

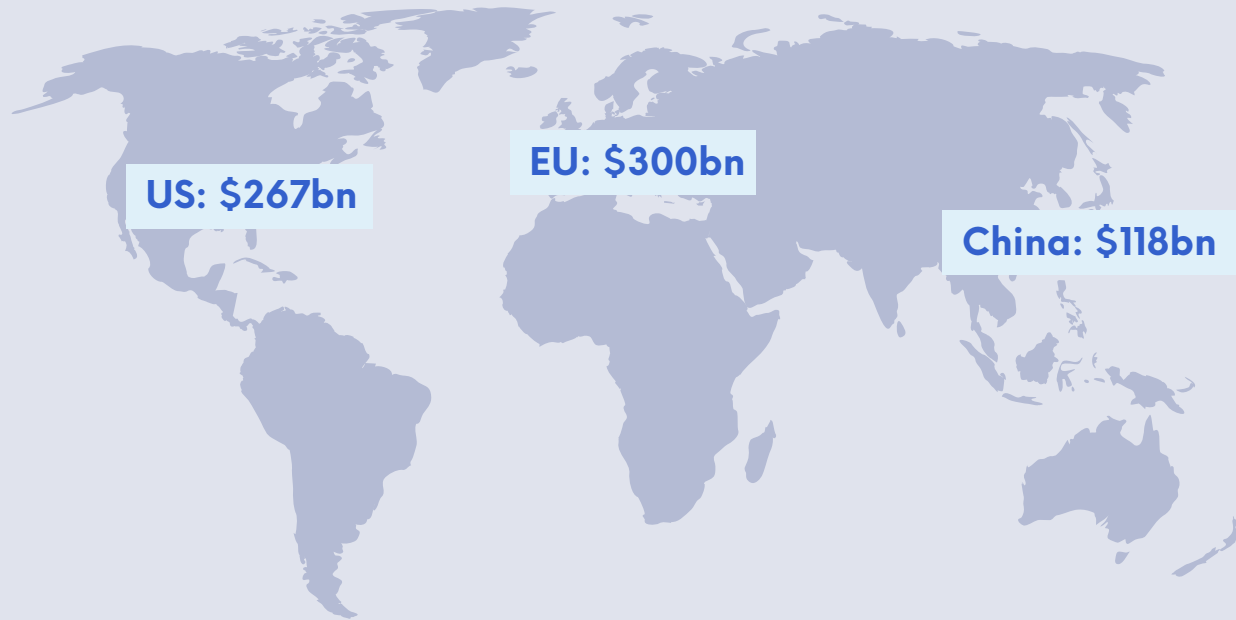
# Mental health re-imagined: Deep data science approach

NAWAL ROY, HOLMUSK FOUNDER AND CEO

APRIL 2023

# The global challenge of our lifetime

## Cost of Behavioral Health (SGD)<sup>1,2,3,4</sup>



## Annual burden<sup>5</sup>



### Poor outcomes



Patients continue to suffer **from poor outcomes across all psychiatric conditions**

### Rising cost



**Rising cost and prevalence**, with mental health topping the list of most costly conditions globally

### Limited innovation

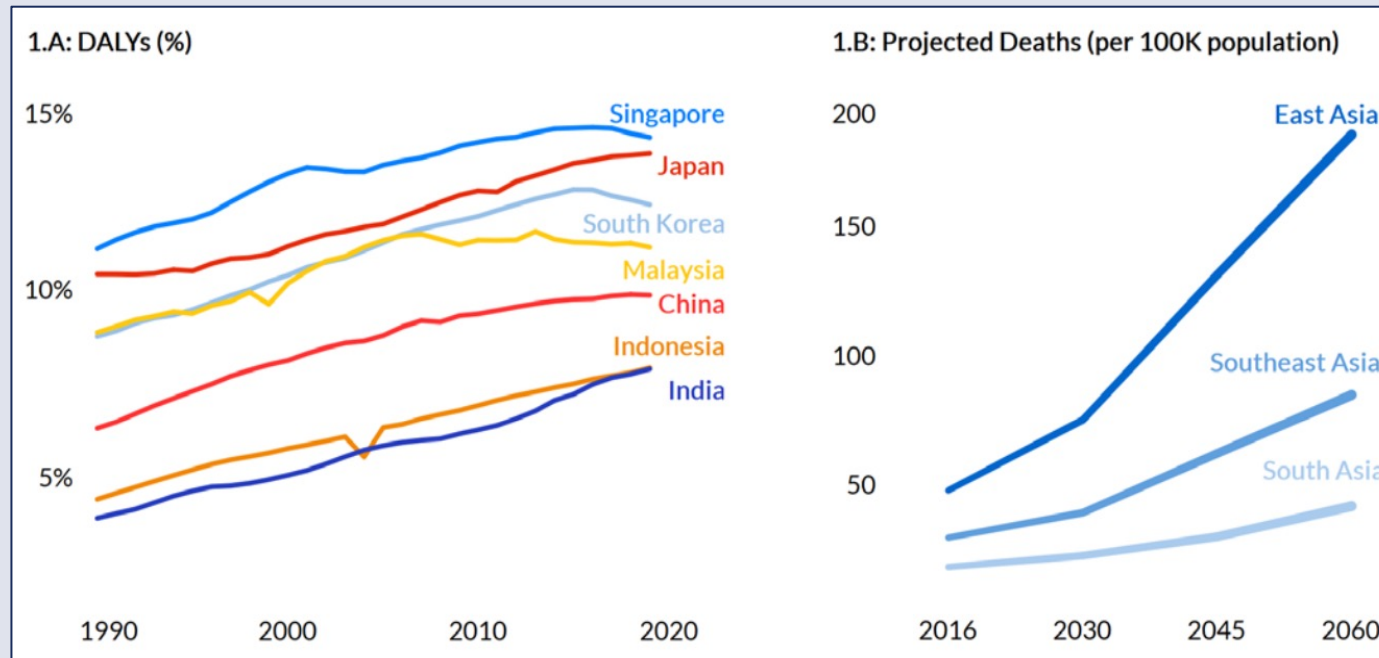


Routine clinical care has **remained largely unchanged** despite increasing need & research

Sources: 1. [Health Affairs](#) 2. [OECD](#) 3. [The National Institute of Health](#) 4. [Cigna](#) 5. [The Lancet](#)

# Rising impact of behavioral health disorders in Asia

## Health impact on DALYs and projected deaths<sup>1,2</sup>



## Evidence gap

Lagging other disease areas in **availability** of aggregated, longitudinal **real-world data**

Majority of insights captured in **unstructured clinical notes**

**Clinical trial outcomes are not translatable** to routine clinical care

**Siloes between behavioral and physical health** and limited understanding of comorbidities

Sources: 1. [Institute of Health Metrics and Evaluation](#) 2. [World Health Organization](#)

# Estimates of lost GDP in US, 2015-2050

Disease	Total disease burden (trillions of USD)
Mental health conditions	18.1
Cardiovascular diseases	11.3
Cancer	10.4
Diabetes	6.4
Chronic respiratory diseases	5.6

- Treatment only makes up 28% of the costs

Source: 1. [The macroeconomic burden of noncommunicable diseases in the United States: Estimates and projections. Plos one. 2018 Nov 1;13\(11\):e0206702](#)

**Endpoints in behavioral health are  
shockingly ill-defined**

**There simply isn't valid and feasible  
quality metrics that the industry relies on**

# RCT $\neq$ RWE

**Clinical research**

**Clinical practice**

# The time is NOW for behavioral health

WITH THE RISING PREVALENCE AND EMERGENCE OF DISRUPTIVE TECHNOLOGIES,  
BEHAVIORAL HEALTH IS AT AN INFLECTION POINT



**AT HOLMUSK,**

We are harnessing these forces to make the **provision of evidence** the basis for decision making in **behavioral health**.

# Clinical informatics for behavioral health



With 100% focus in behavioral health, Holmusk's world-class data is the single source of truth to answer questions in behavioral health

- ✓ **Richest clinical database** in behavioral health, validated through peer-review publications
- ✓ **Curated Behavioral Health data model** to ingest and analyze data across settings and facilities
- ✓ **Proprietary AI/NLP** to unlock understanding from unstructured EHR clinical notes
- ✓ **Evidence generation platform** that is answering pressing questions in behavioral health

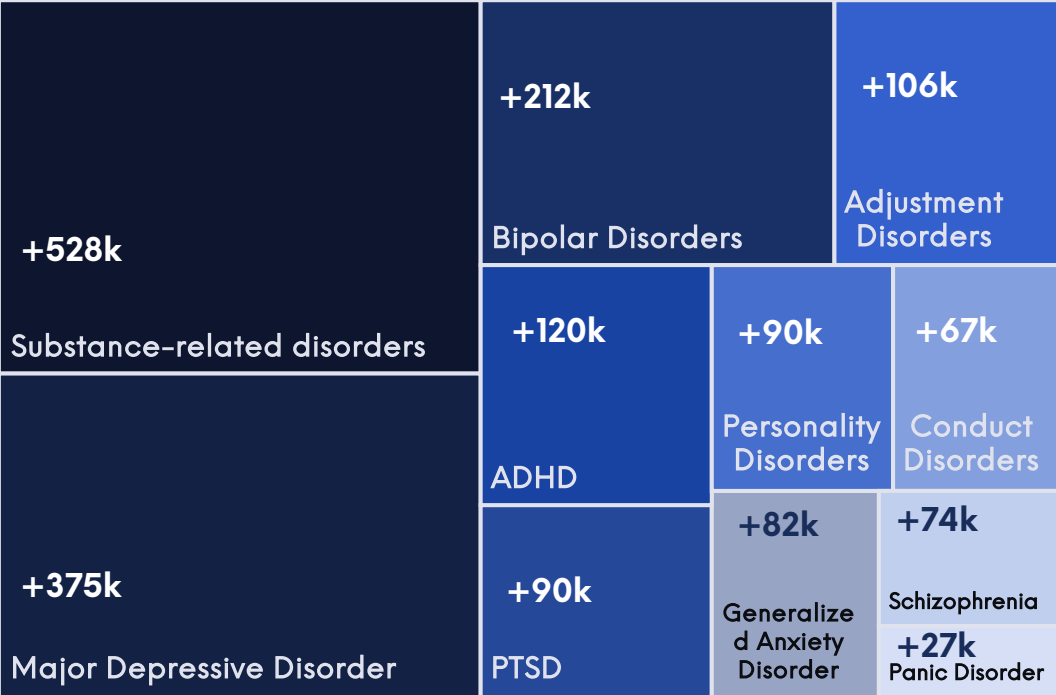


# Leading source for behavioral health RWD

  
**1.4M+**  
Patients

  
**20+ years**  
Longitudinal Data





## Diagnosis Breakdown



Notes: ED – Emergency department    Source: NeuroBlu database March 2023

Proprietary and confidential

## Structured Data

- **Diagnosis Codes**  
(ICD-9, ICD-10)
- **Patient Demographics**
- **Prescription Data**
- **ED, inpatient and outpatient data across the same patients in 39 of 44 clinics**

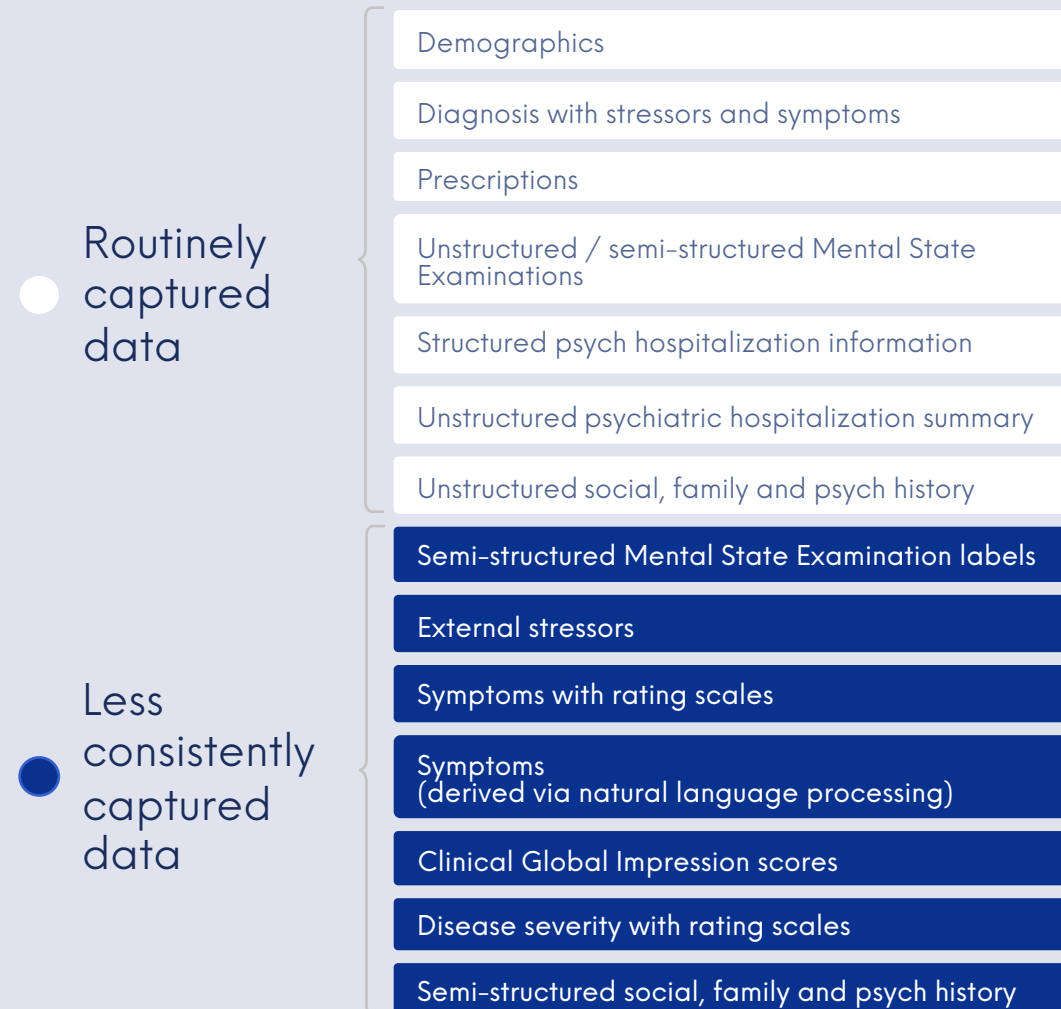


Outcome Measures	Patient Counts
CGI-S	423K
GAF	308K
PHQ-9	48K
CSSRS	57K
QIDS	23K
BDSS	20K
PSRS	10K

## Unstructured Data

- **Clinical notes** at every visit with rich information on each patient
- **Mental Status Examination (MSE)**  
Categorized notes on patient's function, appearance and mood
- **External Stressors**  
Social, relational and occupational events that may affect the patient's mental health
- **Side Effects**  
Clinician-observed side effects from medication

# Holmusk CDM: Harmonizing clinical characteristics across sources and sites



## HOLMUSK COMMON DATA MODEL

- Disease severity, biological, social, occupational, and educational functioning are captured inconsistently and irregularly in routine behavioral health care
- These data are essential to evaluating treatment effectiveness, symptom progression and resolution, and value-based care decisions
- Our Common Data Model (CDM) harmonizes these data across sites, drawing from structured, semi-structured, and unstructured data to **create a single framework for patient outcomes**

[Conforms to OHDSI OMOP v5.4 standards](#)

Notes: CDM – Common data model; RWD – Real-world data

Proprietary and confidential

# NLP unlocks clinical characteristics in datasets

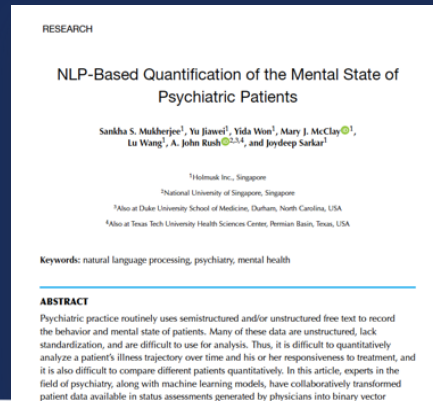
Holmusk's NLP Leverages the richness of the NeuroBlu database to significantly increase the value of health system behavioral health EHR data

ENRICHED CLINICAL DATA WITH BH SPECIFIC CLINICAL CHARACTERISTICS (NLP OUTPUT) AND VALIDATED SCALES (CGI-S, GAF)

Leverage BH specific NLP models to process semi-structured data in BH

Proprietary BH specific NLP model can extract clinical information (published in *Journal of Computational Psych 2021*)

Holmusk's first of its kind AI enriched quantitative BH Real-World Data



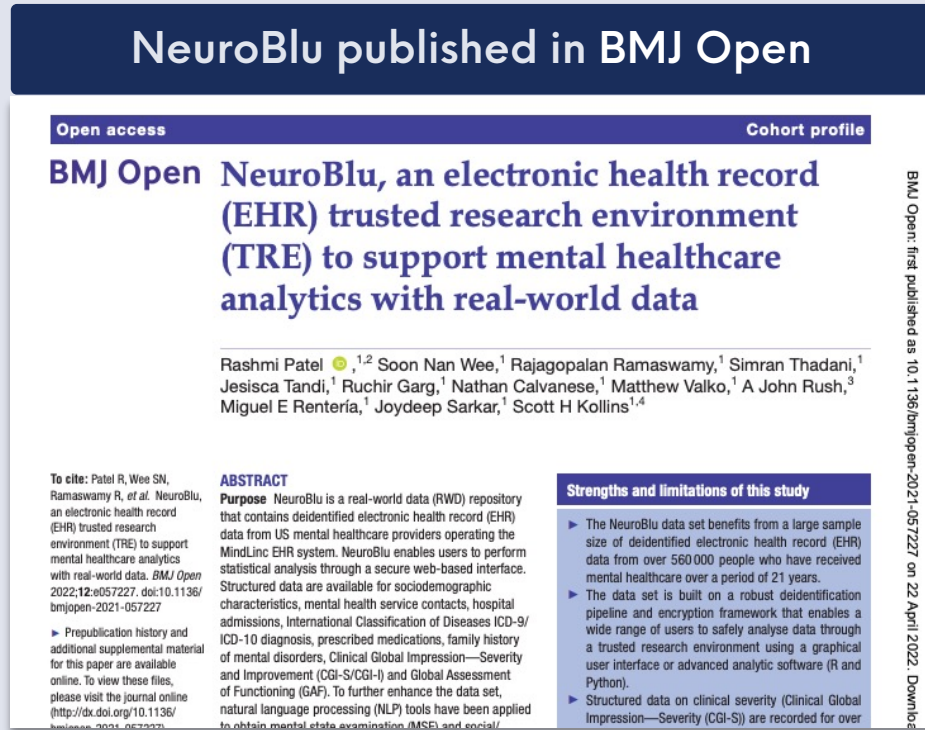
Use AI models for BH scales/scores

AI models for prediction of disease severity (CGI-S, GAF) for patient in EHR database

**Notes:** CGI-S – Clinical Global Impression – Severity scale;  
GAF – Global Assessment of Functioning

# World class trusted research environment platform

Top-ranked mental health publication in the BMJ Open\*



\*<https://blogs.bmj.com/bmjopen/2022/08/25/editors-picks-top-bmj-open-mental-health-papers-published-in-2022-by-altmetric-score/>

## Journal articles:

### Journal of Computational Psych.

NLP-Based Quantification of the Mental State of Psychiatric Patients

### Neuropsychiatric Disease and Treatment

Factors That Affect Patient Attrition in Buprenorphine Treatment for Opioid Use Disorder: A Retrospective Real-World Study Using Electronic Health Records.

### Informatics in Medicine Unlocked

A neural system dynamics modeling platform and its applications in randomized controlled trial data analysis

### PLoS Digital

Best practices in Real-World Data Lifecycle

**10+ more peer-reviewed publications based on NeuroBlu database**

## Conference Abstracts

- Psych Congress
- American Society of Clinical Psychopharmacology
- ISPOR Europe
- American College of Neuropsychopharmacology

- American College of Neuropsychopharmacology
- Academy of Manage Care Pharmacy (AMCP) Nexus
- Schizophrenia International Research Society (SIRS)

# Strategic partnership with NHS UK to enable translational research

## WHAT

Mental Health Mission, a government-funded initiative in U.K. that allows academicians to analyze real-world data and quickly implement their findings into clinical practice using Holmusk's MaST

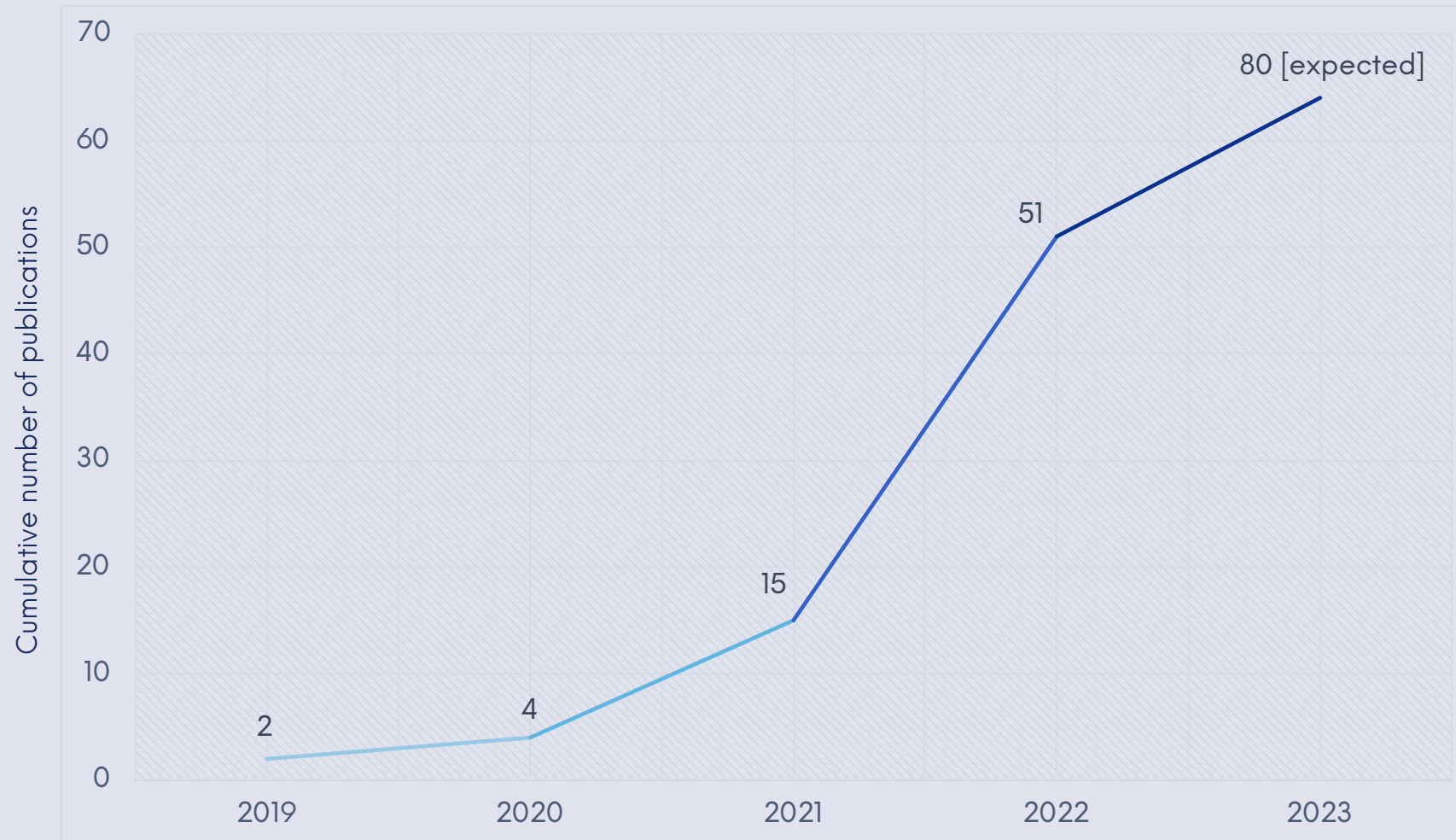
## HOW

We're building a Trusted Research Environment (TRE) to be used with a U.K. dataset, using our expertise with building the world's leading source for behavioral health real-world data

## WHY

To bridge the gap between scientific discovery and clinical implementation, improving care delivery and patient outcomes

# Number of publications and abstract presentations



# Predicting psychiatric hospitalization

First study of its kind, based on real-world data from Holmusk's NeuroBlu Database, shows patients who score highest for severity and instability were 45% more likely to be hospitalized

Lancet Psychiatry 2023

Articles

## Early trajectory of clinical global impression as a transdiagnostic predictor of psychiatric hospitalisation: a retrospective cohort study

Maxime Taquet, Kira Griffiths, Emily O C Palmer, Sheryl Ker, Christian Liman, Soon Nan Wee, Scott H Kollins, Rashmi Patel

### Summary

**Background** Identifying patients most at risk of psychiatric hospitalisation is crucial to improving service provision and patient outcomes. Existing predictors focus on specific clinical scenarios and are not validated with real-world data, limiting their translational potential. This study aimed to determine whether early trajectories of Clinical Global Impression Severity are predictors of 6 month risk of hospitalisation.

**Methods** This retrospective cohort study used data from the NeuroBlu database, an electronic health records network from 25 US mental health-care providers. Patients with an ICD-9 or ICD-10 code of major depressive disorder, bipolar disorder, generalised anxiety disorder, post-traumatic stress disorder, schizophrenia or schizoaffective disorder, ADHD, or personality disorder were included. Using this cohort, we assessed whether clinical severity and instability (operationalised using Clinical Global Impression Severity measurements) during a 2-month period were predictors of psychiatric hospitalisation within the next 6 months.

**Findings** 36 914 patients were included (mean age 29.7 years [SD 17.5]; 21 156 [57.3%] female, 15 748 [42.7%] male; 20 559 [55.7%] White, 4842 [13.1%] Black or African American, 286 [0.8%] Native Hawaiian or other Pacific Islander, 300 [0.8%] Asian, 139 [0.4%] American Indian or Alaska Native, 524 (1.4%) other or mixed race, and 10 264 [27.8%] of unknown race). Clinical severity and instability were independent predictors of risk of hospitalisation (adjusted



Lancet Psychiatry 2023

Published Online

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See Online/Comment

[https://doi.org/10.1016/S2215-0366\(23\)00101-3](https://doi.org/10.1016/S2215-0366(23)00101-3)

Department of Psychiatry, University of Oxford, Oxford, UK (M Taquet PhD); Oxford Health NHS Foundation Trust, Oxford, UK (M Taquet); Holmusk Technologies, New York, NY, USA (K Griffiths PhD, E O C Palmer PhD, S Ker BSc, C Liman MSc, S N Wee BSc, S H Kollins PhD, R Patel PhD);

The study enabled by the NeuroBlu Database could prove useful across the behavioral health care and research ecosystem, from facilitating early intervention to supporting the development of more targeted treatments.

[https://doi.org/10.1016/S2215-0366\(23\)00066-4](https://doi.org/10.1016/S2215-0366(23)00066-4)



# Delivering outcomes today

## Clinical analytics that predicts risk of crisis and patient complexity to manage caseloads

## SOLUTION



# Crisis Risk Tool

## Dynamic dashboard predicting patient risk profiles and likelihood of use of crisis services in next 28 days



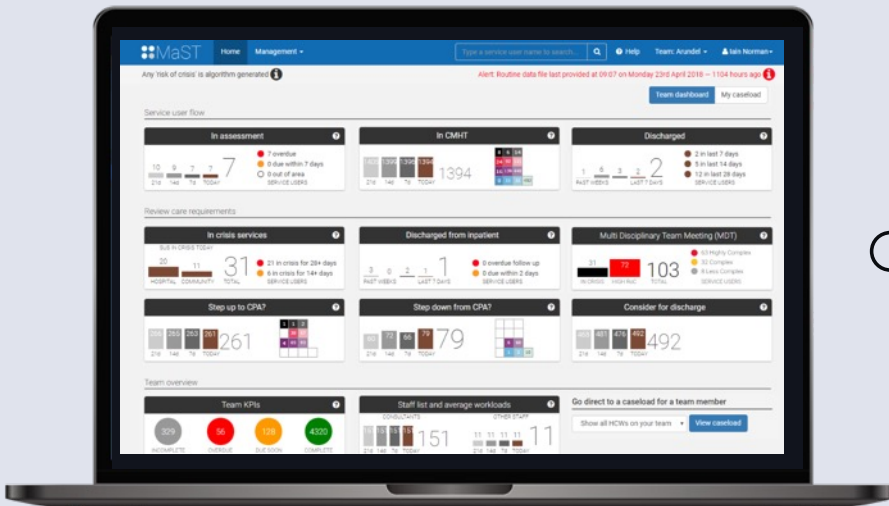
## My Journey

Patient-facing portal to enable patient-reported outcomes and engagement with their care plan



## Digital Pathway Analytics

Tracks individual patient journeys and assesses delivery of care against evidence-based clinical guidelines



## IMPACT OVER 28 MONTHS

Contracted with 9  
Mental Health  
Trusts in UK

- Reduction in crisis events
- Lower hospital admissions
- More follow-ups within 72 hrs
- Lower caseloads

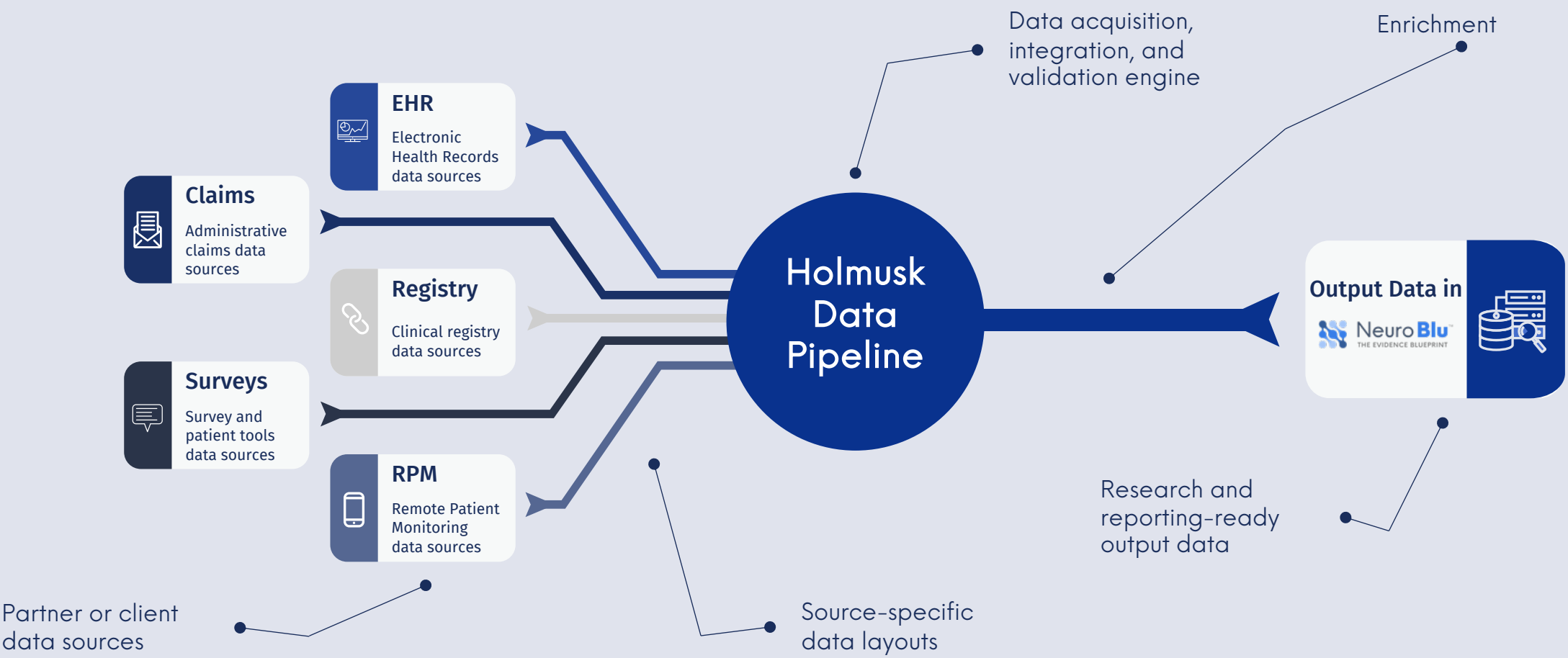


Recognized in the [NHS X Digital Playbook on Mental Health](#) and meets NHS Digital Technology Assessment Criteria



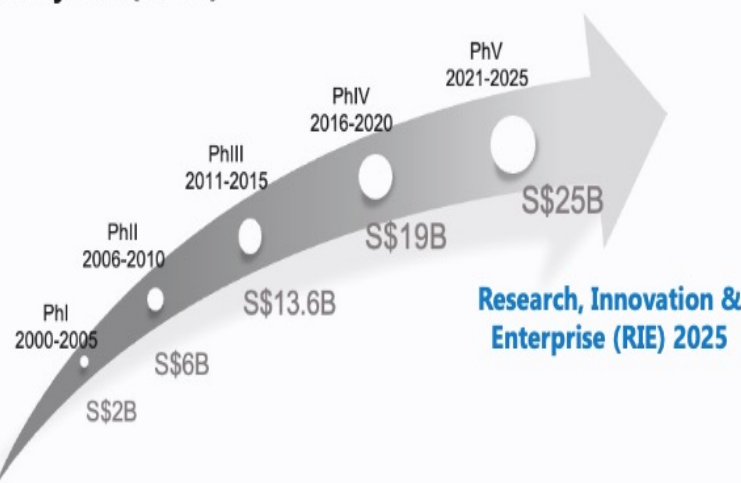
# Future data expansion through tokenization & linkage

LINKING TO EXISTING DATASETS TO LEVERAGE ADDITIONAL DATA SOURCES

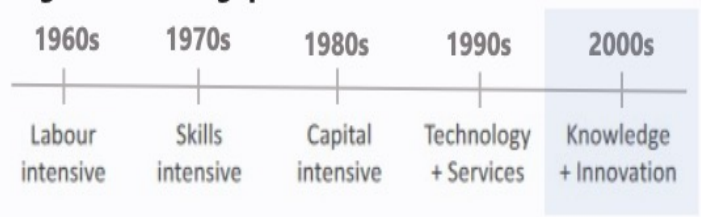


# Singapore – a World-Class Biomedical Hub in Asia

## Public Investment In Research & Innovation over the years (S\$ bil)



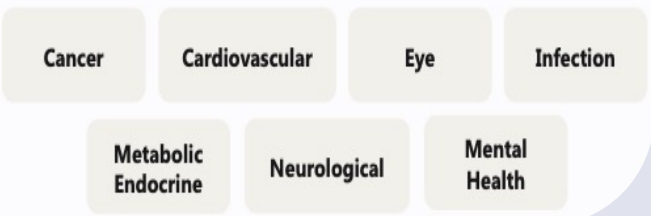
## Aligned with Singapore's economic shift:



## RIE Framework



## Seven areas identified as national priorities for HHP research



Singapore poised to lead the region in healthcare innovation

PROGRESSIVE REGULATORY APPROACH

GLOBAL CONNECTIVITY

MENTAL HEALTH ONE OF 7 NATIONAL RESEARCH PRIORITIES

Source: 1. Biomedical Sciences Industry Partnership Office (BMSIPO) (June 2022), BMSIPO Intro Jun 2022



# Digital biomarkers + path to precision psychiatry

A Trusted Research Environment translating to precision psychiatry tools that drive better outcomes in Singapore

## Innovation:

Standardizing data endpoints



Data-driven care transformation



Digital biomarkers and digital phenotyping



Precision psychiatry tools for early intervention



## Results:

Partnering organizations across SG share AI-enriched data mapped to a common data model

Analytics and digital tools enhance clinical decision, patient engagement, resource utilization

ML-enabled algorithms detect early signs of psychiatric symptoms

Predictive analytics identify at-risk population for prevention programs

**SINGAPORE: leading mental health innovation in the region**

## Building with the spirit of climbing Mount Everest



WEF 2019 Technology Pioneer  
1 of 10 healthcare companies from 80 countries



[Paul Valin summited Mt Everest](#)  
On May 21 2018 at 7:00am