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Negative beliefs about worry at medical school entry: a symptom-level network analysis with independent replication and prospective follow-up

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Abstract

Background: Negative beliefs about the uncontrollability and danger of worry are linked with worry and anxiety, but it is unclear whether this link reflects overlapping item content, holds in an independent sample and carries information about later symptoms. We examined these questions at medical school entry.

Methods: In three entering classes at a Japanese medical school (2023–2025; n = 280), we estimated a regularised partial correlation network of the five Metacognitions Questionnaire-30 domains and the individual items of the Patient Health Questionnaire-9 and Generalized Anxiety Disorder-7. Robustness was examined in nine alternative specifications, including scoring negative beliefs only from items about the danger of worry. Criteria recorded before the next entering class's responses were scored were applied to that class (2026; n = 115). Regression models with heteroscedasticity-consistent standard errors examined symptoms 8 to 10 months after entry, adjusted for baseline symptoms (n = 274).

Results: Negative beliefs were the domain most connected with symptoms, chiefly with excessive worry (partial correlation .24) and uncontrollable worry (.13). Both edges were retained in the 2026 network (.12 and .09), meeting the prespecified criterion, but the replication estimates were imprecise. In the discovery sample both edges persisted when direct item overlap was reduced by scoring negative beliefs from danger items only; the corresponding replication estimates were also imprecise. The links of low cognitive confidence with restlessness and of positive beliefs with depressed mood did not replicate. After adjustment for baseline symptoms, no domain showed a clear association with symptoms at follow-up (five domains jointly: $\Delta R^2 = .027$ for depressive and .014 for anxiety symptoms).

Conclusions: Negative metacognitive beliefs were repeatedly associated with worry symptoms at medical school entry. This association should not be equated with item overlap, replication of the whole network or prediction of later symptoms. Interventions targeting

these beliefs could be tested in students who report current worry, whereas any use of the beliefs to predict later symptoms needs larger prospective studies.

Keywords: Metacognition; Worry; Anxiety; Depression; Medical students; Network analysis; Metacognitions Questionnaire-30; Replication

Background

Depressive and anxiety symptoms are common among medical students worldwide [1, 2]. Entry to medical school is a point at which assessment can be offered to a whole class, and in Japan students enter a six-year programme after high school [3]. Knowing which cognitive processes accompany distress at this point, and whether they predict later symptoms, would help schools decide what an entry assessment should measure.

The metacognitive (self-regulatory executive function) model proposes that beliefs about thinking maintain emotional disorders by sustaining worry, rumination and threat monitoring [4, 5]. Negative beliefs about the uncontrollability and danger of worry are central to the metacognitive model of generalised anxiety [6]. In meta-analyses they differ markedly between patients and controls [7] and, in young people, relate most strongly to anxiety and depression [8]. The Metacognitions Questionnaire-30 (MCQ-30) measures these and four other belief domains [9].

Most studies relate these domains to total symptom scores, which cannot show whether a belief is connected with particular symptoms or with distress in general. Network analysis estimates the partial correlation between every pair of variables and can therefore locate the symptoms through which a belief domain is connected with a symptom cluster [10, 11], and it has been used to study symptoms in medical students [12]. In a university sample, negative beliefs about uncontrollability and danger were the beliefs most closely connected with worry and anxiety [13], and in treatment-seeking adults they were among the most central nodes [14, 15]. Two issues limit such findings. Some negative-belief items, such as being unable to stop worrying, closely resemble worry symptoms, so an edge between them may partly reflect shared wording [16]. In addition, the replicability of cross-sectional networks has been debated [17, 18], and a node's position in such a network does not show that it precedes or drives other nodes [19, 20].

Longitudinal evidence is mixed. Negative beliefs predicted residual change in anxiety and depressive symptoms in a prospective study of students and adults [21]; metacognitive beliefs, prominently those about uncontrollability and danger, predicted later anxiety over two to seven months [22, 23]; and beliefs about uncontrollability were the only domain that predicted later maladaptive emotion regulation and symptoms in a multi-study investigation [24]. Within-person changes in these beliefs have also tracked negative affect and depressive symptoms [25, 26]. In a two-wave population study, by contrast, changes in metacognitive beliefs did not reach even moderate correlations with symptom change [27]. Whether beliefs measured at entry carry information about symptoms over the first year of medical school has not, to our knowledge, been examined.

We therefore addressed three questions in consecutive entering classes at a Japanese medical school. First, which metacognitive belief domains are directly connected with which depressive and anxiety symptoms at entry, and do these connections persist under alternative estimation methods and when overlapping item content is reduced? Second, do the strongest connections replicate in an independent entering class when the tests are fixed before those data are analysed? Third, do entry-stage metacognitive beliefs carry information about depressive and anxiety symptoms 8 to 10 months later beyond baseline symptoms?

Methods

Design and participants

This prospective cohort study was conducted at a national university medical school in Japan. Students in the first-year classes entering in 2023, 2024 and 2025 were asked to complete an online questionnaire (Microsoft Forms) shortly after entry (T1) and again in February of the same academic year (T2). T1 took place in the first week of April in 2024 and 2025 but between 25 May and 1 June in 2023 (two further responses in August), so the interval to T2 was 10 months, or 8 to 9 months for the 2023 class (participant flow in Additional file 1: Fig.

S1). Of 383 enrolled students, 302 (79%) completed T1 and 299 of them completed T2. The discovery sample comprised the 280 T1 participants with sufficient MCQ-30 responses (see Measures; 62, 103 and 115 from the three classes). The prospective sample comprised the 274 of these with T2 data and a recorded age.

The class entering in 2026 completed the same T1 questionnaire on 7 April 2026 (one response on 28 May) and served as an independent replication sample (116 of the 126 enrolled students, including those on leave of absence; 92%). Its T2 had not yet been collected, so it contributed to the network analysis only. Reporting follows the STROBE statement [28] and the reporting standards for cross-sectional network analyses [29].

Separate reports from this cohort address depressive symptom change over the first year, which uses the same PHQ-9 and GAD-7 totals and their mutual prediction, specialty preference at entry [30] and the completion of routine course tasks. None uses the metacognitive measures, the item-level symptom network or the 2026 class; here the totals serve only as outcomes and covariates, and their mutual associations are not reported.

Ethical considerations

The Ethical Committee for Epidemiology of Hiroshima University approved the protocol (approval number E2022-0313), which covers surveys of first- to sixth-year medical students until March 2039. The study was conducted in accordance with the Declaration of Helsinki and the Ethical Guidelines for Medical and Biological Research Involving Human Subjects (MEXT, MHLW and METI, Japan). Informed consent was obtained electronically from all participants: the entry survey form began with an explanation of the study, and students who agreed to participate ticked a statement of consent to participate in the study before answering any questions. Students were told that participation was voluntary and would not affect any academic assessment, and that their responses would not be seen by teaching or examining

staff. Responses were linked across time points by university e-mail address, which was not used in any analysis.

Measures

Metacognitive beliefs were measured with the Japanese version of the MCQ-30 [9, 31], which has been used with Japanese university students [32]. Its 30 items are rated from 1 (do not agree) to 4 (agree very much) and form five six-item domains: positive beliefs about worry (POS), negative beliefs about the uncontrollability and danger of worry (NEG), low cognitive confidence in memory and attention (CC), beliefs about the need to control thoughts (NC) and cognitive self-consciousness (CSC). In the Japanese version the positive-belief items refer to thinking deeply (fukaku kangaeru) rather than to worrying [31]. A domain score was prorated when five of its six items were answered and was otherwise treated as missing. To examine overlap with symptom content, the NEG items were also scored as two three-item subsets: uncontrollability (worrying thoughts that persist, cannot be stopped or cannot be ignored; items 9, 11 and 21 of the original MCQ-30) and danger (worry could make one ill, could make one lose one's mind, or is dangerous; items 2, 4 and 15; Supplementary Methods).

Depressive symptoms were measured with the Japanese Patient Health Questionnaire-9 (PHQ-9) [33, 34] and anxiety symptoms with the Japanese Generalized Anxiety Disorder-7 (GAD-7) [35–37]. Each item is rated from 0 (not at all) to 3 (nearly every day) for the previous two weeks. Internal consistency is shown in Table 1. Self-reported sex (male or female; gender identity was not assessed), age, admission track (general or regional quota) and entering class were also recorded. The questionnaire included further measures (personality, self-control, neurodevelopmental traits, career intentions and health-related quality of life) that were not analysed here.

Table 1. Characteristics of the discovery and replication samples at medical school entry.

Characteristic	Discovery, 2023–2025 (n = 280)	α	Replication, 2026 (n = 115)	α
Female, n (%)	89 (31.8)		39 (33.9)	
Age, years, mean (SD)	18.9 (1.8)		18.6 (1.3)	
Regional-quota admission track, n (%)	47 (16.8)		Not available	
MCQ-30 POS, mean (SD)	17.10 (3.83)	.83	17.22 (3.56)	.76
MCQ-30 NEG, mean (SD)	14.63 (4.34)	.83	15.00 (4.50)	.85
MCQ-30 CC, mean (SD)	13.47 (4.17)	.79	13.70 (4.21)	.80
MCQ-30 NC, mean (SD)	12.90 (3.91)	.74	13.32 (3.84)	.71
MCQ-30 CSC, mean (SD)	14.91 (4.47)	.87	15.06 (4.37)	.83
PHQ-9 total at entry, mean (SD)	4.30 (4.49)	.86	4.75 (5.04)	.85
PHQ-9 ≥ 10 at entry, n (%)	39 (13.9)		20 (17.4)	
GAD-7 total at entry, mean (SD)	4.48 (4.49)	.90	5.34 (4.65)	.87
GAD-7 ≥ 10 at entry, n (%)	42 (15.0)		25 (21.7)	
PHQ-9 total at follow-up, mean (SD)	4.55 (5.55)	.92	Not yet collected	
GAD-7 total at follow-up, mean (SD)	4.59 (5.26)	.93	Not yet collected	

Note. Values are mean (SD) unless stated otherwise. α, Cronbach's alpha in each sample. MCQ-30 domain scores range from 6 to 24. PHQ-9 ranges from 0 to 27 and GAD-7 from 0 to 21. Follow-up (T2) was in February of the first year; for the discovery sample it was available for 277 students. Admission track was not linked for the 2026 class. Age was missing for 3 and 2 students in the two samples. α of the three-item NEG subsets: uncontrollability .78 and .79, danger .78 and .78 (discovery and replication). Abbreviations are listed after the Conclusions.

Every item response was checked against the original form exports, which for the 2025 entry survey were numerically coded (Additional file 1: Table S1). The only errors, 20 T2 responses of 10 students in the 2023 class coded 4 instead of 3 for 'nearly every day', were corrected before analysis. For four students who had submitted the T2 form twice, the first submission was used.

Statistical analysis

Network estimation. We estimated a Gaussian graphical model of 21 nodes (five MCQ-30 domains, nine PHQ-9 items and seven GAD-7 items), in which each edge is the partial correlation between two nodes controlling for all others. MCQ-30 domains rather than items were used to keep the model estimable. Because the symptom items had four categories, skewed distributions and few responses in the upper categories, the input was the Spearman correlation matrix. The model was regularised with the graphical lasso [38], and the tuning parameter was selected by the extended Bayesian information criterion with $\gamma = 0.5$ [10, 39]. Nodes were assigned in advance to three communities: metacognitive beliefs, depressive symptoms and anxiety symptoms. For each metacognitive domain we summed its signed edges to the depressive items and, separately, to the anxiety items. These sums are a

community-specific form of one-step bridge expected influence [11]. Possible redundancy between nodes was examined with the goldbricker procedure [40].

Accuracy, stability and sensitivity. Edge weights, bridge values and their differences were bootstrapped 2,000 times, and we report 95% bootstrap intervals and the proportion of bootstrap samples in which each edge was non-zero (inclusion). Bootstrap intervals of regularised edges cannot be read as significance tests [41], so they were used as indications of precision. Stability was assessed by case-dropping bootstrap (2,000 samples) and summarised with the correlation stability (CS) coefficient, for which values of at least .5 are recommended [41]. Because the choice of estimator trades discovery against caution [42], we estimated nine alternative specifications that varied the correlation type, the estimator and its tuning, the scoring of NEG and the sample (Additional file 1: Supplementary Methods).

Replication. Before any belief or symptom response of the 2026 class was scored, we recorded the discovery results, the data rules and the replication tests in a plan whose SHA-256 checksum and time stamp were stored (Additional file 1: Supplementary Methods, which also record one deviation). The plan was kept locally, not in a public registry; its checksum shows only that it was not altered after being recorded. The primary tests were whether each metacognition–symptom edge with at least 95% bootstrap inclusion was non-zero with the same sign in 2026 (R1) and whether NEG's bridge value towards anxiety symptoms was positive with a 95% bootstrap interval excluding zero (R2). Secondary tests concerned whether that value was the largest of the five domains (R3), whether it stayed positive with NEG scored from the danger subset (R4) and whether POS's negative bridge value towards depressive symptoms replicated (R5). R1 concerns whether an edge is retained with the same sign, not whether the whole network or the size of an edge replicates. Because bootstrap intervals of regularised estimates are not conventional confidence intervals, R2 and R4 are prespecified descriptive criteria rather than significance tests. The 2026 network was

estimated with identical settings and compared with the discovery network through the correlation of edge weights and the Network Comparison Test with 1,000 permutations [43]. Checks not in the plan (unregularised estimates, danger-subset edges and the behaviour of the estimator) were added afterwards (Additional file 1: Supplementary Methods).

Prospective analysis. T2 PHQ-9 and GAD-7 totals were regressed on each MCQ-30 domain (standardised) in three models. Model 0 was adjusted for sex, age, admission track and entering class. Model 1, the primary model, added the T1 total of the same measure and therefore estimates the association with residualised change. Model 2 also added the T1 total of the other measure. The five domains were also entered together in model 1 and tested as a block. We used heteroscedasticity-consistent (HC3) standard errors [44] and applied Holm's correction to the ten model-1 tests [45]. Sensitivity analyses excluded the 2023 class, used the two NEG subsets and fitted negative binomial models. An exploratory analysis added after these results were known used the T2 sum of the two worry items (G2 and G3) as the outcome, adjusted for their T1 sum. With 274 participants, a single added predictor had 80% power at $\alpha = .05$ to detect an increment in R^2 of about .024 (.042 at the strictest Holm-adjusted level). The discovery and prospective analyses were exploratory.

Missing data and software. Participants with a missing MCQ-30 domain were excluded; no PHQ-9 or GAD-7 item was missing. The three-item NEG subsets were scored only when all three items were answered, so the danger subset was missing for two 2026 participants (none in the discovery sample); their other responses were retained, correlations involving the danger subset were based on 113 participants (pairwise deletion), and the information criterion used the average pairwise sample size (the bootnet default). Analyses used R 4.5.0 with bootnet 1.7.1 [41], qgraph 1.9.8 [46] and the other packages listed in Additional file 1 (Additional file 1: Supplementary Methods). Generative AI was used in two ways. Claude Opus 5.5 (Anthropic), working as a coding agent in the authors' local computing

environment, assisted with the analysis and plotting code under the authors' direction and was also used to revise the text. GPT-6 (OpenAI) was used to review drafts of the manuscript and suggest revisions. Individual responses and identifiers were processed only on the authors' computer. The authors made all analytical decisions, reviewed and edited all AI-assisted output and take full responsibility for the content.

Results

Participants

The discovery sample (n = 280) and the replication sample (n = 115) had similar distributions of sex, age, metacognitive beliefs and symptom levels (Table 1; all standardised differences ≤ 0.19). The 22 students excluded for incomplete MCQ-30 responses (16 from the 2023 class; 11 left every item blank) did not differ from included students in T1 depressive symptoms (p = .530); their mean anxiety score was lower (2.8 vs 4.5), but not significantly (p = .069; Additional file 1: Table S2). Descriptive statistics of the network nodes, and domain and total scores by sex, are given in Additional file 1: Table S3.

Metacognition–symptom connections at entry

The discovery network contained 109 of 210 possible edges (Additional file 1: Fig. S2A), 24 of which connected a metacognitive domain with a symptom item (Fig. 1A; Additional file 1: Table S4, Fig. S3). Four of these were non-zero in at least 95% of bootstrap samples. They linked NEG with excessive worry (G3; .24, 95% bootstrap interval .13 to .33) and with uncontrollable worry (G2; .13, .02 to .22), CC with restlessness (G5; .11, .003 to .19), and POS with depressed mood (P2; −.11, −.18 to −.01), the last negatively.

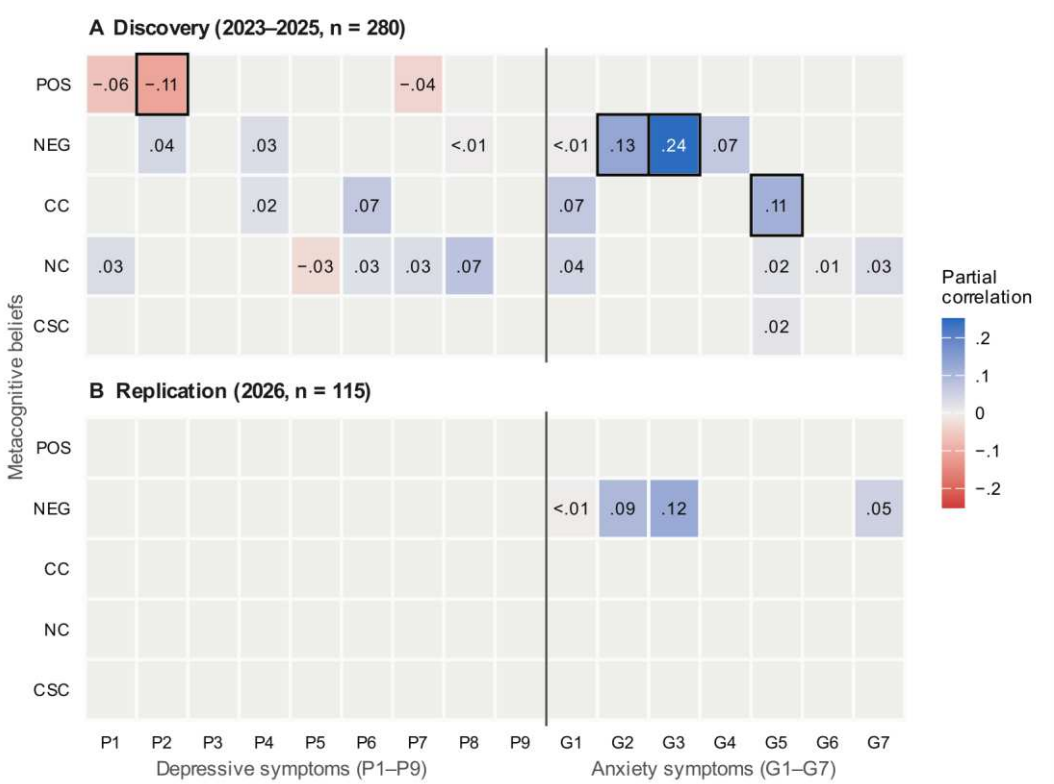

Fig. 1. Metacognition–symptom partial correlations in the discovery and replication samples.

Note. Panel A, discovery sample (2023 to 2025 entering classes, n = 280); panel B, replication sample (2026 entering class, n = 115). Networks were estimated with the graphical lasso (extended Bayesian information criterion, γ = 0.5) on Spearman correlations of 21 nodes. Blank cells are edges estimated as zero; '<.01' marks non-zero edges smaller than .005. Outlined cells in panel A are the four edges that were non-zero in at least 95% of 2000 bootstrap samples and were designated as replication tests before the 2026 responses were scored. The full networks are shown in Additional file 1: Fig. S2. POS, positive beliefs about worry; NEG, negative beliefs about the uncontrollability and danger of worry; CC, low cognitive confidence; NC, need to control thoughts; CSC, cognitive self-consciousness; P1, anhedonia; P2, depressed mood; P3, sleep problems; P4, fatigue; P5, appetite change; P6, worthlessness or guilt; P7, concentration difficulty; P8, psychomotor change; P9, thoughts of death or self-harm; G1, nervousness; G2, uncontrollable worry; G3, excessive worry; G4, trouble relaxing; G5, restlessness; G6, irritability; G7, fear that something awful might happen.

NEG had the largest bridge value towards anxiety symptoms (0.45, 0.33 to 0.57), and the bootstrap intervals of its differences from each of the other four domains excluded zero (Table 2); it was the largest in 99.8% of bootstrap samples. Its bridge value towards depressive symptoms was small (0.07, −0.01 to 0.22) and did not differ from those of CC, NC and CSC. POS had a negative bridge value towards depressive symptoms (−0.21, −0.31 to −0.09). Stability met the recommended threshold (CS = .52 for strength, expected influence, bridge expected influence and edges; Additional file 1: Fig. S4). The goldbricker

procedure flagged eight pairs of symptom items as possibly redundant but no metacognitive node (Additional file 1: Table S5).

Table 2. Metacognition–symptom connections in the discovery and replication samples.

Panel A. Designated edges and danger-subset edges (partial correlations; discovery n = 280, replication n = 115)

Edge	Discovery, regularised (95% BI)	Inclusion	Replication, regularised (95% BI)	Inclusion	Met R1 criterion	Discovery, unregularised (95% BI)	Replication, unregularised (95% BI)
NEG – G3 excessive worry	.24 (.13 to .33)	100%	.12 (.05 to .28)	99%	Yes	.30 (.17 to .43)	.23 (.03 to .42)
NEG (danger items) – G3	.15 (.04 to .25)	100%	.11 (.01 to .26)	98%	Not designated	.19 (.04 to .33)	.20 (−.02 to .40)
NEG – G2 uncontrollable worry	.13 (.02 to .22)	99%	.09 (.03 to .27)	99%	Yes	.15 (−.001 to .29)	.22 (−.002 to .42)
NEG (danger items) – G2	.17 (.06 to .25)	100%	.06 (0 to .23)	93%	Not designated	.21 (.08 to .33)	.11 (−.10 to .34)
CC – G5 restlessness	.11 (.003 to .19)	98%	0 (0 to .12)	33%	No	.18 (.06 to .30)	.06 (−.16 to .29)
POS – P2 depressed mood	−.11 (−.18 to −.01)	98%	0 (−.03 to 0)	5%	No	−.18 (−.28 to −.06)	−.05 (−.28 to .16)

Panel B. Bridge values of each metacognitive domain

Domain	Symptom cluster	Discovery (95% BI)	Replication (95% BI)
POS	Anxiety (GAD-7 items)	0 (−0.08 to 0.04)	0 (−0.04 to 0.12)
	Depressive (PHQ-9 items)	−0.21 (−0.31 to −0.09)	0 (−0.08 to 0.14)
NEG	Anxiety (GAD-7 items)	0.45 (0.33 to 0.57)	0.27 (0.25 to 0.81)
	Depressive (PHQ-9 items)	0.07 (−0.01 to 0.22)	0 (0 to 0.21)
NEG (danger items)	Anxiety (GAD-7 items)	0.42 (0.29 to 0.54)	0.22 (0.08 to 0.81)
CC	Anxiety (GAD-7 items)	0.18 (0.05 to 0.31)	0 (−0.05 to 0.17)
	Depressive (PHQ-9 items)	0.09 (0.002 to 0.24)	0 (0 to 0.48)
NC	Anxiety (GAD-7 items)	0.11 (0.03 to 0.26)	0 (−0.01 to 0.18)
	Depressive (PHQ-9 items)	0.13 (−0.01 to 0.24)	0 (−0.04 to 0.30)
CSC	Anxiety (GAD-7 items)	0.02 (−0.01 to 0.11)	0 (0 to 0.22)
	Depressive (PHQ-9 items)	0 (−0.13 to 0.05)	0 (−0.18 to 0.07)

Note. Graphical lasso (EBIC, $\gamma = 0.5$) on Spearman correlations of 21 nodes. BI, 95% bootstrap interval (2000 non-parametric bootstrap samples); inclusion, proportion of bootstrap samples in which the edge was non-zero. Met R1 criterion: non-zero with the same sign in the 2026 network, as specified in the replication plan; this does not show that the whole network or the size of the edge replicated. NEG (danger items): NEG scored from its three danger items. The danger-item rows and the unregularised estimates (inverted Spearman correlation matrix) were added after the replication. Bridge values are the sums of a domain's signed edges to the items of each symptom cluster. Bootstrap intervals of regularised estimates indicate precision rather than significance; bootstrap samples of the replication class gave denser networks than the point estimate (median 81 vs 14 edges), so the bootstrap distributions were shifted towards larger estimates (Additional file 1: Fig. S5). Differences between NEG and each other domain in the bridge value towards anxiety symptoms (95% BI): discovery, POS 0.45 (0.34 to 0.60); CC 0.27 (0.08 to 0.46); NC 0.34 (0.15 to 0.48); CSC 0.43 (0.28 to 0.55); replication (R3), POS 0.27 (0.24 to 0.80); CC 0.27 (0.24 to 0.79); NC 0.27 (0.24 to 0.78); CSC 0.27 (0.22 to 0.75).

Robustness and item overlap

Across the nine alternative specifications (Additional file 1: Table S6), edge weights correlated .82 to 1.00 with the primary network, NEG's bridge value towards anxiety symptoms remained larger than that of any other domain, and the NEG–G3 and NEG–G2 edges were retained whenever NEG was a single node; adding sex as a node did not change the four edges. When NEG was scored from the danger items only, its edges with excessive and uncontrollable worry were .15 and .17 (Table 2; Fig. 2). When the two subsets (Spearman $\rho = .58$) entered as separate nodes, the danger subset rather than the uncontrollability subset carried the edge with uncontrollable worry (non-zero in 100% and 40% of bootstrap samples; Additional file 1: Table S6).

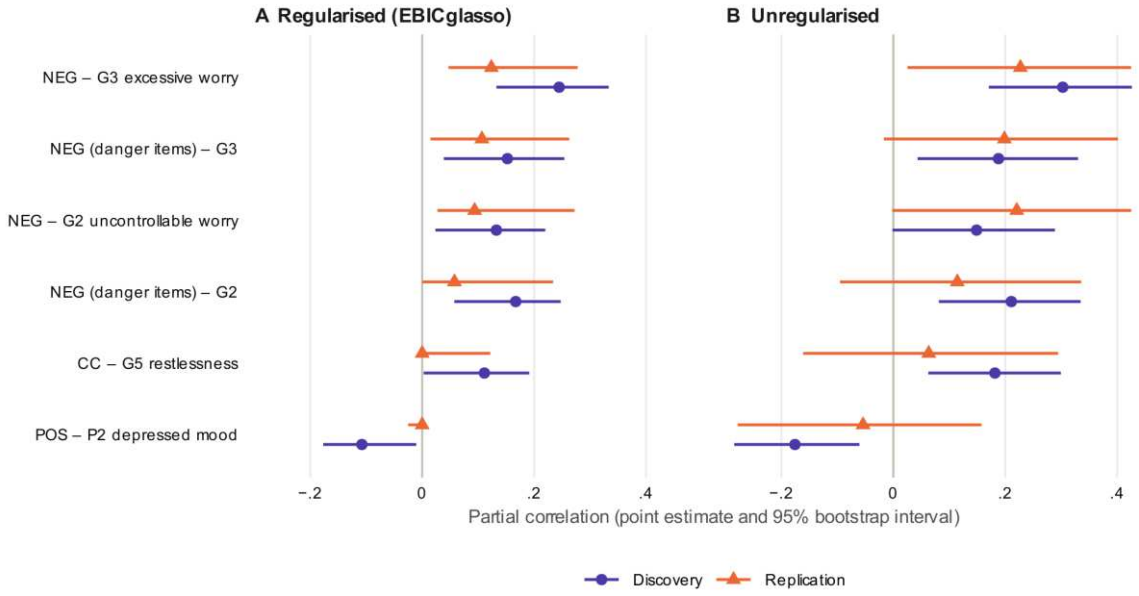

Fig. 2. Designated edges and danger-subset edges in both samples and with both estimators.

Note. The four designated metacognition–symptom edges and the corresponding edges of NEG scored from its three danger items, in the discovery (circles) and replication (triangles) samples. (A) Regularised estimates from the primary networks with 95% bootstrap intervals (2000 samples). (B) Unregularised partial correlations from the inverted Spearman correlation matrix with 95% bootstrap intervals (2000 samples). The danger-item rows and panel B were added after the replication and were not designated tests. Abbreviations as in Fig. 1.

Replication in the 2026 entering class

The 2026 network had 14 non-zero edges (Additional file 1: Fig. S2B). The best denser solution on the penalty path, with 88 edges, had an information criterion 5.3 higher than the

selected solution, and both gave the same results for the four designated edges (Additional file 1: Table S7, Fig. S5). Bootstrap resamples generally yielded much denser networks (median 81 edges), so the selected network density was sensitive to resampling and the bootstrap distributions of the 2026 estimates were shifted towards larger values. Both NEG edges met the R1 criterion: excessive worry .12 (95% bootstrap interval .05 to .28; inclusion 99%) and uncontrollable worry .09 (.03 to .27; 99%; Table 2; Fig. 2). Their unregularised estimates were .23 (.03 to .42) and .22 (−.002 to .42), the latter interval narrowly including zero. With NEG scored from the danger items, the two edges were .11 and .06, but their unregularised intervals included zero. The CC–restlessness and POS–depressed mood edges were zero (inclusion 33% and 5%); even in the discovery subsamples these two edges were recovered in only 75% of cases. NEG's bridge value towards anxiety symptoms was positive (0.27, 0.25 to 0.81; R2) and the largest of the five domains (R3) because the other four had no edges with anxiety items; it remained positive with NEG scored from the danger items (0.22, 0.08 to 0.81; R4). The negative POS–depressive value did not replicate (R5). Edge weights correlated modestly between the samples (Pearson r = .41 over all 210 pairs and .69 over the 80 metacognition–symptom pairs; Spearman ρ = .31 and .28); the Network Comparison Test is reported in Additional file 1: Table S7.

Prospective associations

Adjusted only for demographic variables and class, higher NEG, CC and NC scores were associated with higher T2 depressive and anxiety symptoms (B = 1.10 to 1.47 points per SD), and higher POS scores with lower T2 depressive symptoms (Table 3). After adjustment for the T1 total of the same measure, no domain showed a clear association (all Holm-adjusted p values ≥ .50); the largest estimate was for CC and depressive symptoms (B = 0.72, 95% CI −0.00 to 1.44, p = .050). Upper confidence limits did not exceed 0.26 SD of the T2 totals. The five domains together added 2.7% of variance in T2 depressive symptoms (F(5, 262) =

1.42, p = .216) and 1.4% in anxiety symptoms (F(5, 262) = 0.74, p = .597). Results were similar with additional adjustment for the other symptom measure, after excluding the 2023 class, for the NEG subsets and in negative binomial models (Additional file 1: Table S8). In the exploratory analysis of the two worry items, NEG was associated with T2 worry after adjustment for T1 worry (B = 0.33 points per SD, 95% CI 0.06 to 0.59; Holm-adjusted p = .089 across the five domains), whereas the danger subset was not (B = 0.20, 95% CI −0.09 to 0.50).

Table 3. Entry-stage metacognitive beliefs and symptoms at follow-up (n = 274).

	T2 PHQ-9			T2 GAD-7		
MCQ-30 domain	**Model 0: B (95% CI)**	**Model 1: B (95% CI)**	**p (Holm)**	**Model 0: B (95% CI)**	**Model 1: B (95% CI)**	**p (Holm)**
POS	−0.70 (−1.37 to −0.04)	−0.39 (−0.99 to 0.22)	.210 (1.000)	−0.49 (−1.10 to 0.11)	−0.34 (−0.92 to 0.23)	.243 (1.000)
NEG	1.34 (0.65 to 2.03)	0.35 (−0.43 to 1.13)	.379 (1.000)	1.47 (0.84 to 2.10)	0.33 (−0.46 to 1.12)	.406 (1.000)
CC	1.43 (0.75 to 2.11)	0.72 (−0.00 to 1.44)	.050 (.501)	1.10 (0.49 to 1.71)	0.35 (−0.29 to 0.99)	.287 (1.000)
NC	1.29 (0.51 to 2.06)	0.51 (−0.22 to 1.23)	.169 (1.000)	1.10 (0.39 to 1.81)	0.17 (−0.57 to 0.91)	.652 (1.000)
CSC	0.14 (−0.63 to 0.90)	0.06 (−0.62 to 0.74)	.863 (1.000)	0.38 (−0.30 to 1.06)	0.08 (−0.56 to 0.72)	.810 (1.000)
Five domains jointly (ΔR^2)		.027	.216		.014	.597

Note. B, difference in the T2 total per standard deviation of the MCQ-30 domain, with HC3 95% confidence intervals. Model 0 is adjusted for sex, age, admission track and entering class; model 1 is additionally adjusted for the T1 total of the same measure. p values are for model 1, with Holm-adjusted values for the ten model-1 tests in parentheses. The last row gives the increase in R^2 when the five domains were added together to model 1 and the p value of the HC3 Wald test. Model 2 and sensitivity analyses are given in Additional file 1: Table S8.

Discussion

In three entering classes at a Japanese medical school, negative beliefs about the uncontrollability and danger of worry were the metacognitive domain most connected with symptoms at entry, and this connection ran mainly through the two worry items of the GAD-7 (partial correlations .24 and .13). Both edges met the prespecified edge-retention criterion in the next entering class, although the replication estimates were imprecise, whereas the links of low cognitive confidence with restlessness and of positive beliefs with depressed mood did not. Metacognitive beliefs were associated with symptoms 8 to 10 months later, but not clearly beyond baseline symptoms.

The central place of negative beliefs agrees with the metacognitive model, in which beliefs that worry is uncontrollable and dangerous turn ordinary worry into sustained, distressing worry [4, 6]. It also agrees with meta-analyses [7, 8, 47] and with network studies in university students and treatment-seeking adults [13–15]. The symptom-level network adds specificity: at entry the domain was connected mainly with the two worry items, that is, with the process the beliefs are thought to maintain [5], and far more with anxiety than with depressive symptoms.

Items describing worry that cannot be stopped resemble the GAD-7 item on uncontrollable worry, so shared wording could create edges that do not reflect a relation between distinct constructs [16]. Two findings argue against wording as the whole explanation. The domain kept its edges with both worry items when it was scored only from items about the feared consequences of worry, which reduces direct overlap with symptom wording; in the replication class these edges were non-zero but uncertain. When the subsets entered separately, the danger subset rather than the uncontrollability subset carried the edge to uncontrollable worry in almost every bootstrap sample, although this split was not tested in the replication class. The danger items still presuppose that one worries, so they reduce rather

than remove the overlap. Common-method variance among self-report items may also contribute and cannot be separated from these edges in questionnaire data [48]. Connections with depressive symptoms were weak and spread across domains, and the other two discovery edges with at least 95% bootstrap inclusion did not replicate. The negative edge between positive beliefs and depressed mood may reflect the Japanese items' focus on thinking deeply rather than on worrying [31]. A regularised network of 115 students shrinks weaker edges to zero [41, 42]; even subsamples of that size from the discovery sample missed these two edges in one case in four, so their absence in 2026 does not show that they are absent in the population. Specific edges in symptom networks can be unstable across samples [18]; we therefore regard the NEG–worry edges as the most dependable finding and the other edges as tentative.

The prospective findings qualify the cross-sectional ones. All belief domains except cognitive self-consciousness were associated with at least one later symptom measure, but these associations were largely accounted for by baseline symptoms. The baseline-adjusted models ask whether beliefs carry information among students with the same baseline symptoms; they do not test whether beliefs and symptoms influence each other over time. Their upper confidence limits (up to 0.26 SD of the T2 totals) leave modest associations possible. Prospective and cross-lagged studies have found that negative beliefs predict later symptoms [21–24]. Differences in design may explain part of the contrast: the interval here was longer (8 to 10 months, against two to seven months) [22, 23], the cognitive attentional syndrome through which the beliefs predicted anxiety in one study was not measured [23], between-person prediction differs from within-person dynamics [25, 49], and symptoms at entry were low and only moderately stable (T1–T2 correlations .39 and .38). A node's position in a cross-sectional network does not establish temporal precedence [19, 20], and here NEG's bridging position did not translate into clear information about later total scores. The

exploratory association between NEG and later worry items did not survive correction and can be tested at the follow-up of the 2026 class.

Brief interventions addressing negative beliefs about worry, the targets of metacognitive therapy [4, 50], could be tested in entering students who report current worry. We assessed baseline-adjusted prospective associations, not out-of-sample predictive performance or the clinical utility of adding the MCQ-30 to symptom screening.

Limitations

The study was conducted at one school in which students enter after high school [3], and 79% and 92% of enrolled students took part in the discovery and replication classes, so generalisation to other systems and to non-participants should be cautious. All measures were self-reported, and the Japanese MCQ-30 has been evaluated mainly in university students [31]. Worry was represented only by GAD-7 symptom items, and rumination and the wider cognitive attentional syndrome, which the metacognitive model places between beliefs and symptoms, were not measured [4]. The replication sample was small, its plan was not publicly registered, and network estimates depend on estimation choices [42]. The prospective analysis had two waves and cannot separate stable between-person differences from within-person change [49]. Finally, women were a minority (89 and 39 in the two samples), too few for sex-specific networks.

Conclusions

At medical school entry, negative beliefs about the uncontrollability and danger of worry were the metacognitive domain most closely connected with symptoms, through excessive and uncontrollable worry. These edges were retained in a subsequent entering class, and in the discovery sample they persisted when direct item overlap was reduced, although the corresponding replication estimates were imprecise. The beliefs showed no clear baseline-adjusted association with later total symptom scores. The link should therefore not be equated

with item overlap, with replication of the whole network or with prediction of later symptoms.

Supplementary information

Additional file 1 (.docx). Supplementary methods and results. Replication plan and deviation record with checksums; NEG items and subsets; alternative network specifications; analyses added after the replication; software. Tables S1 to S8: data verification, excluded participants, node descriptives (overall and by sex), all metacognition–symptom edges, goldbricker results, alternative specifications, additional analyses of the replication and full prospective models. Figures S1 to S5: participant flow, full networks, edge accuracy, case-dropping stability and behaviour of the estimator.

Abbreviations

BI: Bootstrap interval

CC: Low cognitive confidence

CS: Correlation stability

CSC: Cognitive self-consciousness

EBIC: Extended Bayesian information criterion

GAD-7: Generalized Anxiety Disorder-7

HC3: Heteroscedasticity-consistent standard errors (type 3)

MCQ-30: Metacognitions Questionnaire-30

NC: Need to control thoughts

NEG: Negative beliefs about the uncontrollability and danger of worry

PHQ-9: Patient Health Questionnaire-9

POS: Positive beliefs about worry

SD: Standard deviation

T1: Entry survey

T2: Follow-up survey

Declarations

Ethics approval and consent to participate

The Ethical Committee for Epidemiology of Hiroshima University approved the protocol (approval number E2022-0313), which covers surveys of first- to sixth-year medical students until March 2039. The study was conducted in accordance with the Declaration of Helsinki and the Ethical Guidelines for Medical and Biological Research Involving Human Subjects (MEXT, MHLW and METI, Japan). Informed consent was obtained electronically from all participants: the entry survey form began with an explanation of the study, and students who agreed to participate ticked a statement of consent to participate in the study before answering any questions. Students were told that participation was voluntary and would not affect any academic assessment, and that their responses would not be seen by teaching or examining staff. Responses were linked across time points by university e-mail address, which was not used in any analysis.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analysed during the current study are not publicly available because participant consent and the ethics approval do not permit unrestricted public sharing of data from a small student cohort, but de-identified data are available from the corresponding author on reasonable request, subject to approval by the Ethical Committee for Epidemiology of Hiroshima University. The analysis code, the replication plan with its checksum and the correlation matrices from which the networks can be re-estimated are available at https://osf.io/f53sp/overview?view_only=dfa1f4caae594a9b8a7402cf3a4b7a5a.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MH and YN contributed equally to this work and share first authorship. MH conceived the present analysis, designed the network, replication and prospective analyses, carried out the analyses, prepared the figures and tables and wrote the first draft of the manuscript. YN contributed to the design of the cohort survey, organised and conducted data collection in all four entering classes, contributed to the interpretation of the findings in relation to student support and critically revised the manuscript for important intellectual content. NH conceived and supervised the cohort study, contributed to the design of the analyses and the interpretation of the findings, and critically revised the manuscript. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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