

Rethinking the scale-up of digital technologies for youth mental health: insights from participatory systems modelling in Western Sydney

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Abstract: The increasing proportion of young Australians aged 15–24 experiencing moderate to very high levels of psychological distress highlights an urgent need to improve access to specialised mental health services. At the same time, advances in digital technologies offer promising opportunities to address the recent slowdown in the growth of mental health service capacity across Australia. This study investigates how varying levels of implementation of digital interventions—referring to both online mental health services and technology-enabled integrated care coordination—influence outcomes in the presence of uncertainties in the social determinants of youth mental health. Using a system dynamics model developed through a participatory approach for the Western Sydney Primary Health Network catchment area, we simulate the effects of implementing digital interventions—ranging from minimal to intensive deployment—on reducing mental health-related emergency department presentations. The simulation results indicate that, although digital interventions can significantly enhance mental health outcomes by alleviating service capacity constraints, the marginal benefits of further implementations may diminish beyond a certain point, as additional implementation does not continue to influence capacity constraints or the associated mental health outcomes to the same extent as observed in the initial stages. The additional resources may achieve a greater overall impact if redirected toward other cost-effective interventions within the youth mental health system. These findings underscore the importance of adopting an integrated approach to cost-effectiveness analysis, not only for selecting among intervention types but also for guiding the scale and strategy of implementation.

Keywords: Participatory systems modelling, system dynamics, mental health, health policy, Western Sydney

1. INTRODUCTION

Australia has experienced a rising prevalence of psychological distress among young people over the past decade. According to the Australian Bureau of Statistics (2022b), the proportion of individuals aged 18–24 reporting moderate to very high levels of psychological distress increased from 33.7% in 2011 to 48.4% in 2022, reflecting an average annual increase of approximately 3.35%. In addition, mental disorders rank among the top ten contributors to the global burden of disease (GBD 2019 Mental Disorders Collaborators, 2022), and suicide remains the leading cause of death among young Australians (Australian Bureau of Statistics, 2022a). These trends underscore the need for timely and effective interventions to improve mental health outcomes for young people.

Given declining growth in the capacity of youth mental health services and the rapid advancement of digital technologies in the mental health domain, digital interventions have been increasingly considered as an interim solution to help mitigate the impacts of delayed and uncertain expansion in the specialised mental health workforce (Hosseini et al., 2025).

In this study, “digital technologies” broadly refer to both online mental health services and technology-enabled integrated care coordination. Online services include resources designed to improve mental health literacy, tools for early assessment, and the delivery of interventions such as cognitive behavioural therapy (Christensen et al., 2004). Furthermore, technology-enhanced care has been proposed to facilitate integrated, multidisciplinary service delivery—empowering both clinicians and service users to monitor relevant mental health outcomes over time, and enabling more tailored care through clinical staging approaches (Hickie, 2022). This is particularly important

because fragmented mental health services often lead to delays in care, reduced treatment effectiveness, and poor continuity across service providers.

While previous research has demonstrated the effectiveness of digital technologies in improving youth mental health outcomes (Andrews *et al.*, 2018; Hosseini *et al.*, 2025; Rognstad *et al.*, 2023), the influence of implementation strategies on these outcomes remains underexplored, especially when there are considerable uncertainties in the broader youth mental health environment. This study addresses this gap by examining how different implementation strategies affect the outcomes of scaling up digital technologies in youth mental health care within an uncertain environment. Specifically, we investigate the key question: Does increasing implementation of digital technologies continue to yield the same improvements in health outcomes as observed initially? In doing so, we consider whether increased implementation necessarily leads to better outcomes, or if a more selective and strategic approach is warranted. Additionally, the analysis captures the uncertainties in the selected social determinants of youth mental health. Using the Western Sydney Primary Health Network catchment as a case study, we developed a system dynamics simulation model to explore these issues. Mental health-related emergency department (ED) presentations for individuals aged 15–24, a key indicator of the performance and adequate service capacity of the youth mental health system, were used as the primary outcome measure in the analysis.

The remainder of the paper is structured as follows. Section 2 introduces the case study and outlines the research methodology, including the modelling approach, data sources, and analytical procedures employed. Section 3 presents and interprets the simulation results. Section 4 discusses the implications of the findings, incorporates perspectives from young people with lived experience of the mental health system, and concludes the paper.

2. METHODS

2.1. Context

This study is part of the *Right Care, First Time, Where You Live* program¹, which aims to strengthen youth mental health systems through the participatory development of strategic decision-support platforms. The program is designed to build community capacity to utilise systems modelling across eight sites in Australia, to inform policy, guide resource allocation, and improve mental health and wellbeing outcomes for young people at the regional level (Freebairn *et al.*, 2022; Lawson *et al.*, 2022; Occhipinti *et al.*, 2021). Within this program, a regional system dynamics model was co-developed with local stakeholders, including young people with lived experience of the mental health system, for the Western Sydney Primary Health Network catchment area. The Western Sydney Primary Health Network supports youth mental health through a variety of services, including *headspace*, a youth-enhanced support service, and child and youth-specific mental health services (Western Sydney Primary Health Network, 2024). This region is characterised by rapid population growth—twice the rate of the rest of New South Wales (NSW)—a relatively high proportion of young people, significant socio-demographic diversity with over 40% of the population from culturally and linguistically diverse backgrounds, and a learning or earning rate that is slightly below the state average (NSW Treasury, 2024; PHIDU, 2024; Western Sydney Primary Health Network, 2023). The prevalence of any 12-month mental disorder among individuals aged 16–24 years in Western Sydney is 31%, slightly lower than the NSW average. However, the rate of help-seeking behaviour in the region is also lower than the NSW average (Australian Bureau of Statistics, 2022c). Despite this, rates of mental health-related emergency department presentation and hospitalisation for self-harm have remained relatively stable over the past five years (Centre for Epidemiology and Evidence, 2024).

Hosseini *et al.* (2025) demonstrated that digital technologies offer both interim and long-term solutions to help address the slow and uncertain growth of the specialised mental health workforce in the region. Notably, the growth rate of youth mental health service capacity in Western Sydney has declined in recent years compared to trends observed since 2010. However, a critical and previously unexplored issue remains: given the uncertainty around social determinants of youth mental health (which includes social cohesion, substance misuse, early life exposures to difficulties, education, employment, etc.), to what extent can the continued implementation of digital technologies sustain improvements in mental health outcomes at the same rate as earlier gains? This represents a critical question for mental health service planning, particularly when making decisions about the appropriate scale-up of digital interventions in the region.

2.2. Research Methods

A participatory approach was employed throughout the modelling process, as detailed by Freebairn *et al.* (2022). Model development began with three in-person preliminary site visits for coordination and planning with the Western Sydney Primary Health Network. This was followed by three in-person workshops involving over 70 representatives from a range of stakeholder groups, including, most importantly, local young people with lived

¹ www.rightcarefirsttimewhereyoulive.com.au

experience of the mental health system. Moreover, nine model development group sessions were held in between workshops, focusing on detailed discussions about the model structure for different sectors and interventions (for further details, see Hosseini *et al.* (2025)). Afterwards, three superuser training sessions were conducted, involving 25 participants from stakeholder groups. One of these sessions was customised for young people with lived experience of the mental health system, which included an advocacy component to support the use of the model.

The model incorporates historical data spanning from 2011 to 2023 and generates projections for the period 2025 to 2035. Its structure and parameter values are grounded in a robust evidence base, drawing on peer-reviewed literature, regional, state, and national time series data, as well as expert input. Model construction, interface development, and simulation analyses were conducted using Stella Architect version 3.0.1². While the model includes all population age groups, this study specifically focuses on individuals aged 15–24 years.

2.3. Model Overview

Figure 1 illustrates the interconnected subsystems of the model and their causal relationships (for detailed model structure, data and evidence used, and validation, see Hosseini *et al.* (2025)). The model comprises 13 subsystems, encompassing population dynamics, social determinants of youth mental health, early life exposures and psychological distress, suicidal behaviour, and youth mental health services.

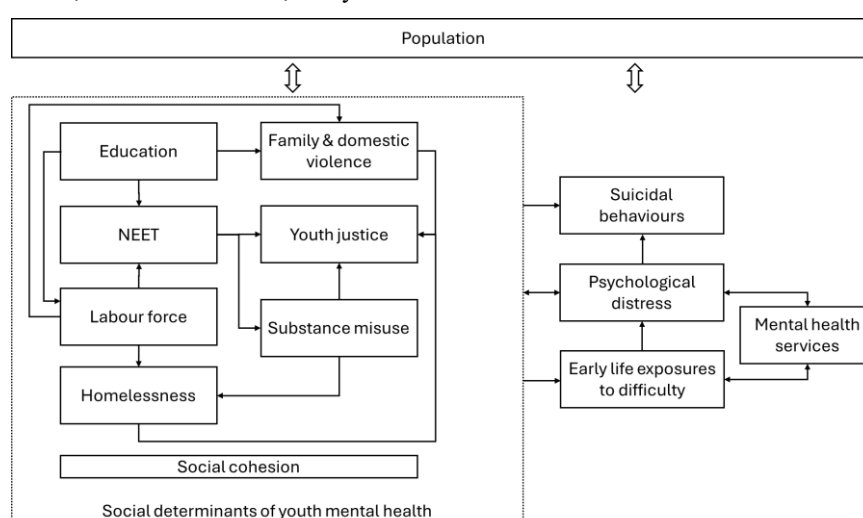


Figure 1. Overview of the subsystems and causal structure of the model (based on Hosseini *et al.* (2025))

2.4. Simulation Analyses

In this study, we examined five implementation scenarios for digital interventions and conducted sensitivity analyses for each to account for uncertainties in selected social determinants. The scenarios range from minimal to intensive deployment. The minimal deployment scenario assumes no growth in referrals to online services—either by general practitioners or through self-referrals by help-seekers—and a baseline uptake of technology-enabled care coordination at 30%. In contrast, the intensive deployment scenario includes a twofold increase in referrals and a 70% uptake of technology-enabled care coordination. The implementation scenarios are as follows:

- Scenario a: growth multiplier for referrals to online services = +2; Tech-enabled uptake = 70%
- Scenario b: growth multiplier for referrals to online services = +1.5; Tech-enabled uptake rate = 60%
- Scenario c: growth multiplier for referrals to online services = +1; Tech-enabled uptake rate = 50%
- Scenario d: growth multiplier for referrals to online services = +0.5; Tech-enabled uptake rate = 40%
- Scenario e: growth multiplier for referrals to online services = 0; Tech-enabled uptake rate = 30%

To assess the impact of uncertainty in key social determinants under the various implementation scenarios, a sensitivity analysis was conducted focusing on three factors: trends in social cohesion, the onset of substance misuse, and adverse early life exposures. The Latin Hypercube Sampling method (Helton & Davis, 2003) was employed to generate 200 random parameter combinations using a multivariate uniform distribution. These variations were applied to simulation projections from 2025 onwards. The parameter ranges for the marginal uniform sampling distributions were informed by the maximum variability observed in historical data and were widened by approximately 50% to account for potential unforeseen influences.

² www.iseesystems.com

- The annual change in social cohesion, measured by the Scanlon-Monash Index (Scanlon Foundation Research Institute, 2023), was adjusted using a multiplier between 0.86 (−14%) and 1.07 (+7%) to reflect uncertainty.
- The annual change in substance misuse onset rate, based on the number of individuals with a 12-month substance use disorder (Australian Bureau of Statistics, 2022c), was adjusted using a multiplier between 0.9 (−10%) and 1 (0%) to reflect uncertainty.
- The annual change in the onset of early life exposures, based on the prevalence of different Strength and Difficulty Questionnaire (SDQ) states and the population in SDQ levels (Australian Institute of Family Studies, 2022), was adjusted using a multiplier between 0.8 (−20%) and 1.16 (+16%) to reflect uncertainty.

3. SIMULATION RESULTS

Figure 2 presents the simulation results from the sensitivity analysis across the five scenarios, illustrating the projected reductions in mental health-related ED presentations among individuals aged 15–24. In each graph, the solid line represents the median value for each year, the darker shaded area indicates the 50% uncertainty interval, and the lighter shaded area indicates the 95% uncertainty interval. The results demonstrate that, despite uncertainties in key social determinants of youth mental health, increased implementation of digital interventions is consistently associated with greater reductions in ED presentations. By 2035, the median projected reductions in ED presentations, compared to the baseline scenario, are 363, 343, 307, 254, and 180 for scenarios a, b, c, d, and e, respectively—highlighting a clear trend of improved outcomes with higher levels of digital intervention deployment. Figure 3 also illustrates the influence of uncertainties in selected social determinants on the projected number of ED presentations among individuals aged 15–24 under different implementation scenarios in 2035. Scenarios involving more intensive implementation of digital interventions tend to exhibit lower relative uncertainty—measured as the width of the 95% uncertainty interval as a percentage of the median—although this pattern is not uniformly observed across all scenarios.

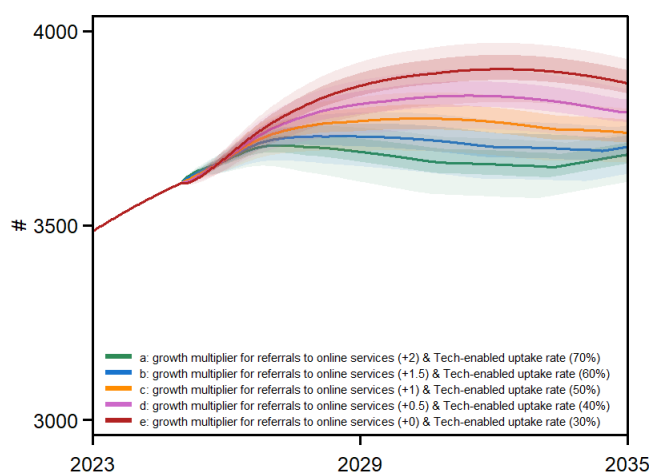


Figure 2. The sensitivity analysis graphs for the impact of different implementation levels of digital interventions on the number of ED presentations for individuals aged 15–24

Implementation scenario	Uncertainty interval in 2035			Relative uncertainty width
	Lower 95%	Median	Upper 95%	
a: growth multiplier for referrals to online services (+2) & Tech-enabled uptake rate (70%)	3612.3	3683.1	3738.2	3.42 %
b: growth multiplier for referrals to online services (+1.5) & Tech-enabled uptake rate (60%)	3633.0	3703.0	3757.3	3.36 %
c: growth multiplier for referrals to online services (+1) & Tech-enabled uptake rate (50%)	3661.2	3738.8	3799.7	3.70 %
d: growth multiplier for referrals to online services (+0.5) & Tech-enabled uptake rate (40%)	3714.6	3791.5	3851.5	3.61 %
e: growth multiplier for referrals to online services (+0) & Tech-enabled uptake rate (30%)	3786.8	3865.6	3927.0	3.63 %

Figure 3. The impact of different implementation levels of digital interventions on the number of ED presentations for individuals aged 15–24

Figure 4 addresses the central research question: Does increasing implementation of digital interventions yield consistent returns in terms of reductions in ED presentations? The figure plots the median results from the sensitivity analysis across each implementation scenario, allowing for a direct comparison of marginal gains. The results indicate that while higher levels of digital intervention deployment are associated with improved outcomes, the relationship is not linear. Instead, a pattern of diminishing returns is observed—demonstrating a saturating trend whereby incremental increases in implementation yield progressively smaller reductions in ED presentations. This suggests that beyond a certain threshold, further scaling up of digital interventions may offer limited additional benefit.

The saturating effect observed in the simulation results arises from the interaction between the demand for mental health services, the available service capacity, and the resulting waiting lists. Increased implementation of digital interventions helps reduce waiting times, which in turn lowers the risk of service disengagement—a critical factor, as individuals who disengage while waiting are more likely to re-present to emergency departments (Cullen *et al.*, 2022). Additionally, shorter waiting times alleviate pressure on the mental health system, enabling more timely care and improved health outcomes (Vacher *et al.*, 2024). However, once the system's bottlenecks are sufficiently relieved, further implementation yields diminishing benefits, explaining the observed saturation in outcomes.

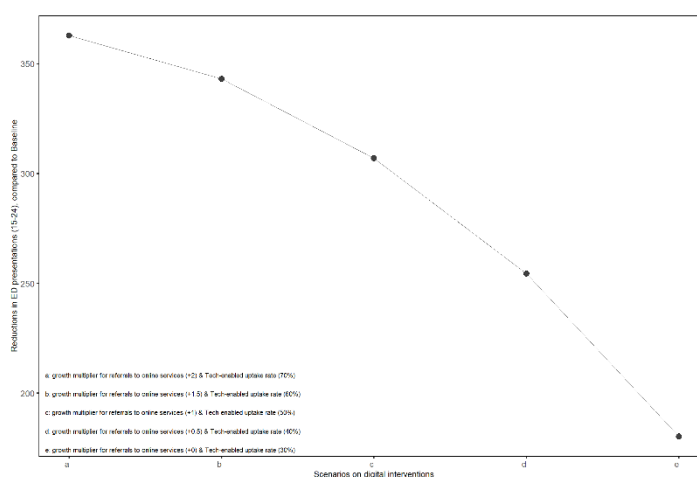


Figure 4. The impact of different implementation scenarios of digital interventions on the reduction of ED presentations for individuals aged 15-24 in 2035.

4. DISCUSSION AND CONCLUSION

Participatory system dynamics modelling was employed to examine the effects of varying implementation strategies for digital interventions on youth mental health outcomes, while accounting for uncertainties in key social determinants. The analysis focused on reductions in mental health-related ED presentations among young people (aged 15-24) in the Western Sydney region, considering uncertainties in social cohesion, the onset of substance misuse, and adverse early life exposures. Five implementation scenarios were developed, varying the level of technology-enabled integrated care (measured by its uptake rate) and the expansion of online services (measured by the growth in referrals). These scenarios ranged from minimal to intensive deployment, allowing for a comprehensive exploration of potential system behaviours under different implementation intensities.

The simulation results revealed a consistent trend of greater reductions in ED presentations as the level of digital intervention implementation increased, given the significant uncertainties related to social cohesion, substance misuse, and adverse early life exposures. However, the relationship between implementation intensity and outcome improvement exhibited a saturating pattern, indicating that further scaling up of digital interventions does not continue to alleviate mental health services' capacity constraints and to yield proportional benefits beyond the initial stages of implementation.

The observed diminishing returns on investment—measured by reductions in mental health-related ED presentations—underscore the importance of adopting an integrated perspective in cost-effectiveness analyses when making decisions about scaling up digital technologies. While existing evidence suggests that digital interventions are cost-effective (Catarino *et al.*, 2023; Crosland *et al.*, 2024), this does not imply that increased expansion is always justified. Rather, allocating additional resources to higher levels of implementation that produce progressively smaller marginal gains may not be the most efficient use of funding resources in terms of reductions in ED presentations. These resources could potentially yield greater impact if redirected to other cost-effective interventions within the youth mental health system, a decision that requires an integrated cost-effectiveness analysis that accounts for other health benefits such as quality-adjusted life years.

4.1. Perspectives of Youth Lived Experience

In line with our participatory approach throughout the entire modelling process—from problem articulation to insight generation—this section summarises the perspectives of two young people (ZWB and DL) with lived experience of the mental health system on the findings presented above (see Textbox 1).

4.2. Acknowledgements

The authors gratefully acknowledge all participants and stakeholders who contributed their time and expertise to the systems modelling workshops that informed this research. In particular, we extend our sincere thanks to the young people with lived experience of the mental health system, whose generous sharing of insights and knowledge greatly enriched the modelling process and the outcomes of this study.

Textbox 1. Perspectives of youth lived experience

We appreciate the input of all the young people who contributed to the model and the opportunity for us to contribute. We emphasise how essential it is for young people with lived experience to participate in decision making on funding, as we experience and hold expertise on how it impacts our lives. These results show that digital interventions can have value in reducing ED presentations and provides evidence for funding decision makers on impactful interventions, given finite resources. However, technology alone cannot be the solution, as evidenced by the diminishing returns on investment. We would also like to reiterate that ED presentations only represent one piece of the youth mental health landscape and are not necessarily representative of overall youth mental health. We need to find the right digital interventions to deliver help and fill gaps, rather than duplicating efforts. Some digital interventions for mental health, though useful, are already widely available, e.g. online resources or mobile apps, and the choice of these can be overwhelming and confusing. Digital interventions can also be more accessible for young people, e.g. peer worker/crisis counsellor web or text chat, self-paced program delivery, telehealth, online forums, etc. However, barriers to accessing technology still exist among young people, e.g. private access to a device and digital literacy. Additionally, some of these digital interventions can be very brief and consequently, not focussed on long term recovery. Technology-enabled integrated care is a digital intervention that presents an opportunity for more holistic care by measuring the efficacy of treatment from the young person's individual perspective. Overall, we encourage the development of innovative digital interventions in collaboration with young people.

4.3. Funding Statement

This research was carried out as part of the Right Care, First Time, Where You Live program, led by Brain and Mind Centre, University of Sydney and funded through an AU\$12.8 million partnership with the BHP Foundation.

4.4. Conflict of interests

JO is Head of Systems Modelling & Simulation at the Brain and Mind Centre, University of Sydney, and is Managing Director of Computer Simulation and Advanced Research Technologies (CSART). IBH is a Professor of Psychiatry and the Co-Director of Health and Policy, Brain and Mind Centre, University of Sydney. He has led major public health and health service development in Australia, particularly focusing on early intervention for young people with depression, suicidal thoughts and behaviours and complex mood disorders. He is active in the development through codesign, implementation and continuous evaluation of new health information and personal monitoring technologies to drive highly-personalised and measurement-based care. He holds a 3.2% equity share in Innowell Pty Ltd that is focused on digital transformation of mental health services. VL is a board member for Matana Foundation, a philanthropic organisation that provides funding to programs for disadvantaged young people in Australia. She does not receive any financial benefit for this role. YJCS is Co-Company Secretary at The Funding Network Australia Limited, a philanthropic organisation focused on supporting grassroots giving for impact. SHH, PC, NH, AS, CV, KT, KHN, SP, SH, SF, SM, ZWB, and DL declare no competing interests.

4.5. Ethical considerations

This study has been approved by the Human Research Ethics Committee of the Sydney Local Health District (Protocol No X21-0151 & 2021/ETH00553) and was conducted in accordance with the National Health and Medical Research Council (NHMRC) National Statement on Ethical Conduct in Human Research (NHMRC 2007, updated 2023). The study utilised only aggregate-level secondary data sources. Stakeholder participation in the model co-design workshops was completely voluntary and they were not the subject of the research. Where relevant, travel and meal costs were reimbursed to participants.

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