



MMC Ventures
Technological
Revolution In
Mental Health

Research Report *2022*

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MMC

The technological revolution in mental health

At the height of the COVID-19 pandemic, another global epidemic was blown into the spotlight – mental health. And we all turned to technology to help us solve it.

Mental health is a huge burden on the global healthcare system and the economy. However – it remains highly under-recognised.

In 2019, nearly a billion people were living with a mental disorder, with more than half of the population in middle- and high-income countries affected by a mental disorder at some point in their lives [1]. **Mental disorders are the leading cause of disability, causing 1 in 5 years lived with disability worldwide.** This has a significant impact on the economy – the cumulative economic output loss associated with mental disorders is expected to be **US\$ 16.3 trillion** worldwide. The two most common conditions of depression and anxiety cost the global economy US\$1 trillion each year – and this figure is expected to keep increasing.

Challenges associated with mental health were exacerbated by the COVID-19 pandemic – with **depression and anxiety going up by more than 25% in the first year of the pandemic alone.** However, the need for social distancing and remote working also **accelerated digital change** and **technology was quickly hailed as the answer** we needed.

Today, there is an “urgent need to transform mental health and mental health care” (WHO), and disruptive technology offers a tremendous opportunity to help accelerate and enable this transformation.

To date, we have seen an era of digital innovation bringing tech-enabled health services to the forefront through telehealth, which connects a doctor or therapist with a patient through a video call. We have also seen the rise of consumer apps promoting mental health awareness and routine stress-reducing solutions.

Fundamentally, we believe there will be a shift from tech-enabled mental healthcare to data-driven mental healthcare. Through connected devices, mobile phones, and other wearable technology, we are gathering more data on how we act, behave, speak, or learn than ever before. This data will be paramount to how we monitor, diagnose, treat, and even understand a broad spectrum of mental disorders in future.

We have explored the mental health landscape, how technology has shaped the industry to date and the technologies that will be the driving force in future to be effective in improving clinical outcomes.



Image: By Nik Shuliahin

A complex and rapidly changing space

Defining mental health

Mental health refers to an individual's emotional, psychological, and social wellbeing. Mental illness more specifically looks at conditions that change a person's mind, emotions, or behaviour (or all three) [2,3].

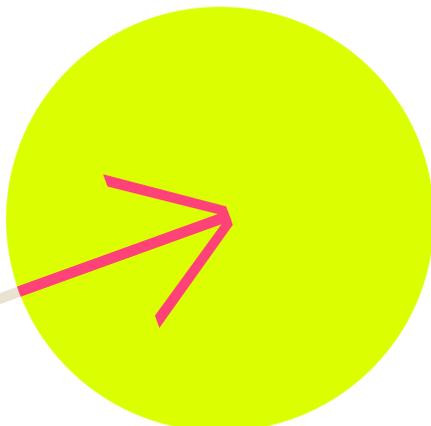
The spectrum encompassed by the term mental health is complicated and somewhat vague. It can range from normal feelings of stress or feeling low (under a clinical threshold) to generalised and long-term anxiety or depression – that may lead to physiological changes in the brain makeup (termed Major Depressive Disorder or MDD and Generalised Anxiety Disorder or GAD) which are above a clinical threshold. We also include in our consideration of mental health developmental and ageing disorders such as attention deficit disorders (e.g., ADHD) or Alzheimer's disease, which are not well understood.

One key difference along this spectrum revolves around clinical involvement – helping dissociate the more severe end, involving health services or “mental healthcare” to the less structured and more general consumer offerings termed as “wellness” or “wellbeing”.

For our research, we analysed over 200 “digital mental health” companies using some aspect of technology applied to mental health or mental well-being. From a technology standpoint, we chose to categorise them into two segments.

● **Maturing mental health solutions** – solutions which have typically taken the form of **an app** delivering self-guided wellness, or meditation as well as educational content, therefore, predominantly targeting the **sub-clinical end** of the spectrum. We also consider solutions that look at using information and communication technologies for the provision of **remote telehealth** services.

● **Emerging, data-driven, technologies** – platforms that integrate personalised data and use advanced computational psychiatry methods to help identify new markers of mental disease. The technologies further provide complex and adaptive digital therapeutics that allow for individual treatment programmes. These solutions target the entire spectrum but critically look to tackle clinical populations and problems – driving **superior clinical outcomes either with or without the involvement of clinicians**.



Challenges to achieving better global mental health outcomes

It is generally recognised by The Lancet, the World Health Organization (WHO) and others that there are significant global challenges to positive changes in mental health.

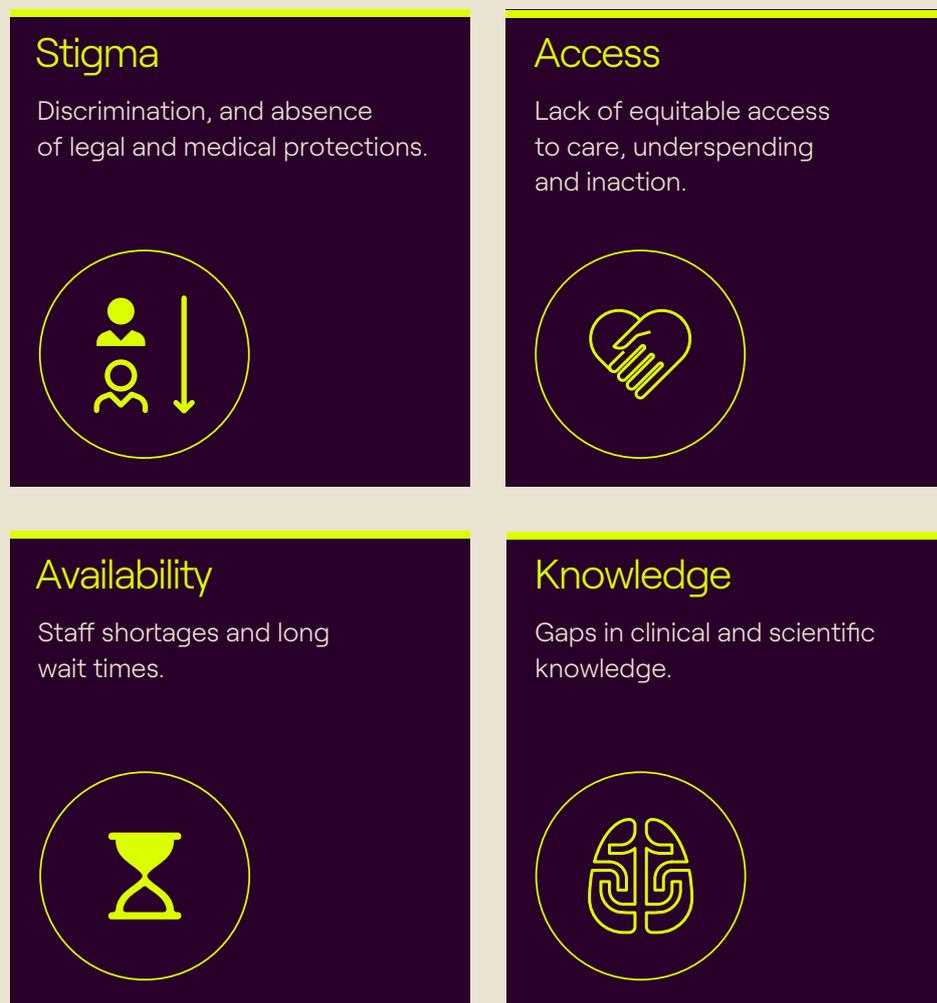


Figure 1: Major Challenges to achieving better global mental health outcomes (adapted from Deloitte).

● **Stigma and discrimination;** Individuals facing mental ill-health face greater stigma and discrimination than those with physical disabilities [4]. This stigma and discrimination, which may exacerbate mental health conditions, can be seen throughout society and more prominently in both employers and the media [5]. These views often impact a person's ability to find work or live in decent housing as well as be included in mainstream society [6].

● **Access** to specialised mental health care is subject to extreme regional variations with 123 million Americans living in a designated mental health shortage area and across the country [7], fewer than half the individuals in need of mental health services receiving care [8]. In the UK, the pattern is much the same, with waiting times to see a mental health professional varying starkly between less than 10 days in 26% of trusts to over 31 days in 10% of them – and at worst, in some UK regions patients must wait up to 65 days to see any sort of mental health trained professional.

● **The availability of mental health services is also facing** deep challenges, which has seen little growth over the last 10 years despite the increasing demand [9, 10]. This is not about to change as the severe shortage of mental health clinicians is expected to remain constant over the next few years [11].

● **Research into understanding mental health disorders is sparse and has long depended on heuristics and old conventions.** This has seen impacts reverberating through the care pathway, most notably on treatment. Clear treatment options for mental health problems are often very scarce and have limited efficacy. Despite heavy investment [12], new drug development discoveries have been sparse since the 1950s. For example, only 54% of adults with depression show any sign of improvement after medication [13], and even fewer are actively in remission. Drug adherence, due to side effects and perceived ineffectiveness, is lower than in most other disciplines. This can be attributed to several accumulated factors to lead to this, one of which is the overall difficulty of understanding and measuring the brain and the behaviour it generates [14]. This has led to unclear classification, with a lack of discrete categorisation between disorders, as well as a lack of clinical ability to measure change. Currently, there are no approved biomarkers as part of the diagnostic criteria for any psychiatric disorder. For example, the diagnosis of MDD relies only on clinical and subjective evaluation of symptoms. Similarly, diagnosis, even for the most well-defined conditions, is fraught with errors, with nearly 75% of schizoaffective disorders being misdiagnosed [15].

Most of the world's population lacks access to affordable, effective, and timely mental health care, despite the large increase in telemedicine platforms. However, modern advances in our ability to collect and analyse data mean that we can now start creating a more detailed understanding of brain functionality to a level that may have a positive impact across neurology and psychiatry.

Driving change in mental health

Having determined some of the key drivers of change in mental health, we have started to see the initial stages of transformation in the field and expect the next wave of truly disruptive and transmutative technology to have a tangible impact on mental health services – from the provision of care to the fundamental understanding of the brain under altered states.

1

An increased understanding and consideration for mental health care. Whilst stigma still exists, the taboos around mental health are slowly diminishing. Employers are accepting the importance of mental health in their workforce and investing in their workforce. The COVID-19 pandemic accelerated the acceptance of mental health as a substantial issue both at the employer and individual level and drove an appetite for new treatment models.

2

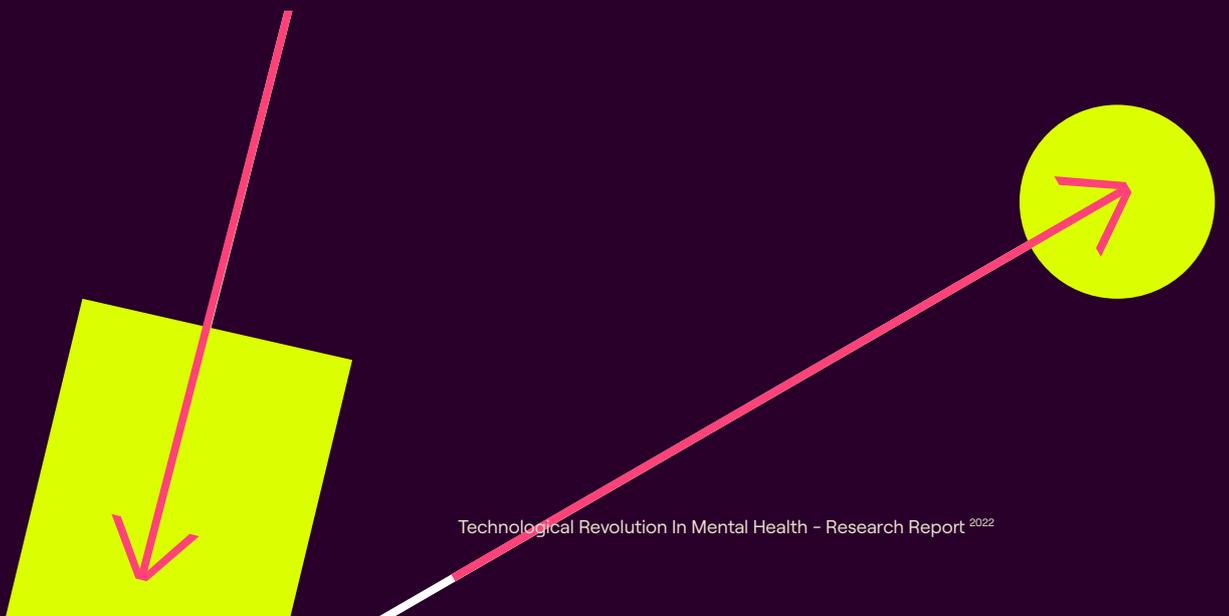
Acceptance of virtual healthcare. Telemedicine technology has been available for many years, but penetration has been low. As mobile phones and modes of digital access have proliferated, so has people's acceptance and trust of digital health services. This was further accelerated by the COVID-19 pandemic as most of our lives moved to a remote first approach. Now Gen Zs are 4x more likely than Baby Boomers to prefer virtual care to in-person care. With more than 70% of younger generations saying they prefer telehealth and 44% saying they may switch health provider if telehealth visits aren't available going forward [16]. In addition, certain patient groups and communities, which have historically faced stigma and discrimination [17], find virtual or digital care more accessible and preferable.

3

Improved sensors in mobiles and wearables. Consumer products containing sensors are sophisticated to capture clinical (e.g., heart rate) and behavioural (e.g., movement) information. This increased level of sophistication in consumer technology mean they can now act as a platform for a host of data collection technologies. This is in line with the trend we see with the "Consumerisation of Healthcare" (see this trend in our [MMC digital health thesis](#)) where individuals are more informed on their health and are looking for a better service from their providers based on their personalised data.

4

The sophistication of new technologies to drive a better understanding of mental health. Data analysis has gone multi-modal, combining neuroimaging technologies with real-world behavioural data and improved computational modelling, welcoming a new era of Big Data in Psychiatry [18]. Rapidly advancing research into next-generation machine learning platforms (e.g. through federated learning [19] or transfer learning, which can learn from siloed datasets and apply the learnings elsewhere) is allowing for better decision making from the bench to bedside. Machine learning and computational modelling methods are enabling insights into ever more significant and more complicated data sets, promoting a better understanding of the specific mechanisms of disorders [20]. Therefore, the development of more robust algorithms can be used to surface insights which historically haven't been possible due to limited data and compute.



Role of technology in increasing global access to mental health care

Technology has already transformed most of the world and industries beyond any possible recognition compared to only a decade ago – and it is set to transform the mental health sector as well.

The initial success of digital mental health has led to impressive and rapid growth in the number of digital mental health solutions. There are over 10,000 apps related to mental health in the Apple and Google Play stores [21]. This growth has been **largely unregulated and most of these 10,000 solutions are not evidence-based [22]. This growth has mainly been driven by employers and consumers who, whilst initial clinical evidence is often required, this is not something that is accurately tracked in most cases.**

This initially led to a slowdown in adoption, partly due to market saturation, but also due to challenges of clinical effectiveness [23, 24]. Without a solid evidence base and scientific backing, clinical practitioners are unlikely to use or recommend tools to their patients [25]. The importance of clinical rigour and the need for governance is now being recognised [26]. Platforms, such as [Syndi Health](#) are offering rankings and evaluations of the clinical effectiveness of hundreds of these digital mental health apps allowing users to be more confident when making healthcare choices.

Defining data driven technologies and precision mental health

‘Data-driven’ technologies work, by collecting and analysing data, usually from the patients to inform and support the level of care provided. Artificial Intelligence is a type of data-driven technology used to derive insights from large data sets as well as leverage these data to predict outcomes.

Precision mental health aims to apply the insights from data-driven technologies as well as utilise decision-making solutions and prediction abilities of AI models to accurately predict the right treatment, at the right time in the right dose for the right person. In mental health, this also includes the ability to design a new treatment protocol at an individual patient level.

The potential for data-driven and automated technologies to unlock some of the other key challenges in mental health such as reducing stigma, increasing availability, and increasing our fundamental understanding of the cognitive and biological processes that malfunction in mental health.

Financial landscape: A story of two sizes

The incredible growth of digital mental health services cannot be properly understood without considering the financial landscape. Below, we summarise findings from a study of the funding and deal history of over 200 companies in the field.

Deal Count & Capital Invested



Figure 2: Deal and Funding history from 2011 to 2022 (year to date) [source: pitchbook].

Over the last few years, digital mental health has experienced an enormous increase in interest, attention, and deal flow over the pandemic period. However, this drops off in 2022. Whilst this is partly explained by the macro-environment, we believe the reduction in funding is greater in mental health.

Investment by deal count and overall capital invested since the end of the pandemic has reduced. The number of investments nearly doubled over the pandemic period (2018 to 2021), but this has dropped back to nearly pre-pandemic numbers in 2022. The total capital invested in digital mental health follows a similar trajectory, with a nearly **7x increase between 2018 and 2021** - representing **an average increase in capital invested per company of 417% from 2018 to 2021**.

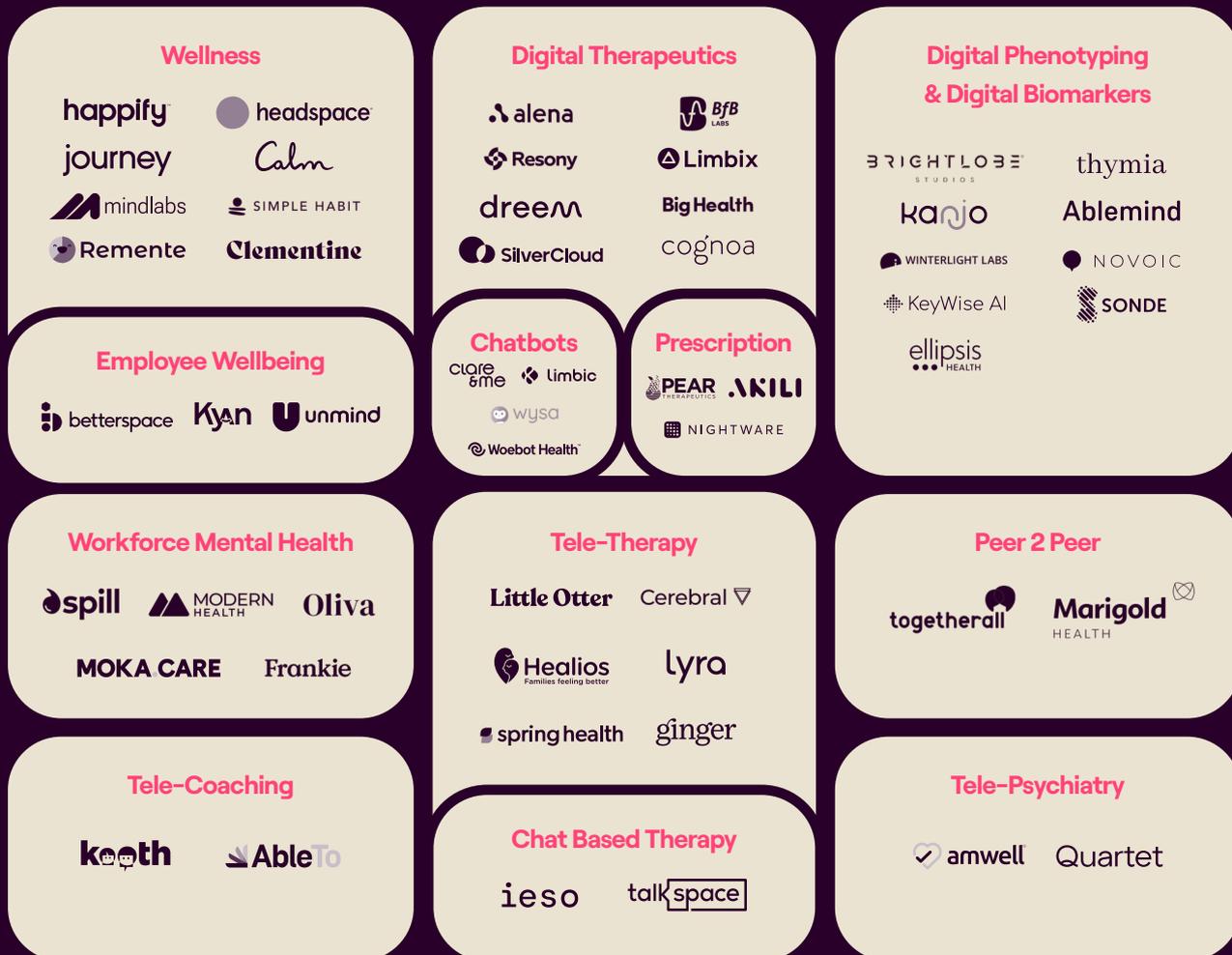
Of the 200+ companies we analysed, 20 have exited (acquisition or IPO) - 90% of which did so in or since 2020. Nine are currently considered unicorns (worth over US\$1B). All of the unicorns gained this status from deals and raises completed between 2020 and early 2022, such as [Lyra](#) - \$906.82M raised to date, [Spring](#) (\$295.99M raised), [Cerebral](#) (\$461.40M raised) or wellness apps (e.g. [Calm](#)). We have classified this cohort of companies within the maturing end of the technology spectrum.

It is, however, impossible to look at the above graph and not comment on the drop back down to near pre-pandemic numbers. With the number of deals and the total capital being invested coming close - if not below 2018 values.

When we compare this to the more general space of digital health, we see a similar picture when it comes to the number of deals, highly increasing over the pandemic period but with a substantial drop-off in deal count over the first 9 months of 2022. However, when we look at the total capital invested, we observe continued and sustained growth into 2022 - representing an average increase in capital invested per company of 440% since 2018.

The story of digital mental health, however, is different when we look solely at **earlier-stage businesses**. Indeed, the above numbers and sector growths have significantly been skewed by the IPOs and sizeable later-stage funding deals (series E-F) of Cerebral or Lyra. If we restrict our analysis to earlier stage deals (series B or earlier), we see **an average increase in capital per company of 67% since 2018**. This suggests that investors are increasingly looking for the next generation of technology companies in what we class as emerging, data-driven technologies.

Snapshot of the digital mental health landscape 2022



Telemedicine & Peer-to-Peer support networks

In this section, we consider the provision of care using of telecommunications platforms or video conferencing technology enabling the connection with people who can provide mental health services or support. We also include platforms designed to connect you to coaches and trained listeners, as well as community platforms (peer-to-peer support). These platforms therefore use **modern technology as an enabler of care rather than a way of transforming the current model.**

This segment of the technology landscape has seen some of the greatest successes in digital mental health to date. In our research, we outlined over 1/3 of companies providing telehealth services in mental health or platforms that enable peer-to-peer and community-based support. These companies have raised over \$13B over their lifespan, making it the largest segment we outlined in our research. Tele-mental health has seen 9 exits (IPO or M&A deal) and 9 unicorn companies over the last few years.

- Mental health care appears to be particularly well suited for telemedicine as it utilises mainly audio-visual information as diagnostic and therapeutic tools and there is little need for hands-on procedures or laboratory tests. Therefore, lending itself more than most to remote care when compared to other areas of medicine.
- The role of tele-health in mental health care has become even stronger as we have seen a recent drive towards the first-line use of non-drug-related therapies in mental health – such as the provision of Cognitive and/or Behavioural Therapies (e.g., CBT) [27].
- As the problem of accessibility, availability and affordability have been recognised – so has the use of teleconferencing platforms to start reducing the mental health deserts and providing greater care across the globe.

Although tele-mental health has helped with the accessibility of care throughout some countries, this remains a limited solution. Indeed, leveraging clinical specialists through video conference or chat allows them to reach out to more patients within the same time period, however, this is **not solving the underlying availability problem** whereby there is an insufficient number of trained professionals able to deliver valuable support.

Data-Driven Therapy in telehealth

Therapy is slowly becoming data driven. Through the advancement in psychological metrics, we are seeing more therapists rely on data and data-driven insights to improve their performance and clinical outcomes. TalkSpace and Spring Health are US companies that are pushing this new aspect of care forwards and are leading the way towards more “feedback-informed treatments”.

Today this insight is primarily driven by questionnaires and the recommendations by rule-based engines. There is already evidence that using data can decrease the number of clients who leave therapy or see a deterioration in their mental health. Therefore, further empowering users of these platforms to use their voices and be in control of their care. Ieso Digital Health, a UK platform that provides CBT via a text-based online conversation between therapist and patients, has also successfully trialed more data-driven approaches. In 2019, Ieso built a deep learning model that was able to identify different ideas that were discussed during therapy sessions and showed an association between therapist strategies and content and clinical outcomes in therapy [28].

SPOTLIGHT: EMPLOYER MENTAL HEALTH SOLUTIONS - SELLING TO CORPORATES

Companies are recognising the costs associated with not addressing their employees' mental health needs. In addition, there is a growing emphasis on companies controlling their healthcare costs. Therefore, we have seen a major growth in interest from big corporations to offer mental health provisions within their employee benefits package – with a goal to reduce attrition and absenteeism as well as increase employee retention.

This has led to a ‘newer’ wave of approaches in telehealth, wellness products and digital therapeutics, specifically looking at selling to employers and aiming to unlock productivity within office settings. For most companies, these initiatives are driven by the CMO or the Chief HR Officer. We are yet to see a strong underlying rigour and desire for clinical effectiveness from these institutions who are – for now – mainly focused on providing wellness tools to their staff and struggle differentiating between competing offers. However, corporate commissioners are getting more familiar with mental health platforms and are demanding higher levels of clinical rigour from the solutions they choose. Most employers are looking for wellness products with the ability to sign-post to further clinical assistance as needed, as well as technology which has the ability to passively track employee wellbeing and the way this is impacted by both work and improved by the solution offered.

Traditionally, following the purchase, most organisations do not continue to track outcomes – therefore only relying on user engagement metrics. However, we have seen evidence that **this is changing as the space is maturing** and organisations and purchasing officers are paying closer attention to the clinical validity of the solution they choose and their ability to track how the usage of the solution helps their workforce.

We have further noted a need for solutions that drive more holistic understanding and change in workforce mental health. Indeed, without the right backdrop and adoption, point solutions remain often ineffective or insufficient. A recent report on employee burnout from the McKinsey Health Institute show similar trends, with companies focusing on individual-level interventions that aim to remediate symptoms, rather than resolving the causes [29].

Mental Health apps: From Digital Vitamins to Digital Therapies

Today, the prevention, management and treatment of mental health disorders can be delivered through fully digital means – which has true potential **to increase access to treatments**.

Smartphone applications and other internet-based solutions propose a wide array of solutions and can be used alone, supported by a clinician, or blended with other traditional mental health therapies. It remains important however, to consider these solutions on a gradient, with one of the key distinctions being between mental wellness solutions and digital therapeutics.

● **Mental Wellness & Mindfulness** platforms tend to a healthy and subclinical population – usually through pre-recorded or group video coaching, mindfulness exercises, meditation sessions or educational content. These apps are designed to be used as a routine companion to general physical well-being and often have no or little clinical supporting evidence. Over the last few years, and particularly during the pandemic, the solutions have had a growing impact in both the consumer markets through companies such as Calm and Headspace (both valued at over \$1B) and in the workplace (e.g. Modern Health or Unmind). We have identified up to 25% of companies currently delivering mindfulness, and well-being content, these companies have raised an accumulated US\$1B, of which nearly 75% was during the pandemic period.

● **Digital Therapeutics** solutions, on the other hand, aim to build digitised solutions to address a specific need. They are clinically validated to ensure safety and effectiveness and are subject to greater clinical, security and regulatory scrutiny. These solutions range in their intended use cases, from more supportive options that we term supportive digital therapeutics – this encompasses targeted solutions for subclinical anxiety and depression and self-guided longer-term solutions to help with disease management, such as Happyr. At the other end of this spectrum, we consider more targeted therapies that have undergone rigorous clinical trials and are meant to be prescribed by a medical professional for the management and treatment of specific conditions.

Three such companies are currently operating in the US with full FDA clearance and can only be accessed through prescriptions – Pear Therapeutics (Insomnia, Substance Use Disorder [30], Opioid Use Disorder [31]); Akili Interactive (childhood ADHD [32]) and NightWare (Nightmare Disorder – usually associated with PTSD). Digital therapeutic solutions also range significantly in the clinical disorders they target. Below, we outline some of the core segments of mental health and how many solutions are currently available or being developed to tackle them. This shows an overrepresentation of depression and anxiety solutions but nonetheless a good coverage of the most prevalent disorders. We have currently identified around 10% of companies (around 20 companies) working to develop digital therapeutics, who have raised nearly \$3.0B. Digital Therapeutics has also seen 3 exits of which 2 very recently – both of which are now publicly traded (Pear Therapeutics and Akili Interactive).



Figure 3: The number of analysed solutions either on the market or in public pipelines for mental health disorders. Here we classify these solutions further as either supportive DTx (clinically validated everyday use platforms), Targeted DTx (DTx targeted at specific disorders often with time limited treatment periods that are available on the Apple or Google play stores store of through self-referral) and Prescription DTx (DTx only available through a direct prescription of a clinical professional).

Most **digital therapeutic** approaches revolve around **CBT**, or CBT-inspired methodologies delivered through digital means. CBT was first developed in the 1960s and is now widely accepted as an effective treatment for various mental health disorders from anxiety and depression to PTSD or Schizophrenia [33, 34]. Since 2019, CBT is now considered first-line therapy for many clinical behavioural disorders before medication [27].

This approach has seen much success as CBT is a codified and methodological approach of psychology that requires little patient specificity and relationship building and is usually delivered as a short course of 6 to 8 weeks. It seems, therefore understandable that these approaches have lent themselves to being digitised and outcomes have reliably shown comparable results to in person/therapist delivered sessions where **50-60% of patients** achieve full recovery¹ [35, 36].

Adherence to therapy in person can be bolstered through relationship-building and interpersonal discussions. Only once possible through F2F therapist interactions, this has become achievable through the development of **AI-powered chatbots**, such as *Woebot*, who have shown they can create genuine bonds between humans and conversational AI agents “companion apps” [37]. Using **natural language processing (“NLP”)** to power chatbots has transformed their ability to deliver personable and more complex therapeutic approaches through fully digital means. This could be the answer to solving the inaccessibility of structured mental health care as well as provide an effective solution to those who wish to interact digitally in a more discreet way. Supporting this, evidence suggests that people seemed to prefer opening up and disclosing more to a virtual therapist than a real one [38]. User engagement remains one of the main metrics tracked today to measure the impact of many digital mental health solutions. This is an important consideration; mental health is associated with some of the highest high drop-off rate – even for in-person therapies. Companies have turned to games and other broader techniques to drive user engagement, which drives regular use and therefore increases the potential data capture opportunities.

Digital interventions also have the potential to target an individual’s cognitive pathways. Our increasing understanding of the specific cognitive processes that drive clinical symptoms is allowing us to move to more targeted approaches. *Alena*, is using cognitive models from computational psychiatry to specifically tailor games that permit the assessment and treatment of social anxiety at an individual level.

In general, we do not have a good way to assess or In general, we do not have a good way to assess or quantify the effectiveness of mental health treatments. However, this is where the data comes in – digital interventions have the added benefit of collecting incredible amounts of data about patients and their path to better health. **Adaptive and personalised** interventions (e.g. nudges to provoke a certain behaviour) that aim at improve patients’ clinical outcomes are becoming a reality. With the right metrics, and the right algorithms, digital treatments, likes *Akili’s EndeavorRx*[®] are now able to tailor the treatment to each patient’s individual needs automatically. This approach often remains based on ‘simpler’ decision trees rather than more complex AI models, and most of the solutions currently on the market remain more standardised i.e., a given digital therapeutic will provide a 6-week CBT course to help manage or treat substance abuse. Gathering and adapting machine learning models with ongoing psychological and behavioural data has the potential to lead us towards a **more personalised and adaptive model of care** [40].

SPOTLIGHT: REGULATION

Currently, to approve a digital therapeutic solution and grant it the necessary status as a medical device, regulators need to see and validate the effectiveness of every possible patient journey within the programme.

This, of course, means developing personalised medicine is difficult as using anything but simple decision trees would lead to an array of pathways too large to validate in traditional RCTs. However, a growing acceptance and understanding from both the public and regulatory bodies towards artificial intelligence methods is opening up a future where automated and personalised treatments are possible.

Acceptance and recognition for the use of digitised therapies is growing – during the COVID-19 pandemic, the FDA issued guidance aimed at improving the availability and access of prescription digital therapeutics providing computerised CBT [39].

Biomarkers: Combining Technologies for personalised mental health care

Unlike medical interventions, there are no blood tests that can measure the success of therapy. In mental health, very few metrics exist to help us monitor patients' progress, help predict their relapses and create objective diagnoses. Mental health disorders are diagnosed by clinical professionals in a highly subjective manner – leading to high rates of misdiagnosis and strong inter-professional differences [41, 42].

Biomarkers are objective, quantifiable physiological and behavioural data collected and measured using digital devices such as portables or wearables. This space, therefore, presents a key role for deep technology (such as AI and Neural Networks) to offer advances in mental health understanding – from basic principles to the delivery of care. Modern advances in machine learning, and natural language processing allow us to create more objective and data-driven metrics of mental health state.

When compared to the other technologies presented here, this is a much less mature space – closer to the forefront of clinical and scientific research but with some of the most exciting potential to drive monitoring, understanding as well as diagnostics and preventative medicine. We identified 14 companies (5%) operating in the space, most of which are at a very early stage in development – having raised a total of \$136M.

As discussed throughout this report – **machine learning and data-driven models will help deliver greater functionality through most of the technologies described.** The most significant advances are likely to **come from combining currently separate technologies.** Indeed, most of the point-of-care solutions discussed in this report – are seeing the value of data-driven insights. However, delivering valuable knowledge from data, especially in a field as misunderstood as mental health, remains a key barrier to success. Therefore, we consider **biomarkers as catalysts for the other segments of digital mental health.** Only with the use of data-driven models and effective biomarkers can we hope to build adaptive and targeted solutions to mental health disorders – which is needed to drive better outcomes.

Multiple modalities of data are currently being considered and further researched to help quantify and assess mental health states. One of the most common examples we found was using speech data. Linguistics and semantics in speech are known to be disrupted in mental disorders as well as health disorders more generally. Such a complex and subjective area requires advanced computational approaches based on large set data sets to draw correlations.

Natural language processing is a technique used by conversational agents to analyse human dialogue but can also analyse word patterns within sentences and help classify and understand human emotions. Companies using this approach include [Novoic](#), who has found correlations between speech and mild cognitive decline, which is often associated with Alzheimer's disease. Or [Winterlight labs](#), which can identify 550 features of speech and learning using their natural language processing algorithms, which can be used to diagnose, and track changes in response to treatment of neurodegenerative disorders.

NLP has also been used overlaid within a digital therapeutic setting within a conversational AI chatbot, where semantics in the text from an individual is analysed to predict diagnoses and inform a clinician of how serious an individual's mental state may be. An example of this is UK based, [Limbic](#). These techniques can also help classify therapeutic techniques from human therapists and, in work done by TalkSpace or Ieso, to drive more informed human care.

Other technologies are also being developed in this space, that do not rely on human voice or speech at all. Instead, opting to use other strong markers of change and human behavioural health. [Thymia](#) are using computer vision techniques from deep learning to analyse facial expressions and micro-expressions as well as eye movements to help objectify the likelihood and potential severity of depression.

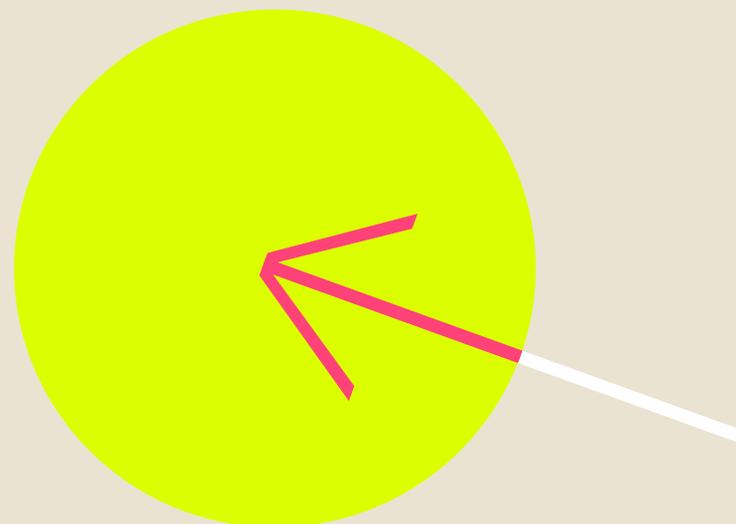
A third popular approach leverages cognitive and computational neuroscience approaches to create games or gamified task to collect direct and behavioural markers of mental ill-health and assess personal changes from baseline levels allowing for more targeted treatments and monitoring (e.g. [Alena](#) or [Kanjo](#)).

These technologies, while all cutting edge, will likely need to be viewed holistically to inform patient care fully. Pear Therapeutics, in their desire to help evaluate and improve outcomes of their digital therapeutic products, have partnered with WinterLight Labs speech biomarkers and Keywise AI's proprietary AI model for keyboard typing analysis in the hope that in conjunction with the insights brought forward may be greater than from a single technology.

Furthermore, to drive value, biomarkers need to be used with other solutions or clinical touch points - the data produced across the patient pathway will increasingly merge and co-inform one another. These can include a robust clinical presence (e.g. dashboards allowing for remote monitoring) helping digital therapeutic companies develop, monitor and adapt their products through an iterative cycle of therapeutic interventions, as well as helping insurers, employers or health providers monitor key outcomes. Variables predictive of diagnosis or treatment effect will inform the dosing of more digital therapeutics. Only in combination can these data sources lead us to a more powerful and preventive model of mental health.

Biomarkers may play a crucial role in the re-classifying mental health disorders, as we move away from hard-coded separations and towards a more data-informed multi-factorial spectrum. Many of which, being heavily R&D led, are targeting business models like Pharma who are developing new drugs for Alzheimer's (e.g., Eli Lilly) and Parkinson's (e.g. Roche [43]) where the biomarkers supported by machine learning models are being used for an additional clinical trial endpoint, which is exploratory in nature, (determines whether the trial is successful) alongside traditional diagnostic end points.

We expect to see more collaborations between pharma and technology companies who are building broader platforms for a holistic view of mental health. This will drive greater success in the development of new drugs and will eventually reach a clinical setting to diagnose and monitor mental disorders. We have seen the recent announcement from Owkin who has partnered with a number of voice biomarker companies to build the data sets and models to turn this into a reality [44].



The Future of Digital Mental Health

At MMC we have the following theses in data-driven mental healthcare.

1: A range of digital biomarkers will be identified in mental health, which will be increasingly collected by sophisticated digital devices, sensors and wearables.

- Digitally delivered CBT will continue to be the key form of data gathering driving personalised care.
- New models will be multi-model integrating a wide array of physical, behavioural, psychosocial, and cognitive metrics allowing for more personalised treatment.

2: Employers, clinicians and individuals will increasingly focus on clinical outcomes.

- Clinical impact of solutions will be tracked by buyers (insurers, employers, health providers). This is ultimately driven by strong user engagement metrics to promote adherence and drive long-term change. Gamified technologies and personalised interventions will be key to drive engagement and outcomes.

3: The next generation of AI models will revolutionise our understanding of mental health.

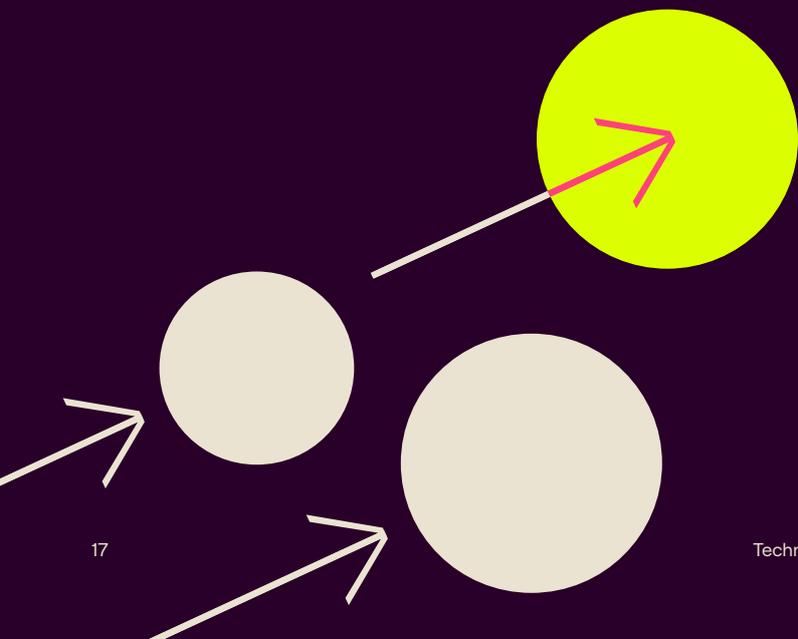
- Deep Learning models can ingest data and draw objective segmentation across the spectrum. Over time, this can also help us to understand the mechanism of disease through tracking progression and change according to treatment.
- Other applications of AI such as decentralised model training and federated learning will be required for greater patient security and anonymity.
- Downstream, interpretable, and explainable AI will

4: Fully digital therapeutics will take market share.

- The limiting factor to the growing mental health pandemic will be the number of therapists available. Data-driven therapeutics specialised for mental health disorders across the spectrum will continue to gain traction and are most likely to excel within the clinical setting – being prescribed and reimbursed provided they can continue to provide evidence-based outcomes.

The way we deliver mental health care requires transformation. Today, treatments for many behavioural health problems are often imprecise and ineffective. This is often due to inconstant diagnoses made from subjective interviews. A lot of these current issues stem from a strong heterogeneity of these issues and a lack of understanding of their origins. Indeed, many similar external manifestations of depression stem from different neurological areas and activation patterns. A new data-driven way of approaching the taxonomy of mental health makes it possible to associate outcomes with the previously less observed underlying neural and cognitive representations. Therefore, advancing clinical practice with more robust matching treatments to the specific underlying problems will lead to more effective outcomes. This increased understanding and separation may also aid the shift towards a more preventative model of care for mental health.

If you are building something in the data-driven mental healthcare space, we would love to talk you!
Contact charlotte@mmc.vc.



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