transformed into a do-it-yourself model, where individuals have more responsibility for decision-making processes. Political campaigns now take place in the metaverse, leveraging the digital landscape to engage with voters. [13]

Legal

Regulations surrounding waste management have been relaxed, leading to concerns about environmental impact. Additionally, the legalization of certain drugs has been approved, shaping the societal landscape. However, the widespread use of facial recognition technologies has led to violations of data protection and privacy rights.

Ethical

Individualism and self-realization have become significant societal values, driving a constant pursuit of personal fulfilment. However, this emphasis on the self has also made society more superficial and self-

centred. Many experts express scepticism regarding the moral decision-making capabilities of AI, questioning whether it can prioritize the common good over individual interests. [15]

This future scenario presents a glimpse into a world transformed by technology and artificial intelligence. While advancements in medicine and technology have improved healthcare and reduced accidents, societal challenges such as privacy concerns, environmental degradation, and ethical dilemmas persist. As we navigate the future, it is crucial to consider the impact of these STEEPLE factors and develop solutions that address the complex interplay between social, technological, economic, environmental, political, legal, and ethical aspects.

Figure 3: A future in which mental health research has made amazing new discoveries.

Figure 4: The cities are far greener, more translucent and more prosperous than before.

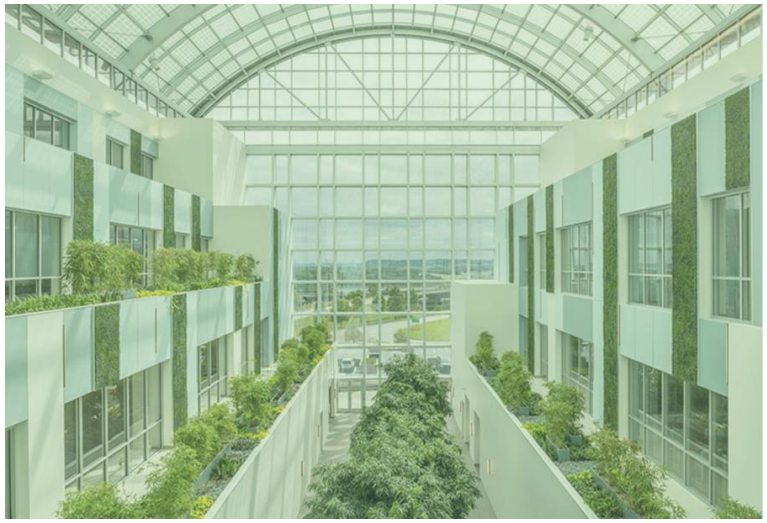


Figure 5: Interiors of public facilities, such as hospitals, are also more open, greener, and offer more treatment options for mental rather than just physical illnesses.

Relevance and Future Prospects

In the envisioned future of 2030, the relevance of our MINT project becomes increasingly clear. As society becomes hyper-connected and the digital realm continues to expand, the need for advanced mental health solutions becomes crucial. Our project addresses the evolving challenges and demands of the future by leveraging artificial intelligence and cutting-edge technologies to enhance mental health care.

The project's focus on providing optimal treatment recommendations, personalized care, and collaborative treatment planning aligns perfectly with the societal shifts towards individualism, self-realization, and self-care. In this future scenario, MINT's empathetic AI avatar and its ability to engage in therapeutic conversations fill a vital gap in addressing mental health concerns.

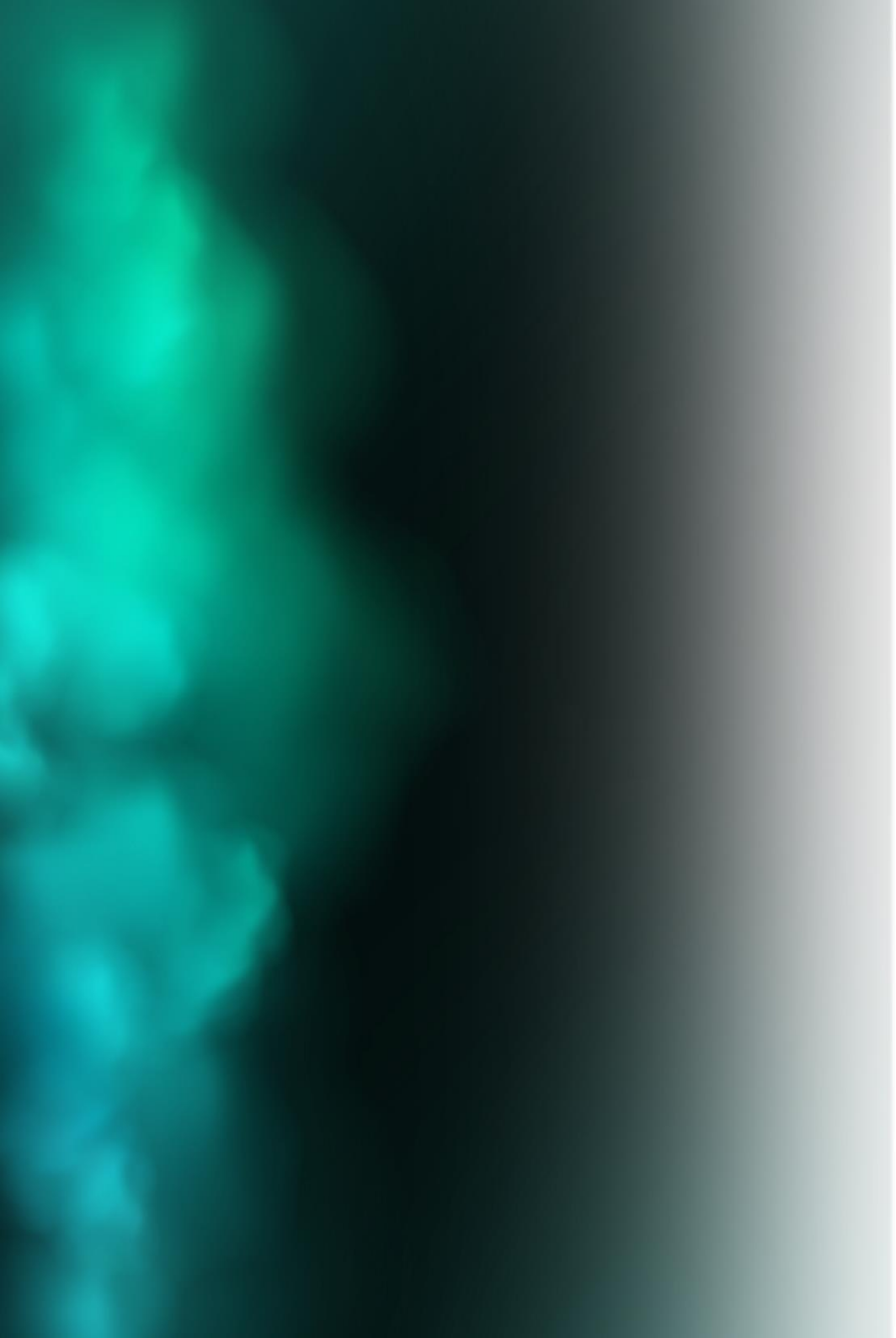
Furthermore, as productivity decreases due to information overload and performance pressure rises, MINT's streamlined workflow for mental health professionals, automated appointment scheduling, and prioritization of high-risk cases are highly relevant. The project's integration of CERN technologies and advanced sensors also aligns with the technological advancements expected in the future, ensuring exact evaluations and personalized treatments.

The increasing pollution of air and water, coupled with relaxed regulations, pose significant environmental challenges. Here, MINT's potential to collect anonymized and aggregated data can contribute to ongoing research, helping develop insights and interventions to combat mental health issues worsened by environmental factors.

In this future scenario, where data protection and privacy rights are violated by constant face recognition technologies, MINT's commitment to data security and privacy becomes indispensable. By implementing robust measures to safeguard patient information, the project aligns with the evolving legal landscape and societal expectations.

The continuous advancements in AI and technology, as well as the increasing prevalence of mental health concerns, create a pressing demand for innovative solutions like MINT. The project's ability to supply comprehensive evaluations, personalized care plans, and optimal treatment recommendations positions it as a valuable asset in the future mental health landscape.

In conclusion, our project MINT is poised to address the future's challenges and demands in mental health care. By embracing societal, technological, environmental, legal, and ethical considerations, MINT offers relevant solutions for a hyper-connected society, where individualism, performance pressure, and privacy concerns prevail. As the future unfolds, the importance of our project becomes even more pronounced, offering transformative approaches to mental health and empowering individuals on their journey to well-being.



4 Design Solution

MINT – Mental health INTelligence

MINT is an AI-centred system that revolutionizes the way we approach mental healthcare. By combining sound psychological knowledge with the latest technologies, MINT provides a comprehensive and personalized approach to mental wellbeing and a streamlined process of treating mental illness. The MINT concept consists of a treatment room with integrated MINT station, a mental health app – MINTSight – and a portable version – MINTGo. In addition, MINT offers workshops for schools, universities, and companies to promote and spread awareness of mental health.

In the MINT treatment room, the system utilizes an AI avatar to engage in therapeutic conversations with patients, while cameras, sensors, and microphones gather essential information. While the system cannot make diagnoses, it can provide a mental health assessment that helps therapists make diagnostic and treatment decisions. Moreover, it prioritizes appointments for high-risk cases, and can develop a mental health plan that is accessable in the MINTSight app together with further features.

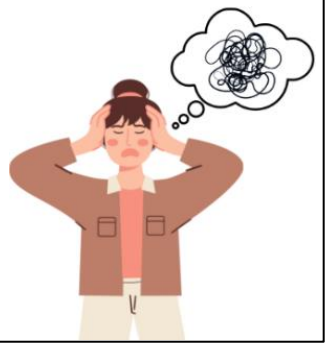
4.1 User Group and Journey

It is important to recognise that mental health is an essential aspect of everyone's wellbeing and therefore everyone is a potential user of MINT. Regardless of age, gender or background, everyone has the potential to benefit from this project. However, certain user groups have a higher risk of developing depression. People who have experienced negative life events such as unemployment, bereavement or traumatic experiences are particularly at risk. These events can have a significant impact on mental health and increase the likelihood of developing depressive symptoms. Additionally, women are more likely to have depression than men. [1]

Briefly follow us through the user journey of Maria.

She is a 29-year-old engineer from Stuttgart, single and living alone in an apartment.

I) She and her long-time boyfriend broke up a few months ago, since when she spends a lot of time on social media. Moreover, she is scared to lose her job, because of several changes. For some time now, she is concerned and has felt lacking in drive and has found it difficult to motivate herself.



II) After she shyly shared her concerns with her friend Sophie, she recommended her to have a MINT evaluation. Sophie recently participated in a MINT awareness workshop at her job. Maria is sceptical first.

III) But because waiting times are long, Maria checks the MINT website for the nearest MINT station. Because MINT is available at many public places and doctors, she quickly finds a doctor in her part of the city. She makes an appointment for the next day.

IV) During her psychological interview Maria feels more relaxed because the AI shows a female caringly humanized avatar. The conversation last one hour.

V) Maria receives an evaluation comforting her, that her mental health is okay, but she has a mild depressive mood disorder. She accepts the automatic appointment in four weeks and receives a mental health plan to bridge the time.

VI) Meet Maria again, four months later. She managed to get a stable and good mental health with the help of the mental health plan and her therapist. Even though her therapy is about to end and some things are still not on the bright side, she is able to keep a positive outlook and feels energized everyday.

VII) Maria recommends MINT to her family and friends if they struggle, and she is organizing a MINT workshop at her company. The different features of MINTSight helped her, so she is still using the app regularly and wants to do annual check-ins.

Figure 6: Graphics for Marias user story

4.2 Basic Concept

To understand the basic concept and ideas of MINT we have here a short segment from the FAQs:

FAQ

PaLu.DiSa

Frequently asked question

- Keep your mind fresh -

- When should I have a MINT session? –

You could have a MINT session every time you feel like it, but it is recommended especially, if you struggle with some of the following aspects for at least 2 weeks:

- Feeling sad, irritable, empty
- Loss of pleasure or interest in activities
- Feeling very tired or low in energy
- Thoughts of self-harm, dying or suicide
- disrupted sleep
- poor concentration
- hopelessness about the future
- changes in appetite or weight

- How can I make an appointment? –

You can easily make an appointment online on our website, in the App or by phone. Make sure you have at least 60 minutes.

- Where can I find a MINT station? –

MINT stations are available at various Medical or therapist's practice, at some public spaces in every big city and in many smaller towns. Moreover, schools, universities, or companies sometimes provide rooms for a treatment session as part of mental health awareness workshops. Check out online, where you can find the nearest MINT station here.

- How does my MINT session work? –

Trained staff will lead you to the treatment room and familiarise you with the environment and the equipment. There will be a screen on which the MINT AI avatar will be displayed. It will have a psychological conversation with you. Cameras and microphones will collect data during the session. Shortly after the session you will receive the results.

- What data is collected? –

MINT will go through different questions, which will give the system an insight into your well-being. The loudly spoken answers are recorded with the microphones. The spoken content, as well as the voice colour, is evaluated. With the cameras, MINT will evaluate your facial reactions and at the same time perform retina scans, if needed. Don't worry, these are harmless to your body, and you won't even recognize them. With your consent MINT will analyse your 24-hour heart rate variance. We will use your private or a rented device. You can get a PPG bracelet 24h before your appointment.

- What will I receive after my MINT session? –

The results include a psychological evaluation together with a personal MINT account. The evaluation is used to determine the urgency for a therapy place and if desired, we will organise an appointment with a suitable psychologist for you. You can view the results online or in the app with your account. And the evaluation will support your therapist to help you in a targeted and quick way.
A mental health plan is included in your account and suited to your personal needs. To check out what a mental health plan is and how MINTSight works read here.

- How expansive is a MINT session? -

Many health insurances cover an annual MINT mental health check in including a one-hour MINT session and at least 1 month of the MINTSight App.

Figure 7: FAQ of MINT

The MINT concept consists of various components with AI at the centre. In the adjacent graphic you can see a simplified system context diagram. The different components such as the MINT Room, MINTSight and MINTGo and how they work are explained in the following chapter. Chapter 4.3 deals with the technical details of the AI, the various data acquisition, recognition and processing systems as well as the CERN technologies ROOT framework and REMUS.

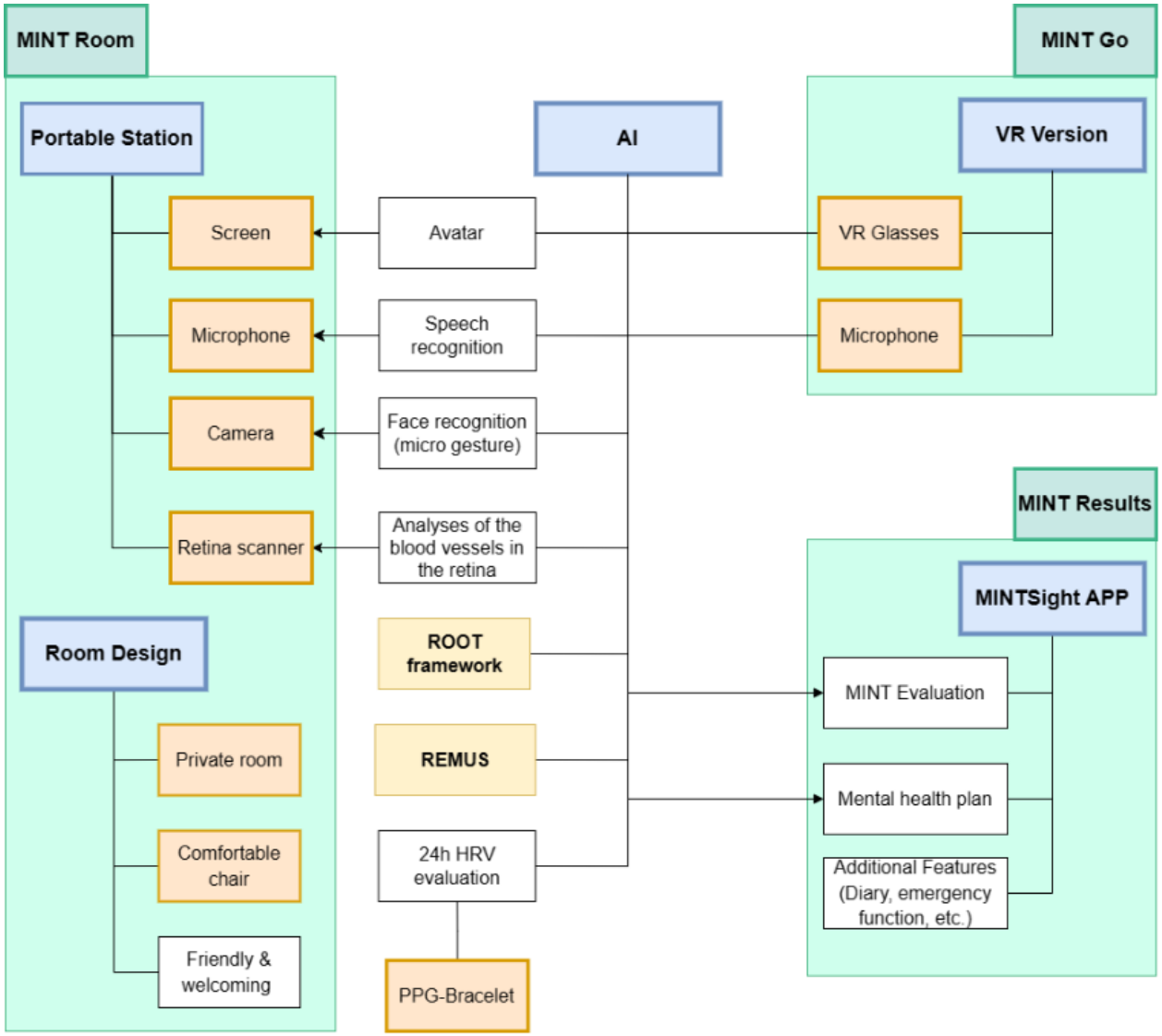


Figure 8: MINT system context diagram

MINT treatment room & MINTStation

The innovative MINT concept offers a flexible and accessible solution, allowing doctors, therapists, and entrepreneurs to rent the MINT system and make it available at various locations within cities and towns. By agreeing to implement the specified room design rules, renters receive a comprehensive MINT station equipped with all the necessary equipment and cutting-edge technologies.

The MINT treatment room is carefully designed to prioritize privacy and create a secure environment where confidential discussions can take place. It is specified that the room must have solid walls and a closable door, ensuring that sensitive information remains confidential.

In terms of design, the focus is on creating a welcoming and comfortable atmosphere that promotes a sense of security and relaxation. The room should exude a bright and inviting ambiance, with careful consideration given to lighting arrangements and the use of colours. While cleanliness is essential, the room should not be overly crowded or distracting with excessive decorations. The exact ambiance and aesthetic choices, such as the placement of lamps or the inclusion of plants, are left to the discretion of the room holder.

Within the MINT treatment room, key elements are a comfortable yet hygienic chair for the patient and a prominent, bright screen for displaying the AI avatar. The screen can be included in the MINTStation. These features ensure that patients can fully engage in their sessions while feeling at ease and supported throughout their mental health journey. In the graphic below you can see examples of potential MINT rooms.

Figure 9: Examples of a MINT treatment room. [16]

The MINTStation consists of a computer, a microphone, cameras, and a retina scanner. The station can be equipped with an integrated screen or connected to an existing one. The computer is used to run the programme and process the data. It has an internet connection to view appointment calendars of neighbouring psychologists and to upload patient results in encrypted form to the patient's account, but also to stay in contact with ROOT and REMUS.

The microphone records the patient's responses. These are understood and evaluated with the help of speech processing and machine learning algorithms. The camera films the patient to detect emotional movements in the patient's face and to take these into account in the analysis or, if necessary, to address them during the session. If necessary, the system will perform a retina scan to gather further information about the mental health of patient. The figure on the right shows the prototype of the station with integrated screen. The screen shows the humanised AI avatar during a session.

Figure 10: MINTStation prototype

App MINTSight

The MINTSight app and the MINT-test are closely linked and work together to provide comprehensive diagnosis and support for depression. The app uses diagnostic information and personal data about patients to create personalized mental health plans tailored to each patient's unique needs.

The app also offers self-monitoring and support features. For example, patients can view MINT-test results in the app and monitor their progress toward recovery. In addition, the app offers personalized advice and activities customized to the patient's needs to help them improve their mental health.

Overall, the MINT-test and app work together to provide comprehensive diagnosis and personalized support for depression.

The app can give the patient full access to the questionnaires and diagnostic results collected during the MINT-test. This can help the patient to better understand their symptoms and take appropriate self-help measures.

MINTSight includes the following functions:

+ Personalized mental health plan

The app creates a personalized mental health plan based on the patient's diagnosis results and needs. The plan can include suggestions for activities, therapies, self-help techniques, and other resources that can help improve the user's mental well-being.

+ Activity tracking and reminders

The patient can track his activities that have a positive impact on their mental well-being, such as exercise, meditation, or social interactions. The app can also send reminders of scheduled activities to ensure that the patient makes time for these activities on a regular basis.

+ Community support

With the provided community platform patients can share their experiences and support each other. This can make users feel like they are not alone with their problems and that there are others who have to master similar challenges.

+ Feedback and progress tracking

The app offers feedback system and comprehensive progress tracking features, empowering the patients to effectively monitor their mental well-being, make informed adjustments, and optimize their strategies for enhanced mental wellness.

+ Diary

A diary program helps patients organize their thoughts and feelings, helping them to better understand their mental state and document their progress. The diary can also be provided to the therapist to give them a better understanding of the patient's mental state.

+ Evaluation

The app provides questionnaires and tests to evaluate the mental well-being of the patients and gives them feedback on their current state. These tests can be similar to the MINT-test and ask questions about mood, stress, sleeping habits, and other factors to provide a comprehensive picture of the user's mental state.

+ Emergency function

In case of mental breakdown or suicidal thoughts, emergency mental advisors are available to the patient through the app. These are reachable by phone call or video chat.

The following figure shows the design of the user interface of the MINTSight app.

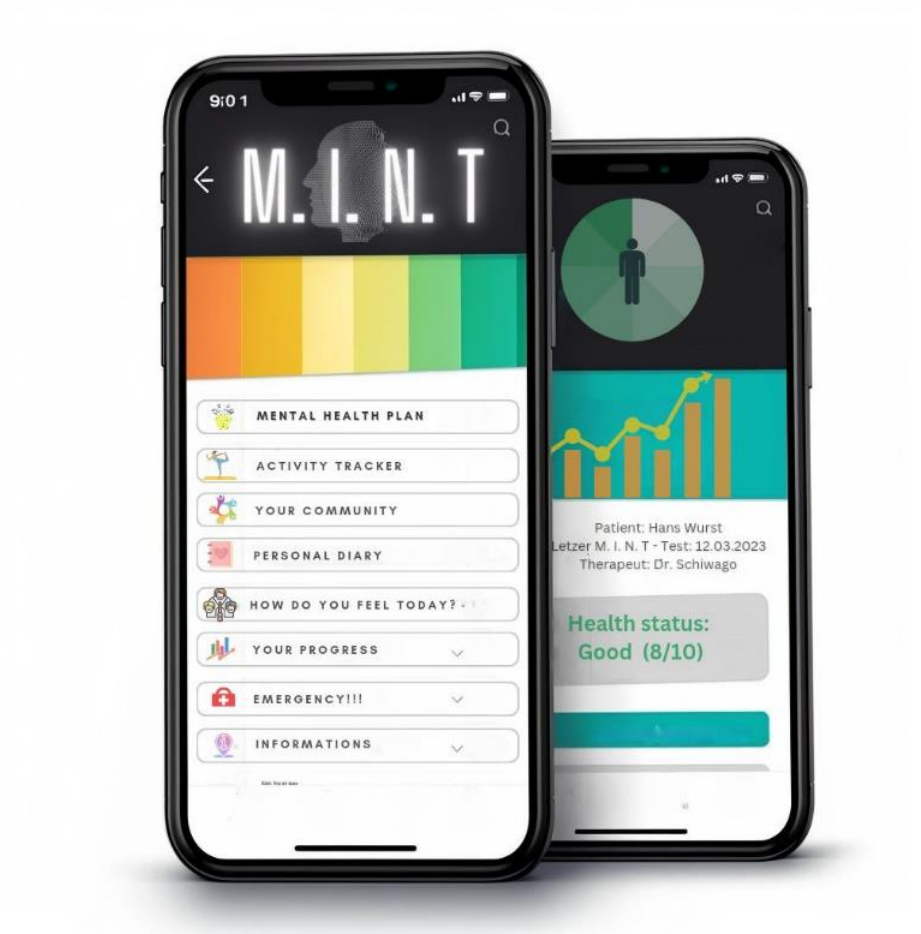


Figure 11: Example UI of MINTSight

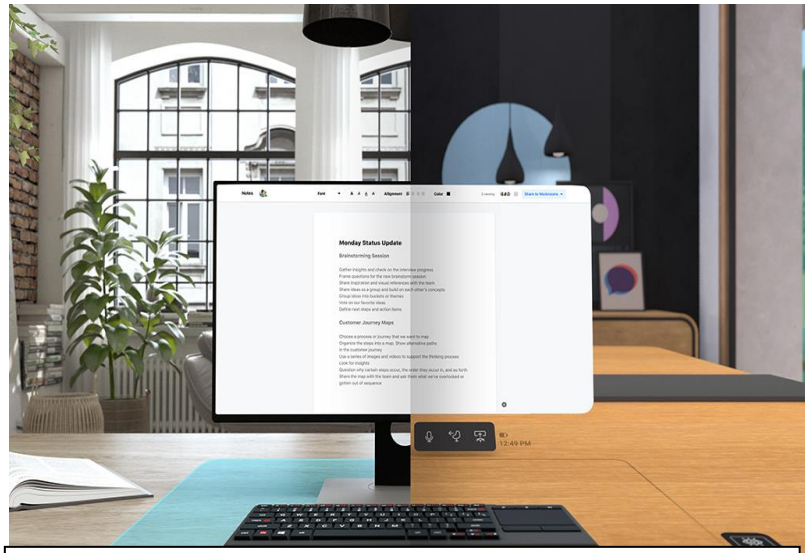
Portable version MINTGo

MINTGo refers to a virtual environment in which it is possible to complete the test for evaluation by the AI. This version is intended to serve as an alternative for all potential users who are unable or unwilling to visit a MINT room in person. Since, for example, physically disabled people can also have mental health problems, this version is meant to offer a possibility for all those who do not have direct and easy access to our stationary system. Even blind or people with extreme fear of visiting a doctor, shyness about personal contact with others (or whatever reasons there might be) can thus easily be introduced to MINT. All other features, such as access to the results in the MINTSight app, remain as before. As long as there is a connection to the Internet, all that is needed is a camera as well as a microphone, both of sufficiently good quality, and a device with the ability to enter the replies to the AI, which is shown on a screen. The AI on the screen guides you through the tests, just like in the regular MINT room, while gathering the needed data. To fully enjoy the virtual space, which follows the same guidelines as the MINT Room, a virtual reality capable hardware (like Oculus, Pico, …) is required.

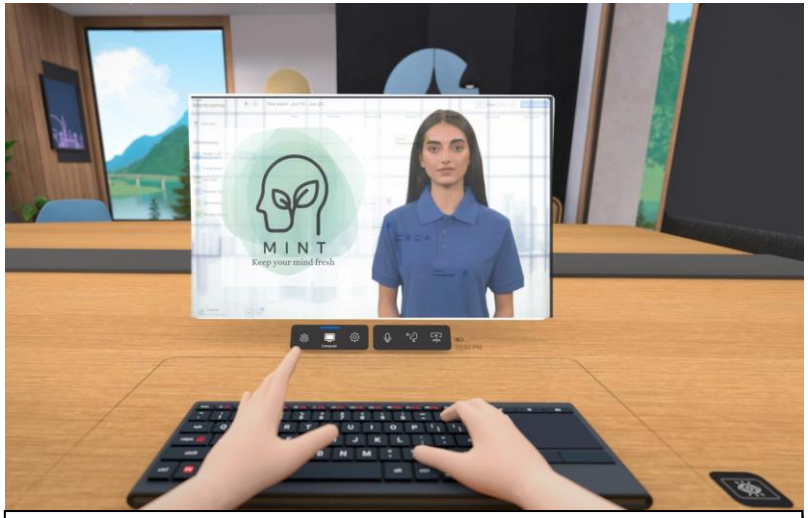
It is obvious that the results of the virtual test may not be one hundred percent as accurate as those from the MINT room, because there are not always the same lighting conditions, distances, cameras and microphones involved. Wearing VR glasses makes emotion recognition even more difficult for outside observers. However, it will be enough for a sufficiently accurate determination, since a general improvement of camera (retina scan) and microphone technology can be expected in the future. Also, the intention is, that after going through a MINTGo session, the possible aversion or fears that may exist against a system like MINT can be reduced to such an extent, that a normal MINT Room session loses deterrence.

The following pictures show examples of how a virtual space for the interview could look like. At the request of the user, it is possible to choose between different rooms and the general object design (see both upper pictures). The image below shows a MINT session on the screen after selecting the desired avatar. The images were created in Meta's Workspace, which provides a platform for creating VR content.

Third person view for supervisor



First person views different rooms.



First person during MINT session.

Figure 12: examples of VR MINTGo session [17, 18]

4.3 Technologies

AI

The AI will be the heart of the system. It will generate a humanised avatar that interacts with the user. The avatar will be personalized to create the most comfortable situation for the user. There will be two default avatars, one male and one female, but beyond that it will be possible to choose freely between gender, physical appearance, voice and speech similar to a computer game. With the option to personalise the avatar we want to provide design justice for every ethnic group. The following image shows examples of a selection of different avatars that can be generated with an AI and can simulate a real conversation (facial expressions, mouth movements and so on).

Figure 13: Examples of AI generated avatars [19]

The AI will lead a natural conversation with the user just like a psychological interview. During the conversation it will collect information about the mental and physical health of the user. It will ask questions according to the PHQ-9 (existing depressiveness questionnaire) and other psychological surveys. For example, how the user's sleep quality was in the last two weeks or if they felt depressed, anxious or unmotivated in that period of time. [20]

It will analyse the user's answers to the test in combination with the rest of the collected data - facial and voice processing, retina scan, heart variability - and evaluate the mental health of the user. Then, the AI offers each user an assessment of their mental stability and, optionally, an appointment with a therapist based on their needs.

Furthermore, the AI will generate a mental health plan for the user based on the evaluation. For the time after the session or till the therapist appointment, the mental health plan will be available in the app. It is possible to personalise the mental health plan according to the user's preferences, experience and schedule.

But why is AI used at all? The goal is explicitly not to replace doctors and therapists with an AI, but to help them and enable them to perform preliminary examinations and scheduling more quickly. In addition to the ease of generating and mimicking human appearance and behaviour to promote well-being and enable openness, AI offers other benefits. Since psychology is a very broad field and not always an exact science, it is not infrequently very difficult to correctly assess individuals based on their behaviour in a short period of time. At the beginning, the AI must be trained with databases (e.g., solved PHQ-9 tests and their results or human faces/voices with associated emotions). Then the AI must learn to combine the individual data streams and make the most precise assumptions possible about the mental state of the probands. That

means for example, that the AI must be able to decide which facial expressions, retina reaction or voice change are easy to fake, and which are not. The results must initially be verified by experts and the entire learning process should be monitored until finally, with a very high probability, disease patterns can be distinguished and classified. Even after this initial phase, MINT should be able to continuously improve its accuracy in determining mental illnesses, or possibly even provide developers with feedback on previously unrecognized correlations or other opportunities for enhancement. Due to the highly individual needs of experts, psychologists and users, the system must therefore remain adaptable, for which an AI is ideally suited.

Facial / speech recognition

Facial expressions in emotions (including micro-expressions) are universal and thus can be interpreted by humans or machines accordingly. Facial muscles generate hundreds of facial expressions of emotion, speech has many different dimensions - from pitch and resonance to melody and voice quality.

Based on the recognition and classification of such subconscious expressions, it should be possible to diagnose mental illnesses such as depression using only artificial intelligence (deep learning). [21, 22]

Existing technologies like from "Affectiva" already show the plausibility and the multitude of possible applications of such technologies. A large amount of accessible data enables the deep learning system to make increasingly accurate diagnoses. For example, "Affectiva" has built up the largest emotion database in the world. It stores more than ten million facial expressions of people from 87 countries. [21]

The general approach is based on four steps to provide algorithms with the ability to recognize emotions and subsequently classify a patient's state of mind through speech and face recognition.

1. Data acquisition: a database is created from its extensive collection of images and video recordings depicting faces with different emotions and audio recordings of people with different emotional states. The images and audio recordings are manually annotated to label the different emotions and mental states.
2. Feature extraction: the software then analyses all the features of the stored data, such as the position of the mouth, nose, eyebrows, and eyes for face recognition (to be seen in figure 14), and the features of the voice, such as volume, pitch, speech rate, and intonation. From all these analysed features, a unique pattern is created for each person and each motional state.
3. Model training: using the annotated data, a machine learning model is trained, which establishes a link between recognized features and the corresponding emotions.
4. Emotion recognition: after sufficient training of the software, the program can be applied to new input. The model analyses the various visual and auditory features of a person and determines the most likely

mental state. This is done by comparing the detected features with the learned patterns. With the help of the high-resolution camera and a microphone, the voice and facial expression can be continuously recorded during a MINT session. [23]

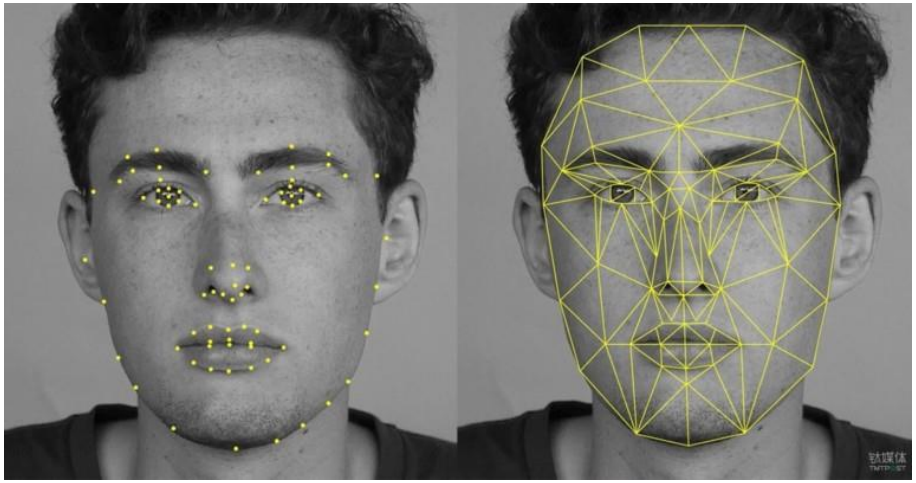


Figure 14: Feature extraction of the important points in the face for emotion recognition [24]

According to "Affectiva", the challenging aspects of Deep learning in terms of emotion recognition are:

- "Multi-modal – Human emotions and cognitive states manifest in a variety of ways including your tone of voice and your face.
- Many expressions – Facial muscles generate hundreds of facial expressions of emotion; speech has many different dimensions – from pitch and resonance to melody and voice quality.
- Highly nuanced – Expressions, cognitive states and emotions can be very nuanced and subtle, like an eye twitch or your pause patterns when speaking.
- Temporal lapse – As emotions unfold over time algorithms need to measure moment by moment changes to accurately depict emotional state.
- Non-deterministic – Changes in facial or vocal expressions, can have different meanings depending on the person's context at that time.
- Beyond emotions – Facial and vocal analysis provides broader people analytics such as cognitive states and demographics.
- Massive data – Human Perception AI algorithms need to be trained with massive amounts of real-world data that is collected and annotated.
- Context – Emotion and expression metrics measured in education are different than those needed in automotive, mobile, or customer care" [21]

Retina scan

Various scientific studies from 2022 show a correlation between retinal parameters, such as vessel density and thickness, and emerging mental illnesses.

The retina is the only neurovascular tissue in the body that is visible and thus provides an easy overview of systemic neurovascular conditions. Using a novel imaging technique called OCTA (Optical Coherance Tomography Angiography), the retina can be examined non-invasively. Normally, this technique is used to detect ocular diseases. Retinal examination is already used as an established method for the diagnosis of other mental disorders, such as schizophrenia and bipolar disorder (see Figure 15).

Studies have shown that MDD (major depressive disorder) patients have lower vessel density, thinner retinal structures and poorer visual function compared to healthy controls. Based on these findings, a system could be developed for potentially effective early detection and evaluation of MDD. [25, 26]

Using OCTA and image processing algorithms that segment retinal parameters allows MINT to detect evidence of depression at an early stage. Continuous improvement in imaging techniques will make retinal examination even easier and more effective in the future, enabling its use as part of the MINT-system.

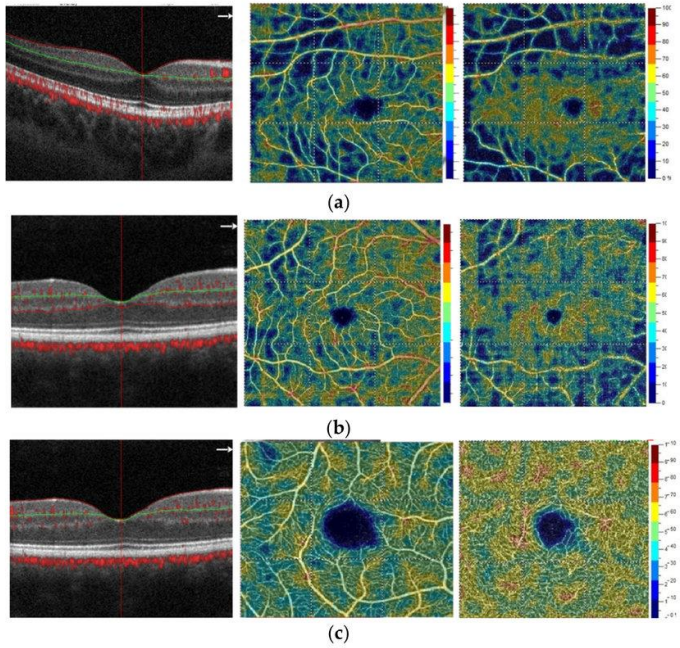


Figure 15: OCTA of the macular vessel density-B-scan, superficial vascular complex, deep vascular complex-in the right eye of patient with (a) schizophrenia, (b) bipolar disorder, (c) control group. [27]

Heart rate variability

Heart rate variability (HRV) refers to the variation in time between successive heartbeats. A healthy heart shows a variable beat rate, which is reflected in a varying time between successive heartbeats. A low heart rate variability is not only an indicator for an increased risk of cardiovascular diseases but also for mental diseases.

Thus, low HRV may be associated with various mental health conditions, including depression, anxiety, and post-traumatic stress disorder. The difference in HRV of a stressed person and a happy person is shown in Figure 16. Some studies suggest that people with depression tend to have lower HRV than people without depression. Understudies show that lower HRV in depression indicates autonomic nervous system dysregulation. In people with depression, there appears to be excessive sympathetic nervous system activity and decreased parasympathetic nervous system activity, which may result in lower HRV.

In combination with additional diagnostic tools, HRV represents a promising method for detecting depressions.

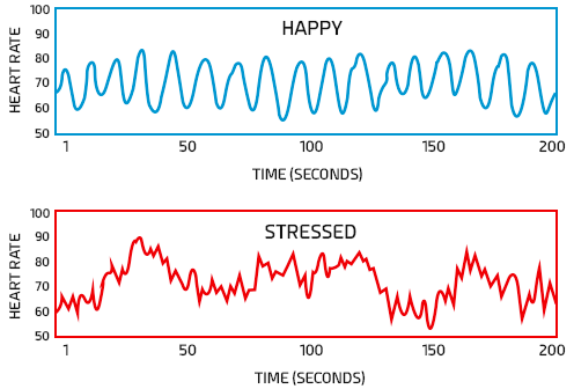


Figure 16: The difference of HRV of a stressed and a happy person [28]

Typically, HRV is measured over a period of 24 hours or longer to capture a sufficient number of inter-beat intervals. HRV can also be measured by special apps or wearables that measure inter-beat intervals through an optical sensor or accelerometer. The most appropriate method for measuring heart rate variability (HRV) in a watch or bracelet is the photoplethysmography (PPG) method. PPG is based on measuring the light absorption and reflection of tissue to determine blood flow and thus heart rate. This is a widely used method for determining heart rate in wearable devices such as fitness trackers and smartwatches.

The PPG method has the advantage that it is easy to implement and does not require large equipment such as ECG monitors. It can also be measured continuously, which allows HRV to be monitored over longer periods of time. There are many wearable devices that use PPG to

measure heart rate and HRV, such as the Apple Watch. Thus, the results could be directly synchronized with the app and evaluated. It could also be measured permanently after the MINT-session during the therapy process and thus permanently collect data about the state of mind. [29–31]

ROOT - Data processing - CERN Tech

One of the suitable CERN technologies used in MINT for data processing and storage is ROOT. It is an open-source high-performance software that provides an object-oriented toolbox for handling and analysing huge amounts of data in a very efficient way. This is possible because ROOT converts the collected data into a set of objects and uses special vertical storage methods to gain direct access to every single attribute within these objects, without having to search through the entire files. The software provides methods for histogram in multiple dimensions, function evaluation, minimisation, curve fitting, cluster finding algorithms and visualization tools. A graphical user interface can be used to setup an analysis system fast an easy, but it is also possible to interact with ROOT via the command line or batch scripts. While the command and scripting or macro language is C++ (interpreter), ROOT has a powerful Python – C++ binding, making it possible to use Jupyter (Julia, Python, and R) as well. It can be dynamically extended by linking external libraries or scripts and can query its databases in parallel on clusters of workstations or on many-core machines. To further accelerate data processing, the database is optimized for the parallel access of multiple processes at the same time (writing and reading of many parties, all simultaneously). Since MINT has to manage and analyse very large amounts of data to deliver realistic results, ROOT is an ideal way to speed up the processing (For data protection considerations see next section). [32–35]

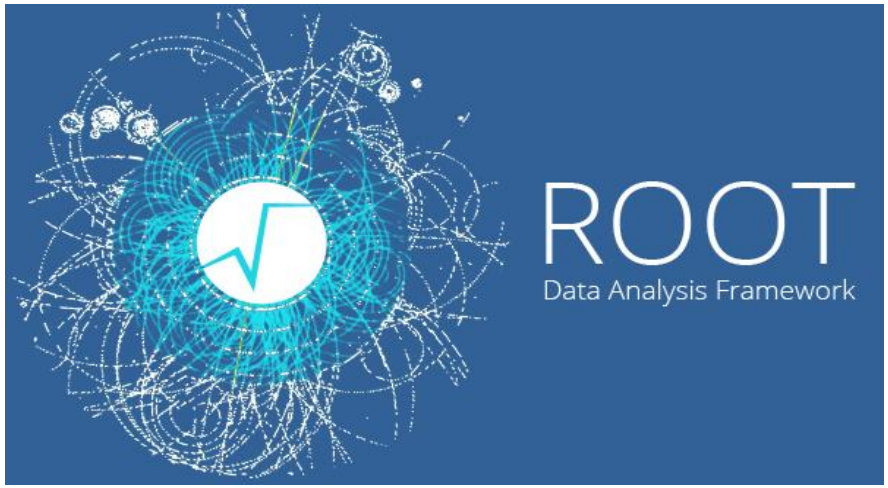


Figure 17: ROOT logo

REMUS - Data acquisition – CERN Tech

Lastly, the CERN technology REMUS will be implemented. It is a supervision, control and data acquisition system (SCADA). The program is ideal for data acquisition of measurements and events that come from

sensors (e.g., camera and microphone). The customizable user interface allows the real-time measurement, monitoring and control of multiple different instruments at the same time. In addition, the installation of new instruments during operation is possible and it is designed to be as scalable and adaptable as possible. Thanks to the complete redundancy and high reliability, updates can be performed without rebooting or downtime of the whole system. It is also capable of sending an alarm in case of malfunctions or when a limit in measurements is reached. If there is a certain urgency to act based on the tests, REMUS can send an alert to the AI in order to provide help as quickly as possible. So, the task of REMUS in our system would be the monitoring and maintenance of the MINT devices and the data collection. The collected data can then be passed from REMUS on to the AI and ROOT for storage and analysis. [36]

Data security

In today's largely digital world, data protection is playing an ever-increasing role. Since MINT collects large amounts of sensitive and personal data, some privacy considerations must be implemented to protect the users and to comply with directives like the General Data Protection Regulation (GDPR) from the EU. Basically, they aim to protect the rights and freedom of each individual. At the beginning the user can generate a MINT account with a login name and a password. Per easy understandable button it is possible to decide if the data will be stored on the server or not. Under this new synonym name the data can be collected and saved on the server if the user wants to. If not, the acquired data will be deleted after evaluation and will only remain on the phone of the user, as long as the app is installed, and the user is logged in. Administrators also have no access to personal patient data. While any personal data is being transferred between the system components, user and doctor, the data is encrypted end-to-end. To see a patient's record, doctors must send a request to the person, who can than confirm it in the app. If a connection between the health insurance company and the MINT system is desired by the user, this must be confirmed separately and linked online via form. This is to ensure that no third party has access to the data at any time. [37]

5 Value

The value of the MINT system lies in its ability to revolutionize the approach to mental health by leveraging advanced artificial intelligence (AI) techniques. This chapter discusses the value proposition of MINT, highlighting the benefits it brings to both patients and mental health professionals. By providing a comprehensive mental health evaluation, facilitating efficient scheduling, prioritizing high-risk cases, and fostering collaborative treatment planning, MINT offers significant advantages over traditional methods.

MINT's AI avatar engages in therapeutic conversations with patients, creating a comfortable and non-judgmental environment for them to express their thoughts and concerns. This empathetic interaction helps patients feel understood and supported throughout their mental health journey. By utilizing various sensors and technologies, MINT gathers essential information about patients' well-being, such as their emotional state, sleep patterns, and activity levels. This data enhances the accuracy of the mental health evaluation, leading to more personalized treatment recommendations. As a result, patients receive improved and targeted care, ultimately contributing to their overall well-being.

MINT's integration with cutting-edge CERN technologies, such as ROOT and REMUS, enables seamless data processing and analysis. Mental health professionals can access valuable insights and visualizations derived from the collected information. This streamlined workflow reduces administrative burdens, allowing therapists to focus more on patient care. By automating appointment scheduling, MINT optimizes the allocation of resources and reduces waiting times for patients. Furthermore, MINT's ability to prioritize high-risk cases ensures that critical cases receive prompt attention, potentially preventing crises or urgent situations.

MINT fosters collaboration between therapists, patients, and the AI system itself. Through regular interactions with the AI avatar, patients actively participate in their treatment journey. MINT helps patients gain a better understanding of their mental health status and guides them in setting realistic goals. The system then collaborates with therapists to develop a personalized mental health plan based on evidence-based recommendations. This collaborative approach empowers patients and enhances treatment adherence, leading to more effective outcomes.

By leveraging the capabilities of AI, MINT has the potential to transform the way mental health is approached and treated. The system's ability to

provide optimal treatment recommendations based on comprehensive evaluations helps therapists make informed decisions. This data-driven approach ensures that patients receive appropriate care tailored to their specific needs, potentially improving treatment outcomes and reducing the trial-and-error nature of traditional methods. Furthermore, MINT contributes to the overall advancement of mental health research by collecting anonymized and aggregated data, which can be used to gain valuable insights into patterns, trends, and the effectiveness of various interventions.

In conclusion, the MINT system offers substantial value to both patients and mental health professionals. By combining AI, sensor technologies, and the power of CERN technologies, MINT provides improved patient care, streamlines workflows for mental health professionals, promotes collaborative treatment planning, and has the potential to transform the field of mental health. The implementation of MINT has the ability to revolutionize mental health practices, enhance treatment outcomes, and contribute to ongoing research in the field, ultimately leading to a more effective and personalized approach to mental health care.

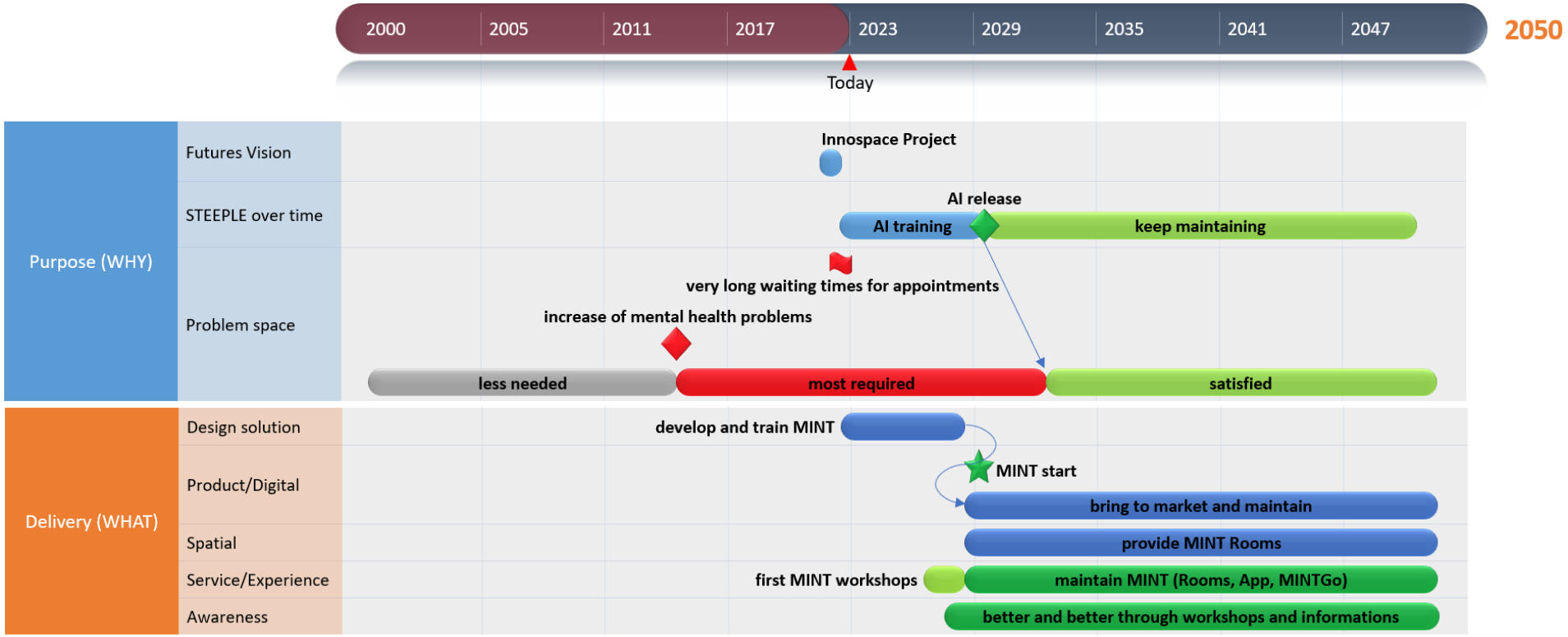
6 Further Development

We now know what MINT can do and how it works. But before MINT is ready to offer its services to mankind, there is still some work to be done. The best way to explain what must be achieved so that MINT can be realized is to look at a timeline. Our journey through the implementation roadmap starts in the year 2000. At that time mental problems were much rarer or at least more unnoticed than today. Since the beginning of the 21st century the numbers are steadily increasing. One of the largest increases up to now occurred around 2011 to approx. 2015. But the increases continue until today. [38]

Because the capacities for specialists (therapists) in this field are not increasing at the same time or in the same amount, this inevitably leads to a shortage of free places and long waiting times for appointments. This is where the CBI project comes into play. Through the content of the lectures at CERN our future visions could take shape. In order to be able to launch MINT on the market by 2030, in-depth research must first be carried out on the subject. For this purpose, interviews have already been conducted with therapists and their opinions have been brought in.

After it is clear that the idea meets with the approval of the experts, the first considerations must be made regarding financing. For training the AI, setting up all program structures and further R&D, a lot of money is needed, especially at the beginning of this phase. First attempts can be made to contact governmental organizations and health insurance companies to find support there. Other donors such as pharmaceutical companies or non-profit organizations can also be contacted. After investors are found, patents and licenses must be obtained. The approval of devices in the medical field is expensive and lengthy, which is why it should be started as early as possible. Once these hurdles have been cleared, the development, improvement and training phase of the MINT system and the AI can begin. General programmers and experts in the field of mental illness are needed for this. The partnership with them will last for a long time, because even after the end of the development phase, some will continue to be needed for maintenance. Before the release of the system, the amount of money required increases again, because the raw materials and the costs for the production of the MINT rooms and devices are needed. Mainly simple materials like wood, plastic, metal and electrical equipment are used. Of course, water, space and electricity etc. are also necessary. The CERN technologies ROOT and REMUS must now also be set up. If there is still not enough money,

there should now be a further attempt to find donors in order to avoid becoming insolvent. Initial awareness and alerting workshops should also be started before the launch of MINT. Maintenance staff and employees for the MINT rooms must be hired. When the System and the initial MINT Rooms are ready (ideally shortly before the release in 2030) MINT can come to the market. If the workshops have been effective, the first income should be generated by the system shortly after the start of the program. Not too much should change from now on. The number of employees required for maintaining the software, the devices and the rooms should no longer vary greatly. The costs for the technologies should remain approximately the same. Ideally, awareness should remain high, which is why workshops should continue to be offered. If everything worked out, the problem of the high number of mental illness cases and the long waiting times for medical help should decrease quickly and then stay at a low level, thanks to MINT.



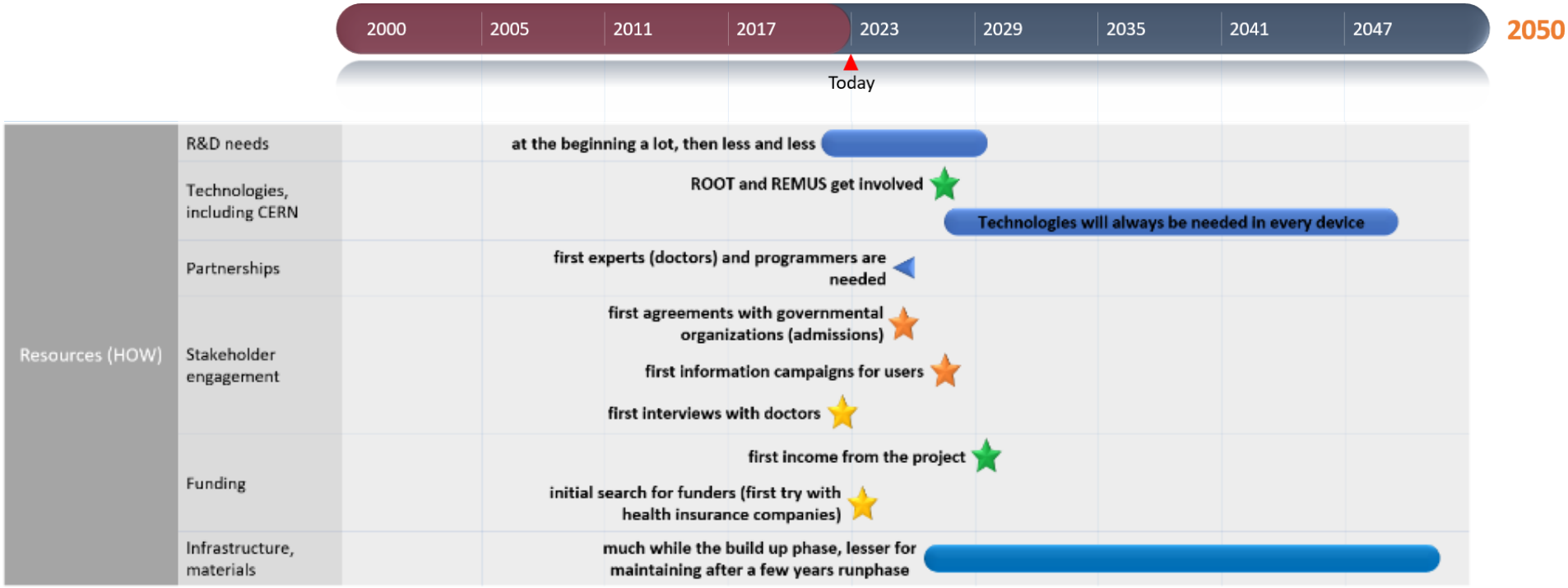


Figure 18: Implementation Roadmap

7 Conclusion

The MINT project, developed by four students from Mannheim University of Applied Sciences, aimed to create an AI system that revolutionizes the approach to mental health. The solution was created based on the United Nations SDG number 3: good health and wellbeing, with a focus on psychological health. Over the course of eight months, starting in September 2022 and ending in May 2023, the project team successfully developed the MINT system – Mental health INTelligence. This system utilizes an AI avatar, advanced sensors, and cutting-edge CERN technologies to engage in therapeutic conversations, gather essential information, and provide optimal treatment recommendations to patients.

Throughout the project, the team achieved significant milestones. The AI avatar was designed to provide a comfortable and empathetic environment for patients, ensuring effective communication during therapeutic conversations. The integration of various sensors and technologies enabled the collection of essential patient data, enhancing the accuracy of mental health evaluations. The utilization of CERN technologies, namely ROOT and REMUS, facilitated seamless data processing and analysis, streamlining the workflow for mental health professionals.

The system successfully automated appointment scheduling, prioritized high-risk cases, and fostered collaborative treatment planning between therapists, patients, and the AI system.

The MINT system has the potential to bring significant contributions to the field of mental health. By providing improved patient care, MINT enhances the overall well-being of individuals by offering targeted and personalized treatment recommendations. The system optimizes the allocation of resources, reduces waiting times, and prioritizes high-risk cases, thereby addressing urgent mental health needs efficiently. Through collaborative treatment planning, MINT empowers patients and fosters active participation in their own mental health journey. Additionally, the collection of anonymized and aggregated data by MINT contributes to ongoing research, allowing for insights into patterns, trends, and the effectiveness of various interventions.

The development of the MINT system was not without its challenges. The interdisciplinary nature of the project required effective communication and collaboration between the team members from different backgrounds—two chemical engineers, one medical engineer, and one software engineer. Overcoming technical complexities and integrating AI algorithms effectively were some of the challenges

encountered. However, the team successfully navigated these obstacles through effective project management, teamwork, and continuous learning.

While the MINT project has achieved its initial goals, there are several avenues for future development and improvement. The system could be further enhanced by incorporating natural language processing algorithms to improve conversation quality and depth. Integration with wearable devices and other IoT technologies could expand the range of data collected, providing a more comprehensive understanding of patients' mental health. Moreover, the system could benefit from ongoing user feedback and iterative improvements to ensure its continued effectiveness and relevance in real-world scenarios.

In conclusion, the MINT project has successfully developed an innovative AI system that has the potential to transform the approach to mental health. Through the combined efforts of the team members from different disciplines, the MINT system provides improved patient care, streamlines workflows for mental health professionals, and promotes collaborative treatment planning. The project's achievements highlight the value of interdisciplinary collaboration, cutting-edge technologies, and a human-centric approach to mental health. The MINT system has the potential to make a significant impact on mental health practices, improve treatment outcomes, and contribute to ongoing research in the field.

THE TEAM

PALU.DISA

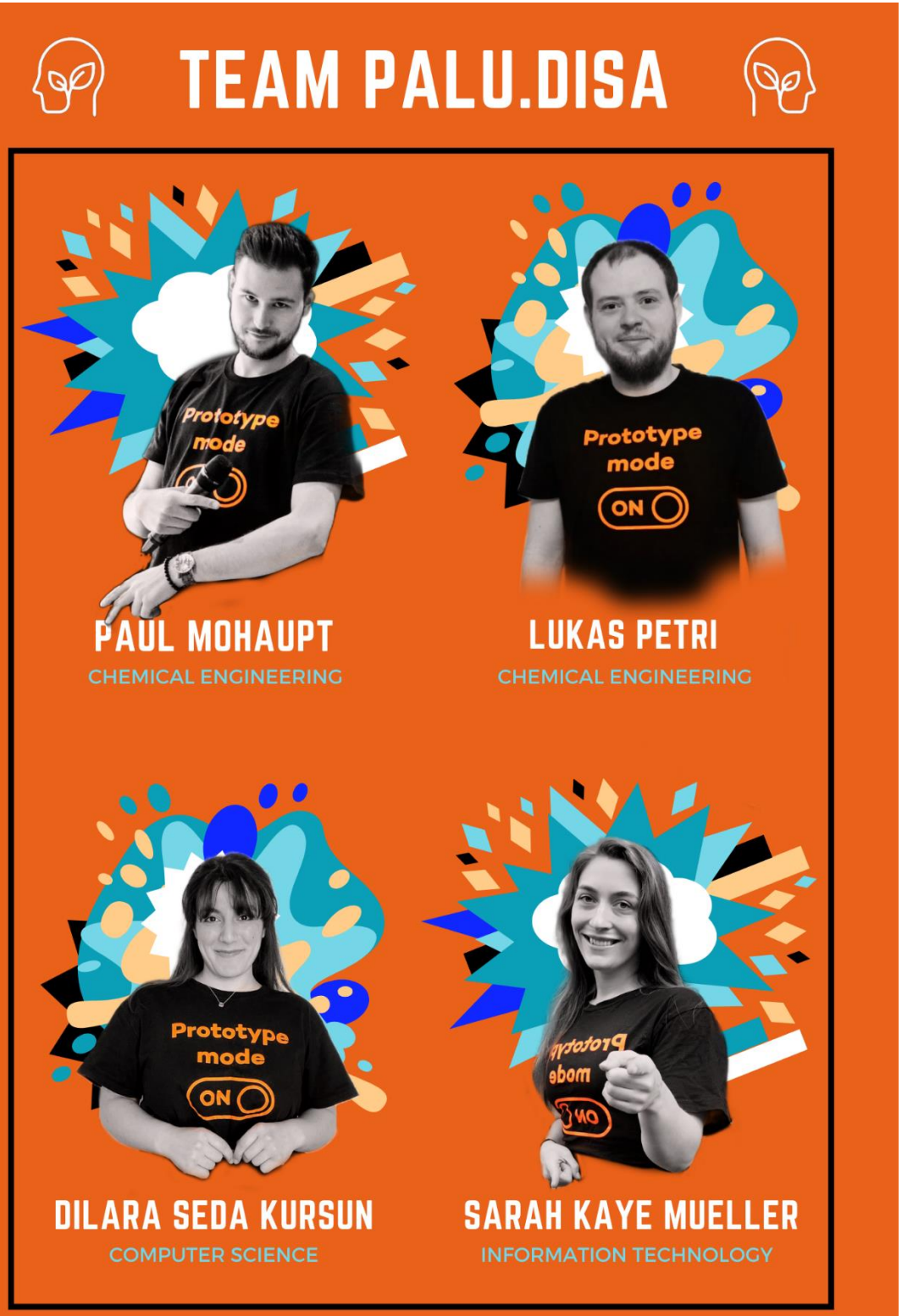


Figure 21: Team poster

Paul

Value of innovating

As part of the CBI project, you learn interdisciplinary skills that no normal course of study can offer. Especially the deep insight into future-oriented technologies of ATTRACT and CERN gives the students a profound understanding of technology. Learning about such technologies in their infancy is very exciting. The special thing about CBI is that it relates the whole project to actual important problems of mankind and thus shows the students at a young age what needs to be done for a better future.

Personal highlight

My absolute highlight was the two-week trip to CERN. As a tech-savvy student, it was very exciting to learn about the technologies that answer the big questions of the universe. Brainstorming and developing ideas there with students from all over the world is an experience that was not only my highlight of the CBI project, but even of my whole studies. It was also very amazing to see how with a slightly different mindset you are able to come up with numerous ideas to solve real problems in a very short time.

Lukas

Value of innovating

The possibility of using innovative and futuristic approaches to solve existing problems with future technologies opens a completely new way of looking at them. Thus, novel and perhaps previously impossible solutions can be found and integrated to address projects step by step. In addition, future problem areas are identified at an early stage and could be prevented from occurring.

Personal highlight

Working together with people from different fields and countries allows access to a variety of views that each individual would not have been able to generate all on his or her own. The combination of future thinking and clearly set goals to improve the world provides additional motivation. In some areas, the latest state of the art is presented and explained or discussed in a way that is easy to understand, even for those not familiar with the subject. These newly acquired perspectives and methods help in working on future projects and allow a confident outlook no matter how intractable it may seem at the beginning.

Dilara

Value of innovating

Deep tech is often associated with futuristic and far-out technologies, but at CBI, we're putting the focus back on people. By harnessing the power of deep tech to address human needs, we're unlocking new opportunities and opening doors to a brighter future, where innovation and progress are driven by a commitment to make a positive impact on the world. And I think - I hope - we made it.

Personal highlight

One aspect that stands out for me is our project's theme. Mental health is often overlooked, yet it is crucially important and valuable. It directly impacts our quality of life and should be given the attention it deserves. Considering the odds of having encountered it already or being affected by mental health problems in the future, it is of utmost importance to handle this matter with caution and take proactive steps.

Sarah

Value of innovating

I had the incredible opportunity to unleash the power of deep technology, explore with curiosity, and innovate with purpose in our CBI project. Witnessing a glimpse of how deep tech could transform our world for the better was truly inspiring. This exciting journey continues to captivate me, and I look forward to continuing to learn more about and work with deep technologies.

Personal highlight

Participating in the CBI project was a defining moment for me, as it allowed me to contribute to a larger goal through our topic-using innovative approaches to address the critical importance of mental health in our lives. Through this journey, I have gained deeper insights into mental health, treatment and the pressing challenges we face today and in the future. I have realized the importance of prioritizing mental health on a personal and societal level. This experience has inspired me to pay more attention to my own mental wellbeing and to be more mindful of the mental health of those around me.

Figure 22: Team picture at CERN Ideasquare

APPENDIX

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