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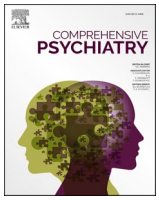

Pathways to suicidal ideation for young people engaged in mental health care

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ABSTRACT

Background: Suicidal thoughts and behaviours (STBs) have a profound impact on individuals, communities, and healthcare systems. A wide range of factors have been shown to be associated with STBs. Within prior research it is also common to distinguish between proximal and distal factors, usually by distinction of short compared to long-term prediction.
Objective: We aimed to learn the proximal and distal factors of suicidal ideation for young people engaged in mental health care using the inferred structure of probabilistic graphical models (PGMs).
Methods and materials: We used cross-sectional data from a sample of 1020 help-seeking individuals aged 12–25 years from Australia that while engaged in mental health care, contributed data to a digital platform. The posterior distribution of the dependency structure assuming both undirected PGMs and Bayesian networks (BNs) was inferred. Causal effects were then estimated using a counterfactual query of the Bayesian networks.
Results: Depressed mood, functional impairment, poor social connection, and psychosis-like experiences were proximal factors. Whereas experiencing a traumatic event, anxiety, insomnia, and unrefreshed sleep were distal factors. Proximal factors had the greatest effect on suicidal ideation, while anxiety symptoms and experiencing a traumatic event were the most influential distal factors.
Conclusions: These relative timings of events and their effects on suicidal ideation could be used to understand the future likelihood of suicidal ideation, and aid planning of targeted interventions.

1. Introduction

Suicidal thoughts and behaviours (STBs) have a profound impact on individuals, communities, and healthcare systems. Suicide is the fourth leading cause of death globally for individuals aged 15–29 years [1], and the leading cause of death for individuals aged 15–24 years in Australia [2]. Suicidal thoughts are problematic in and of themselves and are prevalent [3], with a 12-month prior prevalence rate of approximately 15 % for adolescents worldwide, with variation between 8 and 21 % depending on location and study [4,5]. A recent meta-analysis suggested that lifetime prevalence rates for suicidal ideation was 19 % for youths in Australia and New Zealand [6].

Due to the impact of STBs, significant resources have focused on understanding the associated risk factors [7–9]. These factors are varied and include prior STBs or self-harm [10,11], interpersonal functioning [12–16], personal functioning [17,18], clinical diagnoses [8,19],

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specific psychological symptoms and states [20,21], sleep problems [22], and sociodemographic factors. Most of these risk factors have been found for adult samples, although similar risk factors are often found for youth [23,24]. Specific risk factors for youth include parental relationships [4,25], their parents' prior history of STBs and other clinical factors [26], and school connectedness [24].

Many of these risk factors have been shown to be associated with suicidal ideation specifically, rather than suicide attempts [27,28]. While suicidal ideation is a prerequisite of suicide attempts, only one third of people with suicidal ideation make a suicide attempt within their lifetime [8]. Similar rates of suicidal ideation to attempts are often reported in youths [29–31]. Although, Uddin et al. [5] found 12-month prevalence for suicidal ideation and attempts were comparable in a worldwide youth sample.

This wide array of associated factors raises the question around the relative timing and causal pathways to STBs. Hence, these factors are often split into proximal (i.e., recent predictors of STBs, e.g., recent mood) or distal factors (i.e., long-term predictors, e.g., sociodemographic factors) [7,27]. This proximal-distal distinction can also be framed in terms of causal paths to STBs. In the causal framework, proximal factors are those that have direct effects on STBs. Whereas distal factors are further upstream and thus their effect on STBs is mediated by proximal factors. Understanding these causal pathways would help to identify appropriate intervention and preventative targets, as well as their relative timings.

Probabilistic graphical models (PGMs) are an approach to gain insight into the dependency structure between variables within one's data [37,38]. In PGMs, variables are represented as nodes and conditionally dependent variables are indicated by lines connecting nodes (i.e., edges). Undirected PGMs are a specific case of a PGM that make no claim about the directionality of edges between nodes, which have become commonplace in psychological research [39]. They have been used to show the dependency structure of various factors with suicidal ideation, including theoretically considered factors [e.g., burdensomeness, thwarted belongingness, [40]], along with a range of psychological and behavioural factors [41–44].

Bayesian networks (BNs) are an alternative PGM to describe the dependency structure [37]. BNs represent the dependency structure with a directed acyclic graph (DAG), that has directed edges that if followed cannot result in a cycle. A potential advantage of BNs over undirected PGMs is that they allow for causal interpretations [45,46], thus providing a data-driven approach to causal hypothesis generation and causal effect estimation. BNs can be learnt from observed data up to an equivalence class even from cross-sectional data. A recent paper used BNs to understand the dependencies between clinical and psychosocial factors with suicidal ideation, where they found that suicidal ideation was dependent on total depressive symptoms, total anxiety symptoms, self-efficacy, resilience, and quality of life [47]. However, that analysis did not distinguish between proximal and distal factors of suicidal ideation.

In this paper, we use undirected PGMs and BNs to perform exploratory analysis of the potential pathways to STBs, with a focus on distinguishing between proximal and distal factors, using a range of clinical and psychosocial variables for young people that present to services across Australia.

2. Methods

This study was approved by the Northern Sydney Local Health District Human Research Ethics Committee (HREC/17/HAWKE/480) and all participants gave online informed consent (via an opt-out process).

2.1. Participants

Participants were a group of young people aged 12–25 years who presented to *headspace* services in Australia [48] between November 2018 and October 2023 and used the Innowell platform [49]. Individuals completed an initial questionnaire within Innowell at intake to *headspace*. The questionnaire covers a wide array of clinical, psychosocial, and comorbid factors that may influence an individual's care. Questionnaires were primarily used for triaging purposes, thus making this a secondary analysis of these data. Individual's must have completed all item-level questions that appear within this paper to have been admitted to the study.

2.2. Innowell

Innowell is a digital technology used clinically for the assessment, management, and monitoring of mental health and well-being. The web-based platform allows individuals to complete a multidimensional clinical assessment at entry into care and over the course of care in a self-directed or clinically directed way. Results are displayed on a personalised dashboard to provide a better understanding of an individual's needs, track progress, and get access to recommended self-directed or clinical care options. The tool is not intended as a crisis management tool, although a standardised notification is used for those young people reporting suicidal thoughts and behaviours, so that an immediate clinical response and protocol can be engaged by the service.

2.3. Measures

The initial questionnaire in the Innowell platform covers multiple domains. The domains that we use in this analysis are; 1) mental health, including; psychosis-like experiences using the 16-item Prodromal Questionnaire [PQ16; [50]]; depressed mood using the Quick Inventory of Depression Symptomatology [QIDS; [51]]; anxiety using the Overall Anxiety Severity and Impairment Scale [OASIS; [52]]; mania-like experiences using the Altman Self-Rating Mania Scale [ASRM; [53]], 2) functioning impairment due to mental health using the Work and Social Adjustment Scale [WSAS; [54]], 3) social connection using Schuster's Social Support Scale [SSSS; [55]], 4) lifetime experience of a traumatic event, 5) sleep quality and timings using the BMC Sleep-Wake Cycle [56–59], and 6) suicidal ideation using the Suicidal Ideation Attributes Scale [SIDAS; [60]]. We also account for demographic variables including age, sex, and whether they presented to an urban or regional service [61]. These questions probed those domains over approximately the last four weeks. We also used a question regarding suicide attempts in the past three months from the Columbia-Suicide Severity Rating Scale [C-SSRS; [62]]. See Supplementary Materials 1 for further details.

3. Statistical analyses

All statistical analyses were performed in R version 4.4.1 [63].

3.1. Distinguishing between proximal and distal factors using regression analysis

We first attempted to distinguish between proximal and distal factors through regression analysis on STB outcomes. To understand this, consider a causal process between three variables (A, B, C) represented by the DAG $A \rightarrow B \rightarrow C$ and linear functions relating the variables. The conditional independence we expect in observed data following this causal process is A is independent of C given B. This conditional independency can be discovered using conditional and marginal regression analysis. In this example, a marginal regression analysis of C on A will detect a non-zero association. However, in a conditional regression analysis where C is regressed on A and B simultaneously, the regression coefficient for A will be zero, reflecting that A is a distal factor, where it's influence on C is mediated by B. Whereas both the marginal and conditional regression coefficients of B on C will be non-zero. Therefore, conditional and marginal regression analysis allows us to distinguish between proximal and distal factors along the path to STBs. A caveat is

that this analysis is unable to distinguish between proxies of factors along the paths to STBs, which will be better dealt with by learning Bayesian networks discussed below.

We use this understanding of conditional independence to distinguish between the proximal and distal factors on STB outcomes. Two binary outcomes are considered; 1) those with or without a recent suicide attempt, or 2) those with or without high suicidal ideation (SIDAS $\geq$20). This is estimated using Bayesian logistic regression implemented in the rstanarm package [64]. Marginal odds-ratios were estimated only including the clinical, psychosocial, and demographic factor as a predictor of the STB outcome. Conditional odds-ratios were estimated by including all factors as predictors. We report the odds ratio posterior median and 95 % highest density credible interval [65].

3.2. Undirected probabilistic graphical model

We sampled from the posterior distribution for a Gaussian graphical model (GGM). A GGM is an undirected PGM that assumes the data follow a multivariate normal distribution. This inference was performed using BDgraph [66]. BDgraph uses a birth-death Markov chain Monte Carlo (MCMC) scheme with proposals that add and remove edges. The goal of this MCMC scheme is to sample PGMs in accordance with their posterior probability. The samples retained from the MCMC scheme can then be summarised using common statistical measures. For example, the posterior edge probability is equal to the frequency of that edge occurring in the samples. For results from an MCMC to be robust it is important that we run multiple chains that converge to consistent results. As such, we ran four chains for five million iterations each with the first thousand iterations removed as burnin. As a convergence check, we ensured that the difference in the estimated edge probabilities across all chain pairs was within 10 %. Note that for all inferences for PGMs we removed items that were deemed to overlap with other questionnaires. These removed items were; 1) OASIS_3, OASIS_4, and OASIS_5 that ask about functioning related aspects of anxiety, 2) QIDS_12 that asks about suicidal ideation, 3) PQ16_1 that asks about interest, and 4) PQ16_7 that asks about anxiety when meeting new people.

3.3. Bayesian network

Inference for the posterior distribution of Bayesian Networks was then performed. Estimating the posterior distribution of BNs is difficult due to the large number of possible DAGs. For example, the number of possible DAGs for a 10-node BN is on the order of 10^{18}. Several simplifications were implemented to reduce the possible number of DAGs. We collapsed the items into factors in accordance with prior research. PQ16 items were collapsed into unusual thoughts (sum of PQ16 questions 2, 5, 10, 11, 14) and perceptional abnormalities (sum of PQ16 questions 3, 4, 6, 8, 9, 12) [50]. SSSS items were collapsed into a perceived negative (sum of SSSS questions 1, 2, and 6) and a perceived lack of positive social connection (sum of SSSS questions 3–5) with family and friends [55]. QIDS was collapsed into insomnia (sum of questions 1–3), hypersomnia (question 4), motor activation (sum of questions 15 and 16), recent appetite and weight change (max of QIDS_WEIGHT and QIDS_APPETITE) with the remaining questions separated. This broadly follows the original aggregated items by Rush et al. [51], with the exception that we split out insomnia and hypersomnia and tended to sum rather than calculate the max, so that we could retain information across all items. OASIS, WSAS, and SIDAS were considered as one factor for each questionnaire representing anxiety, functioning, and suicidal ideation respectively, with the total scores used to estimate the BN.

We also made the following assumptions with respect to the pairwise edges. Suicidal ideation could not be a parent of any other nodes, thus assuming that it is an outcome. A traumatic event could only be a child node of age and sex. Unrefreshed sleep could not be a parent of insomnia or hypersomnia nodes. As WSAS asks about functioning conditional on an individual's mental health it could not be a parent of mental health factors. We also assume that age and sex could not be children of any other node.

Posterior sampling of Bayesian networks was achieved using a bespoke implementation of the Partition Markov chain Monte Carlo (PMCMC) scheme [67,68]. We started all chains from an optimised starting point as estimated by taking the *maximum a posterior* estimate over 10^4 runs of tabu search, where each run was started from a random location [69,70]. We ran eight chains of PMCMC for 10^7 iterations saving every 500th iteration, leading to 20,000 samples.

We checked the chains for convergence and resolution. The split-$\widehat{R}$ convergence statistic relates the ratio of the between-chain and within-chain variance. Perfectly converged chains have equal between-chain and within-chain variance, thus $\widehat{R} = 1.0$. In practice $\widehat{R} < 1.01$ is used as a threshold that suggests multiple chains have converged [71,72]. We estimated $\widehat{R} < 1.01$ for both the log partition and DAG scores. Another important metric is the effective sample size (N_{eff}) that provides an estimate for the number of independent samples across the chains, with $N_{\text{eff}} > 100N_{\text{chains}}$ being a common target. We estimated $N_{\text{eff}} = 6645$ using the log partition score and $N_{\text{eff}} = 1081$ for the log DAG score. We also checked the difference of the pairwise edge probabilities between chains [73], where the difference between all edge probabilities between all chains was always $< 20\%$. These statistics suggest reasonable convergence and resolution of the chains.

3.4. Causal effects

We estimated the average causal effects (ACE) across our sample that intervening to deterministically change a node would have on another node. The ACE can be thought of as the typical difference of the effect node if we changed the intervened node deterministically. Thus, ACE is a counterfactual query of the Bayesian network, where the posterior distribution for the ACE of B on A is given by,

$$p\left(ACE_{A,B}|D\right) = \sum_{N}[p(A|do(B{\rightarrow}B+1),N) - p(A|N)]p(N|D).$$

This quantity is marginalised over the posterior distribution of the BNs N given the data D. As $p(A|do(B{\rightarrow}B+1),N)$ is a causal estimand due to an hypothesised intervention, we must correct for the confounders of A and B [74], which is implemented in the Bestie package [75]. Marginalisation over the BNs is implemented by performing this calculation per iteration from our posterior sample of BNs. The ACE posterior distribution is typically multimodal as when there is no path from intervened node B to the effect node A the effect size is zero, and non-zero when there is a path. As such, we chose to report the median and the 25 % and 75 % quantiles. When zero is not within the interquartile range the probability of a path from A to B will be at least 50 %.

4. Results

4.1. Differential odds of suicidal thoughts and behaviours

The sample comprised of 1020 individuals (72.0 % female, 81.8 % urban) with a mean age of 19.6 years (SD, 2.8 years). Of these individuals, 21 (2.1 %) had a suicide attempt within the last three months. The marginal odds of having a recent suicide attempt increased with experiencing a traumatic event (OR, 2.80, 95 % HDI, 1.08, 7.96), female sex (OR, 4.01, 95 % HDI, 1.12, 21.43), depressed mood (OR, 1.35, 95 % HDI, 1.19, 1.52), suicidal ideation (OR, 1.21, 95 % HDI, 1.15, 1.28), psychosis-like experiences (OR, 1.21, 95 % HDI, 1.09, 1.35), anxiety (OR, 1.16, 95 % HDI, 1.04, 1.32), functioning (OR, 1.07, 95 %, 1.01, 1.13), and potentially social connection (OR, 1.12, 95 % HDI, 1.00, 1.28). However, the conditional odds-ratios only increased with suicidal ideation (OR, 1.26, 95 % HDI, 1.18, 1.36) and potentially lowered by personal function (OR, 0.90, 95 % HDI, 0.82, 0.99). This result suggests

that suicidal ideation is the only proximal factor on a recent suicidal attempt. We focus our remaining analysis on suicidal ideation given this result. Further details are shown in Table 1 with more detail provided in Supplementary Tables S3-S5.

There were 321 (31.5 %) individuals within the high suicidal ideation category (SIDAS $\geq$ 20). The marginal odds of having high suicidal ideation increased with experiencing a traumatic event (OR, 1.49, 95 % HDI, 1.14, 1.97), depressed mood (OR, 1.25, 95 % HDI, 1.20, 1.31), sleep (OR, 1.43, 95 % HDI, 1.14, 1.76), social connection (OR, 1.14, 95 % HDI, 1.10, 1.19), anxiety (OR, 1.14, 95 % HDI, 1.10, 1.18), psychosis-like experiences (OR, 1.14, 95 % HDI, 1.10, 1.18), and functioning (OR, 1.11, 95 % HDI, 1.09, 1.14). Whereas being older tended to decrease the odds of having high suicidal ideation (OR, 0.93, 95 % HDI, 0.89, 0.98). Conditional odds ratios suggested that the proximal characteristics that increased the odds of high suicidal ideation were depressed mood (OR, 1.13, 95 % HDI, 1.07, 1.21), psychosis-like experiences (OR, 1.06, 95 % HDI, 1.01, 1.11), functioning (OR, 1.08, 95 % HDI, 1.05, 1.11) and potentially social connection (OR, 1.05, 95 % HDI, 1.00, 1.10), with older age still reducing the odds (OR, 0.91, 95 % HDI, 0.86, 0.97). Further details are shown in Table 2 with further information provided in Supplementary Tables S6-S8. We found no association between mania-like experiences and being in an urban location with either a recent suicide attempt or being in the high suicidal ideation category, thus we do not consider these questions within subsequent analyses.

4.2. Undirected probabilistic graphical model

The inferred item-level undirected PGM was dense with suicidal ideation being directly or indirectly associated with all domains (Fig. 1). As would be expected, we see dependencies between items within each question set. Items in depressed mood, functioning, and anxiety are also highly dependent. Suicidal ideation is directly associated with all

Table 1
Sample characteristics and odds-ratios for a recent suicide attempt. Marginal odds-ratios estimate the unconditioned association for a recent suicide attempt given the sample characteristic. Conditional odds-ratio estimate the association between the sample characteristic and the outcome while controlling for all other sample characteristics. We report the median and 95 % highest density interval for the sample characteristic.

	Total	Recent suicide attempt	No recent suicide attempt	Marginal odds ratio	Conditional odds ratio
No. (%)	1020	21 (2.1 %)	999 (97.9 %)		
Demographics					
Female sex, No. (%)	734 (72.0%)	19 (90.5 %)	715 (71.6 %)	**4.01 (1.12, 21.43)**	1.88 (0.39, 9.90)
Age in years, mean (SD)	19.6 (2.8)	18.9 (2.5)	19.6 (2.8)	0.92 (0.78, 1.05)	1.12 (0.88, 1.43)
Urban, No. (%)	834 (81.8 %)	16 (76.2 %)	818 (81.9 %)	0.74 (0.28, 2.28)	0.79 (0.21, 2.97)
Traumatic Event	548 (28.0%)	16 (76.2 %)	532 (53.3 %)	**2.80 (1.08, 7.96)**	1.99 (0.55, 7.38)
Total Scores, mean (SD)					
Suicidal ideation (SIDAS)	15.2 (11.2)	39.0 (5.5)	14.7 (10.7)	**1.21 (1.15, 1.28)**	**1.26 (1.18, 1.36)**
Depressed mood (QIDS-adjusted)	14.6 (3.8)	17.8 (3.0)	14.5 (3.7)	**1.35 (1.19, 1.52)**	1.11 (0.90, 1.38)
Anxiety (OASIS)	10.4 (4.0)	12.7 (4.7)	10.4 (4.0)	**1.16 (1.04, 1.32)**	0.96 (0.82, 1.12)
Psychosis-like experiences (PQ16)	6.2 (3.9)	9.3 (4.4)	6.1 (3.8)	**1.21 (1.09, 1.35)**	1.11 (0.95, 1.28)
Mania-like experiences (ASRM)	3.1 (2.9)	3.7 (3.2)	3.0 (2.9)	1.06 (0.93, 1.20)	1.11 (0.95, 1.31)
Functioning (WSAS)	21.1 (7.8)	25.2 (7.3)	21.0 (7.7)	**1.07 (1.01, 1.13)**	**0.90 (0.82, 0.99)**
Social connection (SSSS)	8.1 (3.5)	9.6 (3.7)	8.0 (3.5)	1.12 (1.00, 1.28)	0.96 (0.82, 1.10)
Sleep (BMC Sleep-Wake Scale)	2.5 (0.6)	2.6 (0.6)	2.5 (0.6)	1.40 (0.70, 2.95)	0.75 (0.32, 1.89)

Note. Bold odds-ratios indicate when the 95 % highest density credible interval does not include 1. QIDS-adjusted is calculated as the total QIDS score with the value of question 12, which asks about suicidal ideation, subtracted.

Table 2
Sample characteristics and odds-ratios for high suicidal ideation (SIDAS $\geq$20). Marginal odds-ratios estimate the unconditioned odds-ratio for high suicidal ideation given the sample characteristic. Conditional odds-ratio estimate the association between the sample characteristic and the outcome while controlling for all other sample characteristics. We report the median and 95 % highest density interval for the sample characteristic.

	Total	High suicidal ideation	Low suicidal ideation	Marginal odds ratio	Conditional odds ratio
No. (%)	1020	321 (31.5 %)	699 (68.5 %)		
Demographics					
Female sex at birth, No. (%)	734 (72.0%)	242 (75.4 %)	492 (70.4 %)	1.29 (0.96, 1.78)	1.07 (0.77, 1.52)
Age in years, mean (SD)	19.6 (2.8)	19.2 (2.7)	19.7 (2.8)	**0.93 (0.89, 0.98)**	0.91 (0.86, 0.97)
Urban, No. (%)	834 (81.8 %)	254 (79.1 %)	580 (83.0%)	0.78 (0.55, 1.09)	0.95 (0.64, 1.40)
Traumatic Event	548 (53.7 %)	194 (60.4 %)	354 (50.6 %)	**1.49 (1.14, 1.97)**	0.97 (0.71, 1.33)
Total Scores, mean (SD)					
Depressed mood (QIDS-adjusted)	14.6 (3.8)	16.5 (3.4)	13.7 (3.6)	**1.25 (1.20, 1.31)**	**1.13 (1.07, 1.21)**
Anxiety (OASIS)	10.4 (4.0)	11.7 (4.1)	9.8 (3.8)	**1.14 (1.10, 1.18)**	0.98 (0.93, 1.02)
Psychosis-like experiences (PQ16)	6.2 (3.9)	7.5 (4.0)	5.6 (3.7)	**1.14 (1.10, 1.18)**	**1.06 (1.01, 1.11)**
Mania-like experiences (ASRM)	3.1 (2.9)	3.0 (3.0)	3.1 (2.8)	0.98 (0.94, 1.03)	0.96 (0.91, 1.01)
Functioning (WSAS)	21.1 (7.8)	25.0 (7.1)	19.3 (7.4)	**1.11 (1.09, 1.14)**	**1.08 (1.05, 1.11)**
Social connection (SSSS)	8.1 (3.5)	9.2 (3.7)	7.5 (3.3)	**1.14 (1.10, 1.19)**	1.05 (1.00, 1.10)
Sleep (BMC Sleep-Wake Scale)	2.5 (0.6)	2.6 (0.6)	2.5 (0.7)	**1.43 (1.14, 1.76)**	0.93 (0.72, 1.19)

Note. Bold odds-ratios indicate when the 95 % highest density credible interval does not include 1. QIDS-adjusted is calculated as the total QIDS score with the value of question 12, which asks about suicidal ideation, subtracted.

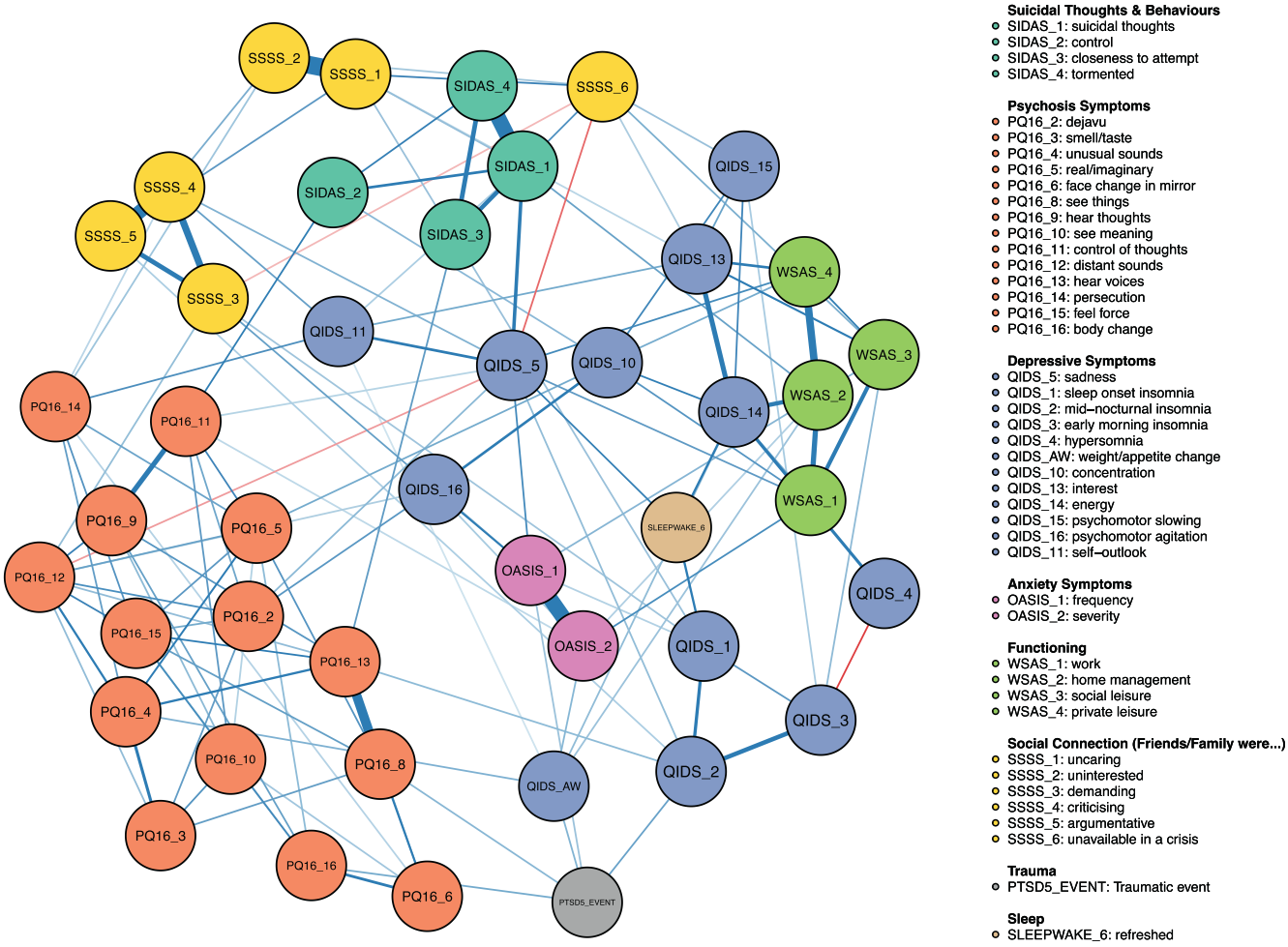

Fig. 1. Item-level undirected probabilistic graphical model. Edges are shown with $p \geq 0.5$.

domains except anxiety and experiencing a traumatic event (PTSD5_EVENT). Nodes that bridge the relationship between their respective domain and suicidal ideation are sadness (QIDS_5), self-perception (QIDS_11), concentration (QIDS_10), uncaring (SSSS_1) and unavailable (SSSS_6) friends and family, hearing voices (PQ16_13), a lack of control of thoughts (PQ16_11), and home management (WSAS_2). See further quantitative detail in Figs. S1-S3 in the Supplementary Material.

4.3. Bayesian network

We show the *maximum a posteriori* estimate for the subgraph that includes suicidal ideation along with its ancestors in Fig. 2. This result shares similarities with the inferred undirected PGM. Suicidal ideation was directly dependent on sadness, functioning, lack of positive social connection, and unusual thoughts. For simplicity, we will refer to nodes that suicidal ideation is directly dependent on as 'proximal factors'. Upstream of the proximal factors we see that suicidal ideation is indirectly dependent on several factors. We will refer to the nodes that have indirect paths to suicidal ideation as 'distal factors'. However, these distinctions should be considered relative rather than absolute. See further quantitative detail in Figs. S4-S7 in the Supplementary Material.

4.4. Causal effects

All question sets have factors with positive average causal effects (ACE) on suicidal ideation. The greatest ACEs on suicidal ideation are from sadness (ACE, 0.30, IQR, 0.28, 0.32), functioning (ACE, 0.20, IQR, 0.18, 0.22), unusual thoughts (ACE, 0.18, IQR, 0.16, 0.20), anxiety (ACE, 0.16, IQR, 0.15, 0.18), perceived lack of positive interactions with family and friends (ACE, 0.16, IQR, 0.14, 0.19), experiencing a traumatic event (ACE, 0.15, IQR, 0.13, 0.16), interest (ACE, 0.14, IQR, 0.12, 0.16), and abnormal perceptions (ACE, 0.12, IQR, 0.11, 0.14).

Nodes appearing early in the topological ordering including experiencing a traumatic event, insomnia, unrefreshed sleep, and anxiety symptoms have wide ranging effects. For example, experiencing a traumatic event has strong effects on many factors including abnormal perceptions (ACE, 0.50, 0.46, 0.54), anxiety (ACE, 0.39, IQR, 0.35, 0.44), unusual thoughts (ACE, 0.37, IQR, 0.34, 0.40), insomnia (ACE, 0.36, IQR, 0.32, 0.40), and perceived negative interactions with family and friends (ACE, 0.36, IQR, 0.31, 0.40). See Fig. 3 for the median values for cases where zero is not within the IQR. Further detail including the IQR along with sampling statistics for those edges with IQR inconsistent with zero showing reasonable convergence ($\max(\widehat{R}) = 1.01$) and resolution ($\min(N_{\text{eff}}) = 3219$) can be found in Supplementary Table S8.

5. Discussion

This work evaluated the dependencies for a range of clinical and psychosocial factors on STBs for those aged 12–25 years in Australia that while engaged in mental health care. Our results consistently revealed that depressive symptoms (particularly sadness), functional impairment, poor social connection (particularly a perceived lack of positive support), and psychosis-like experiences (particularly through hearing voices and a lack of control of thoughts in the unusual thoughts factor) were proximal factors to suicidal ideation, with most other clinical and

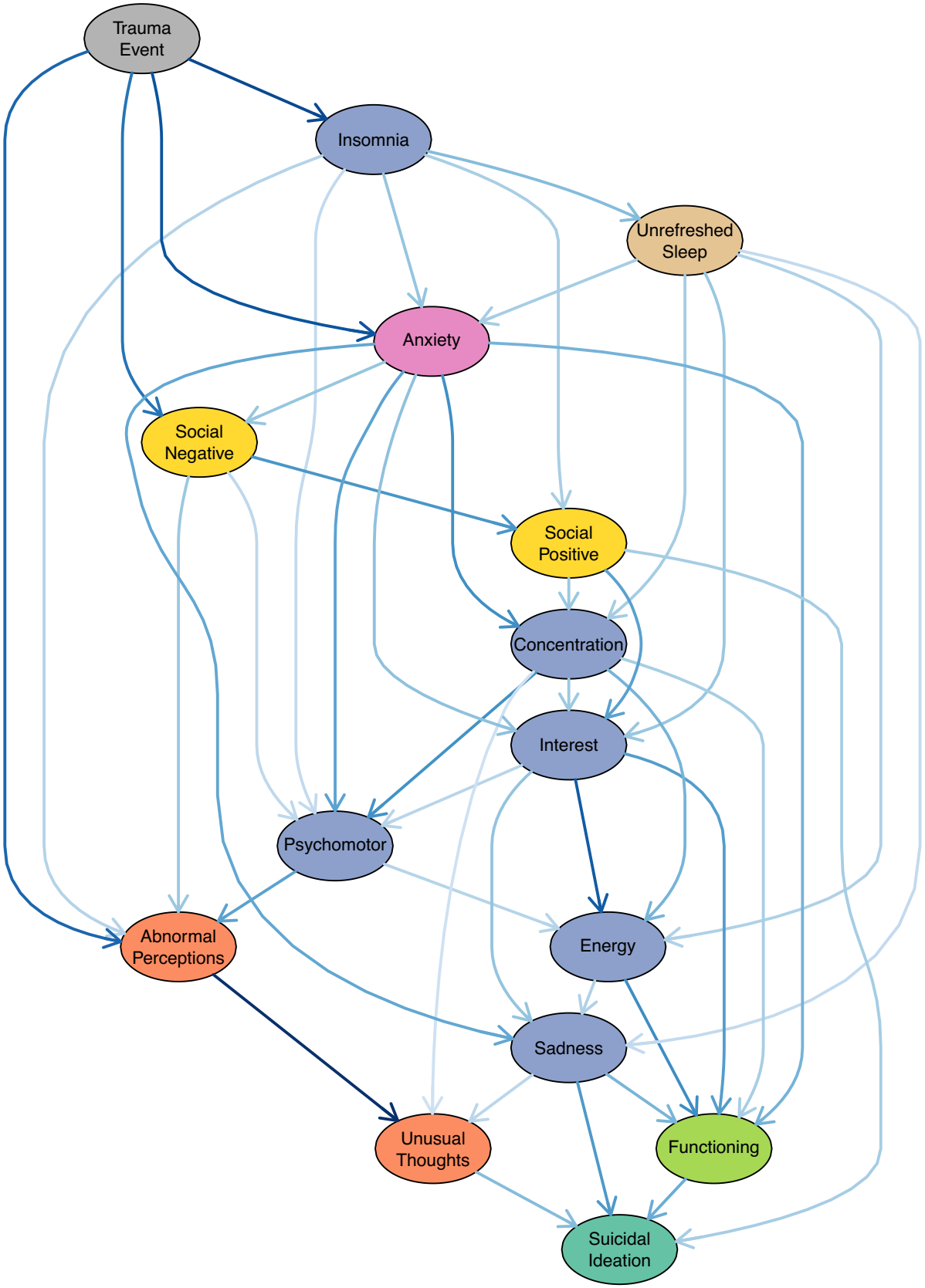

Fig. 2. Factor-level *maximum a posteriori* directed acyclic subgraph. We only show suicidal ideation and its ancestor nodes. All pairwise edges within this subgraph have posterior probability >0.5. Edges are coloured in darker blue in accordance with the estimated value for the linear regression coefficients given the subgraph. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

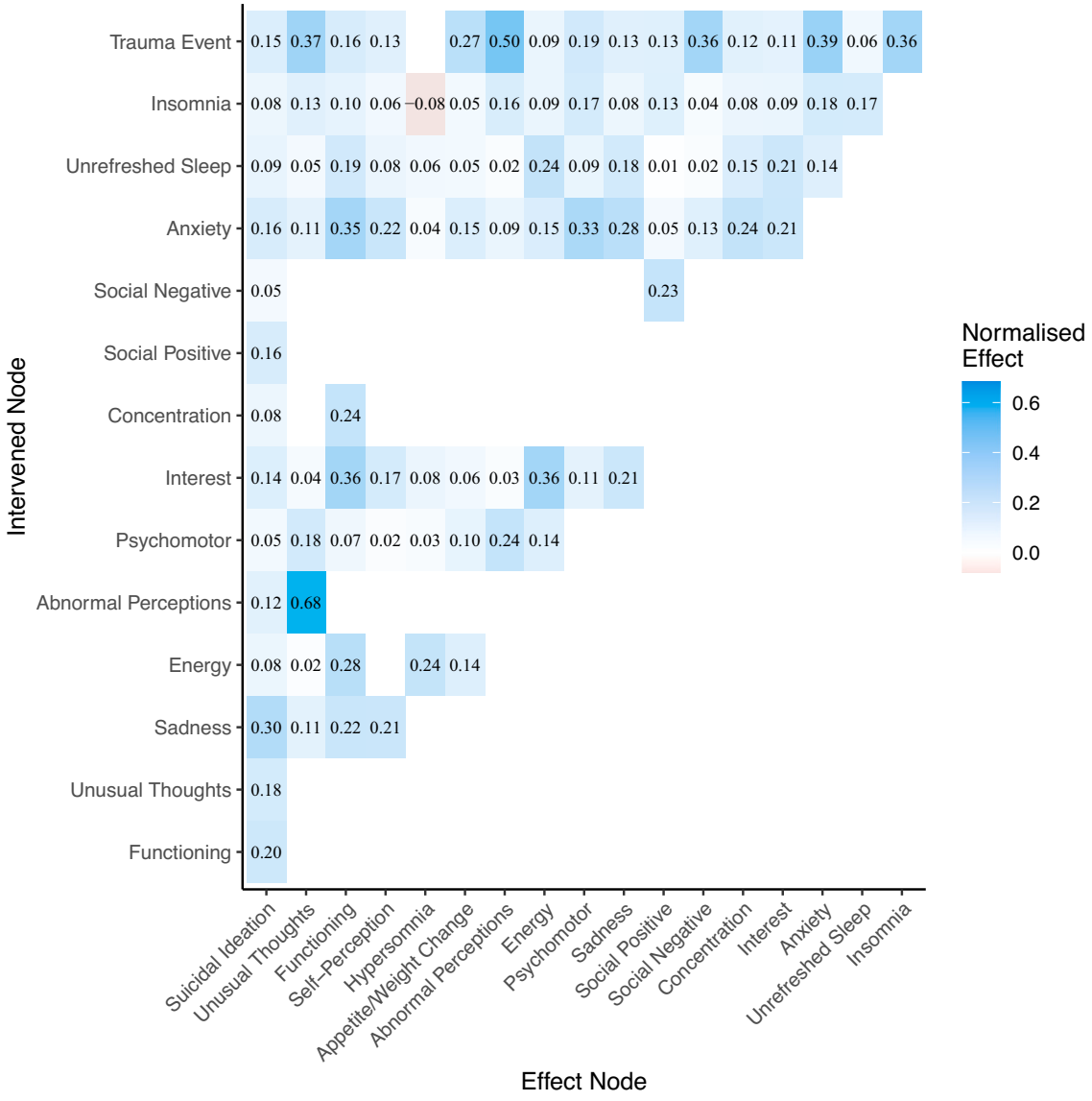

Fig. 3. Factor-level average causal effects. This shows the median change in the effect nodes on a normalised scale given a 1-sigma change for all variables, except for experiencing a traumatic event which corresponds to a category change. We only show causal effects where zero is not within the IQR.

psychosocial factors being distal.

Clinical and psychosocial factors were only marginally associated with a recent suicide attempt. Previous research has also found suicide attempts to be associated with a wide range of factors [9,21]. These analyses tend to focus on marginal associations, which are closely related to our marginal regression analyses. In our regression analysis for a recent suicide attempt, we found that experiencing a traumatic event, female sex, increased suicidal ideation, depressed mood, increased anxiety symptoms, and functional impairment were associated with a recent suicide attempt. However, conditional associations with a recent suicide attempt were primarily due to increased suicidal ideation. This suggests that most clinical and psychosocial factors are likely to influence a suicide attempt through suicidal ideation, which is consistent with analysis that tends to find that risk factors differ for suicidal ideation compared to attempts [28,76]. Thus, our focus in the subsequent analyses was on the paths to suicidal ideation with a primary focus of distinguishing between proximal and distal factors.

Distinguishing proximal and distal factors of suicidal ideation allows for a better understanding of the relevant information required to understand, predict, and prevent STBs. Proximal factors provide the most information about risk of suicidal ideation, as suicidal ideation is conditionally independent of distal factors given knowledge about proximal factors. Thus, given knowledge about an individual's proximal factors, there is little to no extra predictive information gained by understanding the distal factors. On the other hand, understanding an individual's distal factors may provide important context about the paths along which an individual arrived at their current state. This provides important information for interventional decision-making for those with suicidal ideation. Similarly, understanding proximal and distal factors and their effects on suicidal ideation provides information for prevention measures and their relative timings.

For example, the influence of experiencing a traumatic event on lifetime [79] and youth [80,81] STBs is well known. However, the processes by which trauma influences STBs along with other clinical and psychosocial factors is still debated [82]. Our analysis shows that a traumatic event influences STBs indirectly through a complex array of clinical and psychosocial factors. It has proximal effects on insomnia, abnormal perceptions, perceived negative social connection, which further influence other factors that then effect suicidal ideation. This cascade of influence provides suggestions for interventional and preventative targets. Preventing a traumatic event is important, but even with knowledge of an individual experiencing a traumatic event, the

next factors along the path are likely to be good interventional and preventative targets.

This research aligns with current thinking with respect to the assessment and risk management of STBs within clinical care. Recent recommendations for suicide risk suggest that clinicians should take a wide-ranging approach to assessment and risk management [83]. This view suggests that relevant history (e.g., trauma, prior STBs), current clinical and psychosocial presentation (e.g., mood, social factors), protective factors (e.g., problem-solving, coping strategies), and potential future events should be considered during assessment and management of STB risk. Similarly, highly personalised youth care models that tend to take a holistic view of an individual's mental health are also consistent with this view [77,78]. Our approach adds to this by learning the interactions between these multiple factors, although not all potential factors are considered within our analysis.

5.1. Comparisons to theoretical literature

There are several theories that aim to explain the causal pathways to STBs. These theories encompass the progression to suicidal ideation to attempts, while highlighting the distinction between risk factors for suicidal ideation and suicidal behaviours. For example, the interpersonal theory of suicide (IPTS) suggests that thwarted belongingness and burdensomeness cause hopelessness which in turn can lead to suicidal thoughts [32]. Suicidal thoughts plus acquired psychological capability and means then lead to suicidal behaviours. The three-step theory of suicide suggests that the primary precursor to suicidal ideation is psychological pain; where low levels of suicidal ideation require a level of hopelessness, strong ideation requires connectedness to be overwhelmed by their pain, and suicide attempts require both practical means and a psychological tolerance for suicide [33], similar to those of IPTS. The integrated motivation-volitional model of suicidal behaviour includes similar progressional steps from suicidal ideation to attempts, but encompasses lower-level risk factors (e.g., thwarted belongingness, burdensomeness) into higher-level psychological theories, including the diathesis-stress model, theories of planned behaviour, and the differential activation hypothesis [34]. Further theoretical advancements have developed to understand the dynamics of STBs [35,36]. All of these theories highlight the complex paths that can lead to STBs.

The theoretical literature on pathways to STBs suggests that other factors may be of importance. Factors that have been proposed include thwarted belongingness, burdensomeness, psychological pain, and hopelessness leading to suicidal ideation. A suicide attempt typically requires suicidal ideation along with a lowered tolerance to and a means of engaging in suicide attempts. We don't probe all these factors, although some do relate to our factors.

Burdensomeness and thwarted belongness are considered important within the theoretical literature [32] and are often measured using the interpersonal needs questionnaire [86]. Burdensomeness is partially related to self-perception (although it misses the interpersonal concepts relating to how others view them), which was found to be a bridge node between depression and suicidal ideation within the undirected PGM analysis, but was not found to be an ancestor of suicidal ideation in the BN analysis. Thwarted belongingness is related to several items relating to social connection and interpersonal functioning, which both had direct influence on suicidal ideation.

Psychological pain is a broad concept that has been put forth as a key determinant of STBs [87–89]. Psychological pain is typically considered to be a construct that goes beyond depressive or clinical symptoms representing a longer lasting negative deficiency of self [90]. Such a construct may relate to self-perception within our variables, but is likely to go beyond our variables, and thus would be best assessed using a well-defined psychological pain questionnaire [89,91–93]. Thus, we suspect we do not appropriately probe psychological pain within this analysis.

Burdensomeness, thwarted belongingness, and psychological pain may be more proximal factors to suicidal ideation than the clinical and psychosocial variables within our data. However, our factors may influence these theoretical factors. For example, depressive symptoms are likely to affect psychological pain, whereas burdensomeness and thwarted belongingness may be affected by interpersonal functioning, including but not limited to social connection and personal functioning, which we probe in this analysis.

We also show that psychosis-like experiences are a proximal factor of suicidal ideation. This is likely driven by hearing voices and a lack of control of thoughts as shown in the undirected PGM analysis. This is consistent with other evidence linking psychosis-like experiences to suicidal thoughts. It has previously been identified that STBs are higher in individuals with psychosis [84], however, those that exhibit suicidal behaviours tend to be associated with increased severity of depressive or anxiety symptoms [85]. Therefore, it may be unclear whether it is psychosis-like experiences that affects STBs. Our analysis shows that even after conditioning on other factors, including depressive and anxiety symptoms, psychosis-like experiences have a direct effect on suicidal ideation, through unusual thoughts. This is also consistent with research that includes an analysis using undirected PGMs, showing suicidal thoughts dependent on perceptual anomalies, such as hearing voices and sounds, as well as bizarre experiences [43]. The dependency of suicidal ideation on psychosis-like experiences suggests that theoretical models should include these factors. Those models typically cover depressive and social factors along with extra conditions relating to means and tolerance to a suicide attempt. Such models may need to be improved upon by including psychosis-like experiences.

Suicidal ideation was the primary proximal factor to recent suicide attempts. While suicidal ideation is an important outcome in and of itself, and an important prevention target for suicide attempts [3], many individuals with suicidal ideation do not make a suicide attempt. Thus, to understand the paths to suicide attempts, we will need to include variables that are expected to influence the progression from suicidal ideation to attempts, including capability of suicide [94] along with relevant decision-making processes [95,96].

5.2. Future role for probabilistic graphical models

Suicidal ideation fluctuates over both long (e.g., months, years) and short (e.g., minutes, hours) time scales [97–100]. Also, around 20–60 % decide to make an attempt within short time periods (minutes to hours) in adult samples [94,96,101]. STBs also predict and may causally affect clinical and psychosocial factors [11]. This suggests that longitudinal short time-scale data will be important to understand the paths to and from STBs. Some analyses have been completed using ecological momentary assessment data to elucidate the short-term temporal dependencies of STBs [102–104], although much work is still to be done. Dynamic probabilistic graphical models will be an aide to unravel temporal dependencies, and thus longitudinal paths, in such data. Li et al. [41] used undirected dynamic PGMs and Iorfino et al. [105] used dynamic BNs to understand the temporal dependencies between multiple clinical and psychosocial variables with suicidal ideation. However, both analyses had long time periods between observations (months up to 1 year), and thus would be improved by including shorter-term data, to further unravel the paths to STBs.

5.3. Limitations

Robust causal interpretations of learned BNs is only appropriate under very restrictive circumstances. Firstly, all possible confounders and colliders should be included in the analysis. Our analysis has included a wide array of variables to account for this assumption, but we cannot guarantee that all appropriate variables have been included. Secondly, we performed this analysis in a help-seeking population, which could implicitly condition on a collider, which can lead to inferred spurious paths. Thirdly, causal interpretations are more robust between time-lagged variables in longitudinal data. As such, our

analysis only estimates potential causal paths and effects for a help-seeking cohort. These interpretations should be further examined across different data sets within different contexts for different cohorts and across time.

Several choices have been made during this exploratory that could also affect the results. This includes the modelling approaches, selection of relevant questionnaires, and the choice of collapsing specific variables into appropriate factors. However, we show that the proximal and distal factors were reasonably consistent across three different modelling approaches including regression analysis using total questionnaire scores, undirected PGMs at the item-level, and Bayesian networks at the factor-level. As such, we suggest that the results are reasonably robust to these analytical choices.

6. Conclusion

Suicidal ideation can arise from a multitude of clinical and psychosocial factors for youth engaged in mental health care. We found that depressed mood, personal functional impairment, poor social connection, and psychosis-like experiences were proximal factors to suicidal ideation within our data set. Whereas experiencing a traumatic event and anxiety were important distal factors on suicidal ideation. This provides a range of potential interventional targets along with relative timing of events that could improve interventions.

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CRediT authorship contribution statement

Mathew Varidel: Writing – original draft, Conceptualization, Software, Methodology, Formal analysis, Visualization, Data curation. **Ian B. Hickie:** Supervision, Conceptualization, Funding acquisition, Writing – review & editing. **Victor An:** Software, Writing – original draft, Writing – review & editing, Data curation. **Sally Cripps:** Supervision, Methodology, Writing – review & editing. **Roman Marchant:** Supervision, Methodology. **Jo Robinson:** Writing – review & editing. **Louise La Sala:** Writing – review & editing. **William Capon:** Writing – review & editing. **Ashlee Turner:** Writing – review & editing. **Alexander Tashevski:** Writing – review & editing. **Elizabeth Scott:** Investigation, Funding acquisition. **Frank Iorfino:** Supervision, Funding acquisition, Conceptualization, Writing – review & editing.

Declaration of competing interest

I.B.H. 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. E.S. is a Principal Research Fellow at the Brain and Mind Centre, University of Sydney, a Consultant Psychiatrist and Adjunct Clinical Professor at the School of Medicine, University of Notre Dame. She previously served as the Discipline Leader for Adult Mental Health at Notre Dame until January 2025. In addition, she is a member of Medibank's Medical and Mental Health Reference Groups. E.S. has also delivered educational seminars on the clinical management of depressive disorders, receiving honoraria from pharmaceutical companies including Servier, Janssen, and Eli Lilly. Moreover, she has contributed to a national advisory board for Pfizer's antidepressant Pristiq and served as the National Coordinator for an antidepressant trial sponsored by Servier. All other authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.comppsych.2025.152611.

Data availability

All data produced in the present study are available upon reasonable request to the authors.

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