Interrelations of resilience factors and their incremental impact for mental health: Insights from network modeling using a prospective study across seven timepoints

Running title: Network of resilience factors in face of stress

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Abstract

Resilience as an outcome can be viewed as trajectory of stable good mental health or the quick regain of mental health during or after stressor exposure. Resilience factors (RFs) are psychological resources that buffer the potential negative effects of stress on mental health. A problem of resilience research is the large number of conceptually overlapping RFs complicating their understanding as well as the planning and evaluation of resilience interventions. The current study sheds light on interrelations of RFs in the face of the COVID-19 pandemic as a use case for major disruptions. The prospective study assessed a population sample of 1,275 German-speaking people (M_{age}=50.06, 51.5% female) from February 2020 to March 2021 at six critical timepoints during the pandemic. We assessed coping, hardiness, control beliefs, optimism, self-efficacy, sense of coherence (SOC), sense of mastery, social support as well as dispositional resilience as psychological RFs in February 2020, and mental health (i.e., psychopathological symptoms, COVID-19-related rumination, stress-related growth) at all timepoints. Analyses used partial correlation network models and LASSO regressions. Pre-pandemic RFs were strongly interrelated with SOC being the most central node. During the pandemic, networks for all outcomes remained stable. Pre-pandemic SOC was the strongest partial correlate of psychopathological symptoms and COVID-19-related rumination, while stress-related growth showed unique associations with positive reframing and optimism. LASSO regressions supported SOC's incremental validity beyond other RFs for psychopathological symptoms and COVID-19-related rumination, while SOC was unrelated to stress-related growth. Either longitudinally or cross-sectionally, the sum of RFs at most accounted for 39% of the variance in mental health. Our findings provide evidence for SOC playing an important role for mental health and suggest to further examine SOC's incremental validity. Given the differential associations for negative and positive mental health outcomes, resilience research may benefit from using multidimensional outcomes.

Introduction

Resilience as an outcome can be viewed as stable good mental health or fast regain of mental health during or after stressor exposure[1,2]. According to this outcome-based approach, resilient outcomes are partially determined by a variety of resilience factors (RFs) that are supposed to buffer the negative effects of stressor exposure on mental health mediated via a smaller number of resilience mechanisms (e.g., positive appraisal style[1]; regulatory flexibility[3]). RFs may comprise dispositional variables and resilience-promoting traits (e.g., optimism), beliefs (e.g., self-efficacy, control beliefs), and coping strategies[4] (see Table 1). Over the past decades, the number of potential RFs has increased enormously resulting in conceptual overlaps and strong empirical interrelations[5].

For instance, control beliefs[6] are closely related to self-efficacy[7]. On a conceptual level, it may be argued that one can perceive a situation as potentially controllable by oneself (internal locus of control) but does not belief in one´s own capacities to manage the situation (low self-efficacy belief). However, it is unlikely that a person with strong situation-specific self-efficacy beliefs views a situation as externally controlled (external locus of control). This example is just one of many that underscores how poorly some RFs can be differentiated. The missing conceptual clarity hampers the planning of studies on resilience, as they often include a large number of similar and time-consuming RF questionnaires[8], and is a challenge for resilience interventions. Even though resilience is nowadays often understood as an outcome, the mediating mechanisms linking RFs to resilient outcomes are still insufficiently understood[1,2]. Therefore, resilience trainings primarily target RFs, with the outcomes of intervention studies being operationalized as changes in RFs (and mental health)[9,10]. Thus, reducing the large number of potential intervention targets in terms of RFs could advance the development and evaluation of resilience interventions.

Table 1. List of studied resilience factors

Resilience factor	Definition
Active coping (e.g., problem-solving)	Coping as a set of intentional, goal-directed efforts to minimize physical, psychological and social harm of stressors[76]; active coping as utilization of psychological and behavioral efforts that use own resources to handle a stressor[91].
Cognitive emotion regulation (e.g., positive reframing)	Conscious thoughts by means of which individuals regulate their emotions in response to stressors. Positive reframing, as a type of reappraisal, describes thinking about negative or challenging situations in a positive way (e.g., thinking about the benefits or upsides of a negative event).
Humor	Humor represents the capacity to perceive or express the amusing aspects of situations[92].
Hardiness	Hardiness is an ability to handle unexpected changes (challenge) with ease, combined with a sense of meaning in daily life (commitment) and personal control (control)[93].
Locus of control / control beliefs	Locus of control represents the degree to which people believe that they have control over outcomes in their lives[6]. A strong internal locus of control reflects the belief that outcomes are primarily a result of own action, an external locus of control is associated with viewing external factors as primary causes of outcomes.
Optimism	Optimism reflects the extent to which people hold generalized favorable expectancies for the future[75].
Religiosity or spirituality	Religiosity and spirituality describe any feeling, thought, and behavior that arises from the search for the 'sacred'. Religiosity also includes group or social practices, while spirituality refers to personal beliefs and experiences[94].
Self-efficacy	Self-efficacy describes an individual's subjective perception of his or her capability to perform a specific behavior or to achieve something[7].
Sense of coherence	Sense of coherence is the key component of the salutogenesis concept[32]. Individuals with high levels of sense of coherence perceive their lives as comprehensible, manageable and meaningful[72]. Comprehensibility describes the perception of the environment as predictable, structured, and explicable. Manageability refers to the belief that available internal and external resources are sufficient to meet situational demands, and meaningfulness describes the belief that challenges are worthy of engagement and coping.
Sense of mastery	Sense of mastery describes a person's belief that they are able to control important circumstances in their life[95].
(Perceived) social support	Perceived social support describes the network of social resources perceived by an individual[96].
Dispositional resilience	Dispositional resilience is a personality trait that helps individuals to cope with adversity and achieve successful adjustment and development in face of stressors[97]. The concept is closely related to hardiness.

Note. The selection of resilience factors is based on an updated version of resilience factors presented in Kunzler et al. [10] and Schäfer et al.[15]. Other concepts that are discussed as resilience factors are hope (closely related to optimism), meaning and purpose in life (closely related to the meaningfulness component of sense of coherence), positive emotions/affect and self-esteem, with the latter two being investigated as resilience factor, resilience mechanism and outcome[98,99]. Recently introduced concepts like regulatory flexibility[86] were not included as they have not been examined in systematic reviews.

Here we set out to use network analyses to shed light on the overlapping and most likely interrelated RFs[11]. Network analysis allows to estimate and visualize associations between variables without providing information on the underlying dimensional structure as is mandatory for other

approaches[12]. First studies have employed network models in the field of resilience research to investigate how RFs relate to each other[13,14]. A study using a network approach on RFs[13] compared a network of RFs for adolescents with and without exposure to childhood adversity, finding that interrelatedness of RFs was higher in the non-exposed group, and that the network model in the exposed group comprised more negative relations. This suggests that various RFs rather hamper than support each other. A similar approach was chosen by Thoma et al.[14] who compared network models of RFs and stress-related risk factors for older adults with and without early-life adversity. They found a larger number of relevant associations in the group without early-life adversity, while the impact of current stress was stronger in the stress-exposed group.

Being the hitherto largest and most disruptive global stressor of the 21st century, the COVID-19 pandemic is an important use case for resilience research[15]. Stress caused by COVID-19 not only results from the fear of the virus, but also from the substantial impact of containment measures such as school closures[16]. As stress is one of the leading causes of the onset and persistence of mental disorders[17], it is not surprising that the COVID-19 pandemic has serious mental health consequences for substantial parts of the population[18]. In line with this notion, meta-analyses found increased symptom distress[15,19] and elevated rates of depressive and anxiety disorders in the general population[18].

To our knowledge, only a small number of studies employed a network model approach to RFs in the context of the COVID-19 pandemic[20–22]. However, only one study on young adults examined a broad set of RFs and used prospective data[22]. Independent from the use of network models, there is little knowledge on RFs, their interrelations, and predictive values for mental health during the pandemic. Existing evidence remains mostly limited to the first wave of the pandemic until summer 2020[15]. Most research has been conducted on (perceived) social support, which may be caused by the potential harm due to social isolation during the pandemic[23]. While some studies found higher levels of social support to be associated with better mental health[24–26], studies examining a broader set of RFs did not find a significant association between social support and mental health[27,28]. Similarly, with respect to cognitive emotion regulation, findings were mixed for different

strategies[27,29] and also for single strategies in different studies[24,27]. To our knowledge, only a small share of longitudinal studies compared the predictive value of a broader set of RFs[27,28,30], with many only investigating different aspects of a single RF and none of the studies focusing on the relationship between RFs or a broader range of stress-related outcomes including positive aspects. Thus, a prospective study examining the associations of a broad set of RFs and their unique predictive value for mental health is missing.

Using the COVID-19 pandemic as a use case, the current study aimed at: (i) examining the network of pre-pandemic RFs; (ii) investigating the relative importance of RFs for mental health over time by establishing a network model including RFs and multiple mental health outcomes (i.e., psychopathological symptoms, COVID-19-related rumination, stress-related growth[1]); and (iii) examining which RFs are important predictors of mental health at different timepoints during the pandemic. Building on previous studies showing the incremental validity of sense of coherence (SOC) beyond other RFs[32,33], we assumed SOC to be a strong component of the network, both cross-sectionally and when predicting psychopathological symptoms and rumination over time. We had no hypothesis for stress-related growth.

Methods

Study design and sample recruitment

The current study derived from a cross-sectional study on RFs conducted in February 2020. In March 2020, the study team decided to widen the scope of the project and to investigate the association between SOC and psychopathological symptoms during the COVID-19 pandemic[34,35]. Six follow-up assessments took place until March 2021. Assessment points were chosen to capture critical points of the pandemic (see SM1). For sample recruitment, we used the WiSoPanel[36] holding *N*=14,369 German-speaking adults who live in Germany, Austria, Switzerland, or border regions in neighboring countries. The panel holds socioeconomically diverse individuals with heterogeneous

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[1] As it is debatable whether the COVID-19 pandemic constituted a traumatic stressor for large shares of the general population[31], we use the term 'stress-related growth' when referring to pandemic-related growth.

demographic backgrounds. Data was collected online via SoSci Survey[37]. The study was conducted in accordance with the ethical standards of the ethics committee of Saarland University but was exempted from approval. For the present analyses, we used data of 1,275 respondents (63.5% of the baseline sample) who completed at least two assessments of mental health outcomes.

Measures

Resilience factors were assessed at pre-pandemic baseline in February 2020, mental health outcomes were collected until March 2021.

Mental health outcomes

COVID-19-related rumination. COVID-19-related rumination was assessed starting in March 2020 using a modified version of the Perseverative Thinking Questionnaire[38]. The 15-item instrument assesses core characteristics of rumination and was mildly adjusted to assess COVID-19-related rumination[35] (see SM2). Each item was rated on a 5-point scale, and higher scores indicate more intense rumination. Internal consistency was excellent at all assessments (Cronbach's alpha [α]=.97; McDonald's omega [ω]=.97).

Psychopathological symptoms. Psychopathological symptom burden was measured using the Brief Symptom Inventory-18[39], a short version of the Brief Symptom Checklist. The 18-item scale is a measure of general psychopathological symptom burden. Each item is rated on a 5-point scale, with higher scores indicating more severe symptoms. The internal consistency was excellent (range across assessments: α/ω=.94–.95).

Stress-related growth. Stress-related growth was assessed starting in April 2020 using an adapted version of the Posttraumatic Growth Inventory[40]. The 21-item scale was modified to assess COVID-19-related growth (see SM3). Each item was rated on a 5-point scale. Higher scores indicate higher levels of growth. The internal consistency was excellent at all assessments (α/ω=.96).

Resilience factors

Adaptive coping. The Brief COPE Inventory[41] was used to assess coping strategies. The 28-item instrument measures 14 coping strategies each with two items, based on a 4-point scale. For the current analyses, we used the Brief COPE subscales showing negative, at least marginally significant, cross-sectional associations with psychopathological symptoms at baseline: active coping (r=-.05, p=.017), emotional support (r=-.04, p=.065), and positive reframing (r=-.06, p=.013). These subscales showed acceptable to good internal consistencies (active coping: α/ω=.71; emotional support: α/ω=.83; positive reframing: α/ω=.76).

Hardiness. Hardiness was assessed using a German translation of the Dispositional Resilience Scale[42,43]. The 15-item scale assessed hardiness using a 4-point scale, with higher scores indicating higher levels of hardiness. The scale demonstrated good internal consistency (α/ω=.84).

Internal control. Internal and external locus of control were assessed using the Brief Scale for the Assessment of Internal and External Control Beliefs[44]. The instrument consists of two subscales measuring internal and external control, each comprising two items. All items are rated on a 5-point scale. For the current study, we used the internal control subscale with good internal consistency (α/ω=.80).

Optimism. Dispositional optimism was assessed using the Scale for Optimism-Pessimism 2[45]. The 2-item scale assesses optimism and pessimism on a 7-point scale. For the current study, we used the optimism item. Higher scores indicate higher levels of optimism.

Self-efficacy. Generalized self-efficacy was assessed using the General Self-Efficacy Short Scale[46]. The 3-item scale assesses self-efficacy on a 5-point scale and higher scores indicate stronger self-efficacy. The internal consistency was excellent (α/ω=.91).

Sense of coherence. SOC was assessed using the 9-item German short version[47] of the original Orientation to Life Questionnaire[48]. The measure uses a bipolar 7-point scale with a verbal anchor at each pole. Higher scores indicate higher levels of SOC. The scale showed excellent internal consistency (α/ω=.90).

Sense of mastery. Sense of mastery was assessed using a German version of the Pearlin Mastery Scale[49]. The 4-item instrument uses a 4-point scale. Higher scores reflect a stronger sense of mastery. The scale demonstrated good internal consistency (α/ω=.89).

Social support. Perceived social support was assessed using the Brief Form of the Perceived Social Support Questionnaire[50]. The 6-item instrument uses a 5-point scale, and higher scores indicate higher levels of perceived social support. The scale showed excellent internal consistency (α=.92; ω=.91).

Dispositional resilience. The Resilience Scale 13[51] was used to assess self-reported resilience conceptualized as personality trait. The scale is a German short version of the Wagnild and Young Resilience Scale[52]. Dispositional resilience is assessed using 13 items rated on a 7-point scale, and higher scores indicate higher levels of dispositional resilience. The scale showed excellent internal consistency (α/ω=.94).

Statistical analyses

All analyses were performed using R version 4.4.2[53].

Handling of missing data. The *Rbtest* package[54] was used to test for types of missing data (i.e., missing completely at random, missing at random). For data missing completely at random or missing at random, we performed *k*-nearest-neighbor imputations using the *VIM* package[55].

Correlational network analysis. For the network analyses, we used the packages *bootnet*[56], *qgraph*[57], and *mgm*[58]. We calculated cross-sectional partial correlational networks of RFs using a mixed graphical model (mgm). For all models, RFs were the variables - called nodes - of interest. Interrelations between the nodes represent partial correlations and are called edges. First, we calculated a network comprising RFs at baseline and examined moderator effects of age, gender, and educational level on edge weights[59]. Second, additionally to the RFs, we included the mental health outcomes in the network. Importantly though, we estimated these networks separately both for the different mental health outcomes as well as for all peri-pandemic timepoints. Third, we examined moderating effects of the mental health variables for the RF edge weights.

The mgm estimation employs a penalty approach for false-positive findings (least absolute shrinkage and selection operator method, LASSO[60]). The LASSO approach shrinks small edge weights to zero. To choose the most appropriate network, we used the Extended Bayesian Information Criterion (EBIC), setting its hyperparameter to $\lambda=.25$[61] and the threshold by Haslbeck and Waldorp[58] for models without moderators as well as no threshold for models including moderators. We applied bootstrapping with 1,000 draws to evaluate the robustness of edge weight estimates based on 95% confidence intervals. We used correlation stability (CS) coefficients to examine centrality stability (expected correlation: .70). CS coefficients above .50 allow for a valid interpretation of centrality indices[11]. We used *strength* as centrality index that describes how well a node directly connects to other nodes (i.e., the sum of absolute edge weights).

LASSO regression. To identify relevant correlates - referred to as predictors - of time-varying mental health variables, we used LASSO regressions. LASSO regressions were employed using the *glmnet*[62] and *caret*[63] packages. The LASSO approach[2] is recommended for predictor selection as it minimizes overfitting by incorporating a penalty to the log-likelihood function and shrinks small and imprecise coefficients to zero[64]. For an initial assessment of all time-varying variables, we employed a model predicting each mental health variable based on all RFs. For all following assessments, we included baseline scores of mental health outcomes as predictors to examine the incremental validity of RFs. All models used 20-fold cross-validation for the selection of optimal λ[65]. Optimal λ was defined as the λ that minimizes the cross-validation error plus one standard error, which reflects the most parsimonious model with comparable accuracy[66]. For model performance, we assessed the deviance ratio (range: 0–1) that can be interpreted similar to R^2 in linear regression. All models were checked for multicollinearity, without evidence for multicollinearity problems (variance inflation factors <5). For sensitivity purposes, all models were re-estimated controlling for age, gender, and educational level.

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[2] Mathematically the LASSO approach used for correlational network models and LASSO regressions are similar, with two major differences: i) the LASSO regressions do not focus on RF interrelations, and ii) the correlational networks do not include time-varying variables (i.e., baseline scores) and background variables like age, gender, and educational level.

Results

Sample characteristics

Our sample comprised 1,275 respondents (M_{age}=50.06, SD=13.49, range: 20–95 years, 51.5% female). Three respondents had no school degree (0.2%), 13.1% reported to have 9 years of school, 32.1% had 10 years of school, 19.8% had an A-level exam, 31.8% held a university degree, and 3.1% completed a doctoral degree. A comparison of the study sample with the German general population can be found in a previous publication[34].

Dropout analyses

Respondents included in our study sample were significantly older than those who dropped out after the baseline assessment, $t(2005)$=8.00, p<.001, d=0.37, and more likely to be women, $\chi^2(1)$=2.11, p<.001, *Cramer's V*=.11, but were equally educated, $t(2005)$=1.63, p=.103, d=0.08. Moreover, they reported lower symptom levels in February 2020, $t(2004)$=2.07, p=.039, d=0.10, lower levels of dispositional resilience, $t(2004)$=-4.23, p<.001, d=-0.20, and SOC, $t(2004)$=-3.21, p=.001, d=-0.15, while there were no differences in other RFs, p≥.079. A comparison of complete cases versus non-complete cases can be found in SM4. Thus, dropout was somewhat selective, which should be considered when interpreting the following results.

Handling of missing data

Regression-based tests indicated that missing data was statistically completely missing at random for 19 variables included in our analyses and missing at random for one variable. Thus, missing data was handled using imputation.

Baseline resilience factor network

The network model of pre-pandemic RFs is presented in Figure 1. Of 55 possible edges, 21 were included in the model, of which 20 were positive (95%; see SM5). Bootstrapped confidence
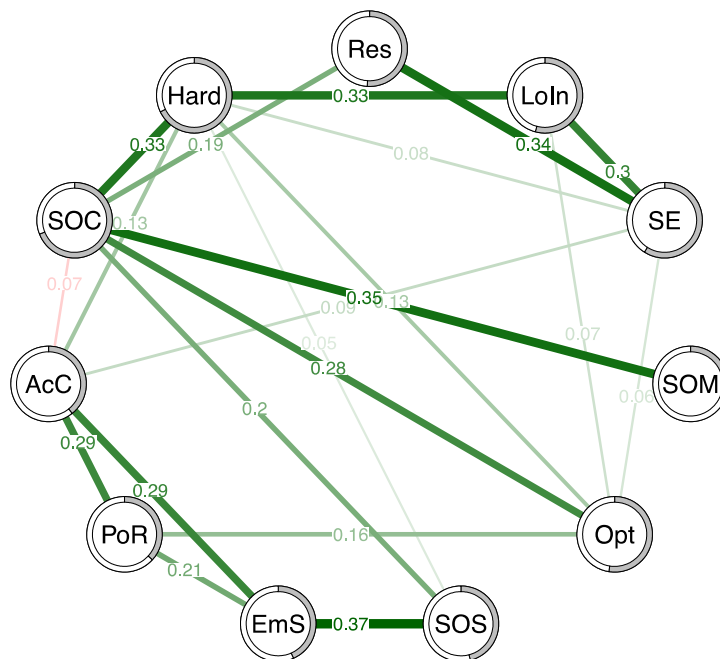
intervals of edge-weight parameters indicated acceptable precision (see SM6.1). The strongest associations were found between i) coping using emotional support and social support (r=.37), ii) SOC and sense of mastery (r=.35), and iii) dispositional resilience and self-efficacy (r=.34). SOC and active coping had the only negative interrelation (r=−.07).

Centrality. The correlation stability coefficient (r=.75) allowed for a valid interpretation of centrality. Strength centrality indicated that SOC was the most central node.

Predictability. In general, predictability was high and ranged from R^2=.32 for sense of mastery to R^2=.69 for SOC.

Moderation. Moderation analyses indicated that edge weights were not amplified by respondents' age, gender, and educational level.

a. Resilience factor network in February 2020

b. Strength centrality

Figure 1. Network model of resilience factors in February 2020 and strength centrality
Note. Absolute values of partial correlations. Green lines indicate positive relationships, red lines negative relationships. Wider lines represent stronger associations. Predictability of nodes is indicated by the grey parts of the circles surrounding each node. Strength centrality is shown on the right. AcC=Active Coping; EmS=Emotional Support (Coping); Hard=Hardiness; LoIn=Internal Locus of Control; Opt=Optimism; PoR=Positive Reframing (Coping); SE=Self-Efficacy; SOC=Sense of Coherence; SOM=Sense of Mastery; SOS=Social Support; Res=Dispositional Resilience.

Network of resilience factors and psychopathological symptoms

Figure 2 presents the network models including RFs and psychopathological symptoms before the pandemic and at six timepoints during the pandemic. Of the possible 66 edges, networks ranged between 20 (August 2020) and 23 edges (January 2021), of which all but the relationship between SOC (as well as social support in January 2021) and psychopathological symptoms were positive. Bootstrapped confidence intervals of edge weights indicated sufficient precision (see SM6.2). For all networks, the strongest positive relationship was found between coping using emotional support and social support, while the strongest negative association emerged between pre-pandemic SOC and psychopathological symptoms that ranged between $r=-.32$ (November 2020) and $r=-.43$ (February 2020).

Temporal stability. To examine network stability over time, we correlated edge weights for each timepoint (see SM7). Overall, stability was very high ($r \geq .98$) and remained stable when limiting the edges to those including symptoms as time-varying variable ($r \geq .94$).

Moderation. We examined psychopathological symptoms as moderator of edge weights. Moderation analyses indicated that symptom levels did not amplify edge weights in either timepoint.

LASSO regressions. We predicted psychopathological symptoms (once for each timepoint) based on pre-pandemic RFs in February 2020, while controlling for baseline symptoms (see Table 2). In February 2020, higher levels of SOC were associated with lower symptoms, while higher levels of positive reframing were related to more severe symptoms. For all other timepoints, only SOC and baseline symptom levels remained relevant predictors after regularization. These results remained stable when including age, gender, and educational level as control variables (see SM8). Except for coping using emotional support, which was found to be associated with more severe symptoms in February 2020, results remained unchanged when sociodemographic characteristics were included.
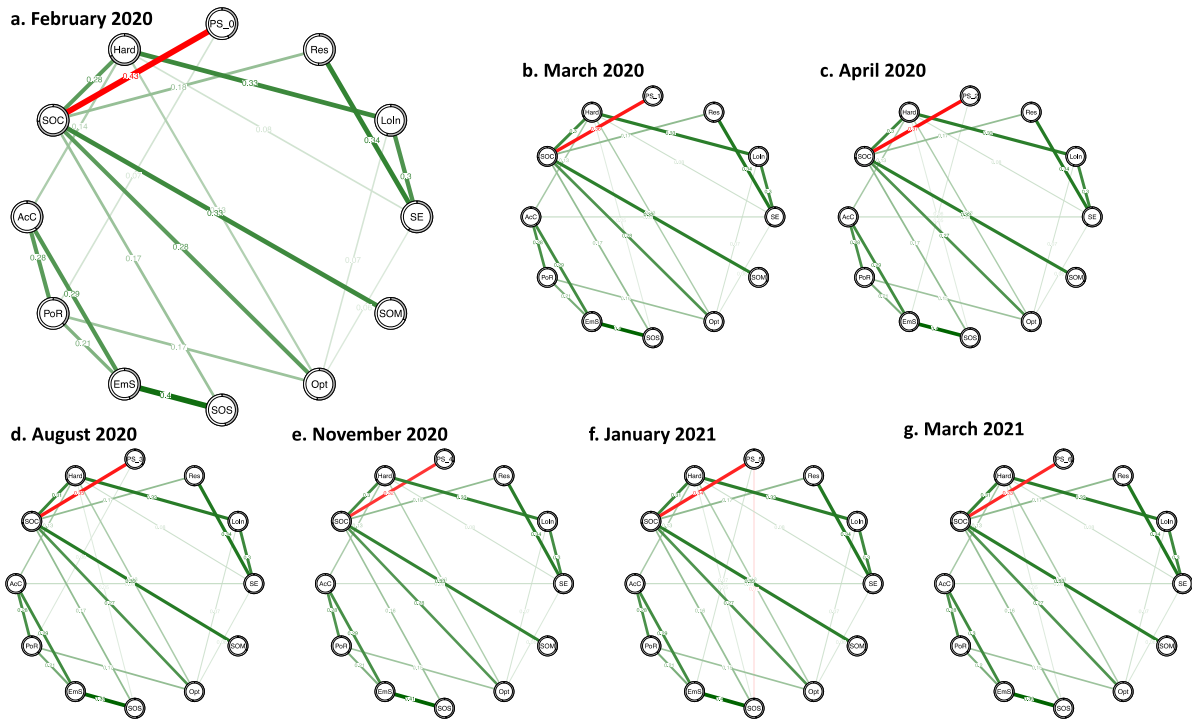
Figure 2. Network model of pre-pandemic resilience factors and psychopathological symptoms during the pandemic

Note. Absolute values of partial correlations. Green lines indicate positive relationships, red lines negative relationships. Wider lines represent stronger associations. Predictability of nodes is indicated by the grey parts of the circles surrounding each node. AcC=Active Coping; EmS=Emotional Support (Coping); Hard=Hardiness; LoIn=Internal Locus of Control; Opt=Optimism; PoR=Positive Reframing (Coping); PS=Psychopathological Symptoms; Res=Dispositional Resilience; SE=Self-Efficacy; SOC=Sense of Coherence; SOM=Sense of Mastery; SOS=Social Support.

Table 2. Predictor selection for psychopathological symptoms, COVID-19-related rumination, and stress-related growth based on LASSO regressions

	February 2020	March 2020	April 2020	August 2020	November 2020	January 2021	March 2021
Psychopathological symptoms							
Baseline psychopathological symptoms (February 2020)	–	higher	higher	higher	higher	higher	higher
Active coping	•	•	•	•	•	•	•
Coping using emotional support	•	•	•	•	•	•	•
Hardiness	•	•	•	•	•	•	•
Internal locus of control	•	•	•	•	•	•	•
Optimism	•	•	•	•	•	•	•
Positive reframing	higher	•	•	•	•	•	•
Self-efficacy	•	•	•	•	•	•	•
Sense of coherence	lower	lower	lower	lower	lower	lower	lower
Sense of mastery	•	•	•	•	•	•	•
Social support	•	•	•	•	•	•	•

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	February 2020	March 2020	April 2020	August 2020	November 2020	January 2021	March 2021
Dispositional resilience	•	•	•	•	•	•	•
Deviance ratio	.39	.54	.52	.53	.43	.44	.40
COVID-19-related rumination							
Baseline COVID-19-related rumination (March 2020)	–	–	higher	higher	higher	higher	higher
Active coping	–	•	•	•	•	•	•
Coping using emotional support	–	•	•	•	•	•	•
Hardiness	–	•	•	•	•	•	•
Internal locus of control	–	•	•	•	•	•	•
Optimism	–	•	•	•	•	•	•
Positive reframing	–	•	•	•	•	•	•
Self-efficacy	–	•	•	•	•	•	•
Sense of coherence	–	lower	lower	lower	lower	lower	lower
Sense of mastery	–	•	•	•	•	•	•
Social support	–	•	•	•	•	•	•
Dispositional resilience	–	•	•	•	•	•	•
Deviance ratio	–	.03	.42	.33	.36	.39	.30
Stress-related growth							
Baseline stress-related growth (April 2020)	–	–	–	higher	higher	higher	higher
Active coping	–	–	•	•	•	•	•
Coping using emotional support	–	–	higher	•	•	•	•
Hardiness	–	–	higher	•	•	•	•
Internal locus of control	–	–	higher	•	•	•	•
Optimism	–	–	higher	•	•	•	•
Positive reframing	–	–	higher	•	•	•	•
Self-efficacy	–	–	•	•	•	•	higher
Sense of coherence	–	–	•	•	•	•	•
Sense of mastery	–	–	lower	•	•	•	•
Social support	–	–	•	•	•	•	•
Dispositional resilience	–	–	•	•	•	•	•
Deviance ratio	–	–	.10	.51	.53	.50	.49

Note. Summary of LASSO-based predictor selection. Psychopathological symptoms, COVID-19-related rumination and stress-related growth were used as criterion. The optimal penalty term (λ) was chosen based on 20 cross validations. The results remained stable when we included age, gender, and educational level as control variables (Supplementary Material Table SM8). Deviance ratios can be interpreted as R^2.

–   Variable not included in the model
•   Set to zero based on LASSO regularization
higher   higher levels of the predictor are related to higher levels of the criterion variable
lower   higher levels of the predictor are related to lower levels of the criterion variable

Network of resilience factors and COVID-19-related rumination

The network models including rumination are in Figure 3. Of 66 possible edges, networks

ranged between 22 (March 2020, August 2020, January 2021) and 26 edges (April 2020), of which all

but the associations between SOC and rumination as well as between SOC and active coping were positive. Bootstrapped confidence intervals of edge weights supported the robustness of edge weight estimation (see SM6.3). Again, the strongest positive relationship was found between coping using emotional support and social support. The strongest negative association was found for SOC and rumination ranging from $r=-.10$ (March 2020) to $r=-.18$ (April/August 2020).

Temporal stability. Network stability was very high across all timepoints including all variables ($r\geq.99$) and when limiting variables to time-varying rumination ($r\geq.85$).

Moderation. We investigated whether edge weights were moderated by rumination, but rumination did not amplify any edge weight.

LASSO regressions. We predicted rumination based on pre-pandemic RFs in February 2020, while controlling for baseline symptom levels at all other timepoints (see Table 2). In March 2020, a higher SOC was associated with lower rumination, however, accounting for a small amount of variance (deviance ratio: .03). At all other timepoints, a higher SOC and lower baseline rumination were related to lower rumination. These results remained unchanged when age, gender, and educational level were included as control variables.
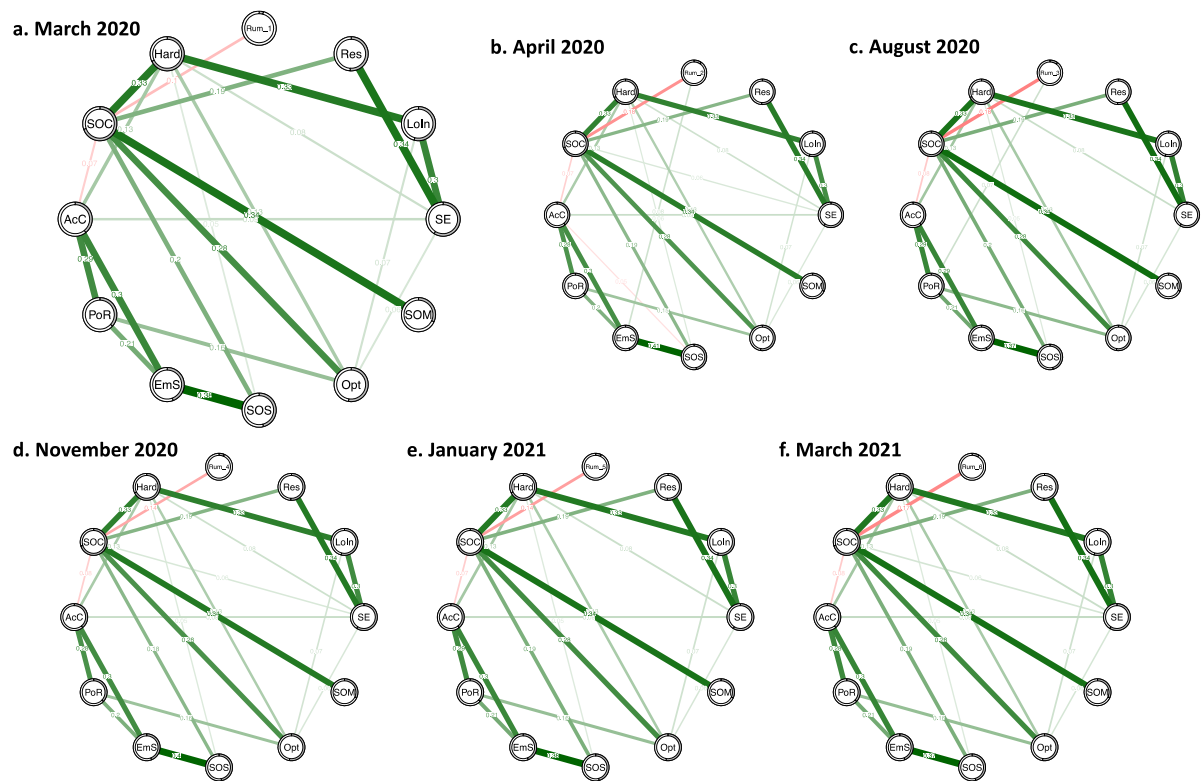
Figure 3. Network model of pre-pandemic resilience factors and COVID-19-related rumination during the pandemic

Note. Absolute values of partial correlations. Green lines indicate positive relationships, red lines negative relationships. Wider lines represent stronger associations. Predictability of nodes is indicated by the grey parts of the circles surrounding each node. AcC=Active Coping; EmS=Emotional Support (Coping); Hard=Hardiness; LoIn=Internal Locus of Control; Opt=Optimism; PoR=Positive Reframing (Coping); PS=Psychopathological Symptoms; Res=Dispositional Resilience; Rum=COVID-19-Related Rumination; SE=Self-Efficacy; SOC=Sense of Coherence; SOM=Sense of Mastery; SOS=Social Support.

Network of resilience factors and stress-related growth

The networks including stress-related growth are shown in Figure 4. Out of 66 possible edges, the number of edges ranged between 21 (August 2020) and 24 (April 2020). Except for the association between SOC and active coping, all links were positive. Bootstrapped confidence intervals of edge weights indicated acceptable robustness (see SM6.4). In contrast to the network models including psychopathological symptoms and rumination, SOC showed no direct association with stress-related growth. Again, the strongest positive association was found between coping using emotional support and social support. Across all timepoints, stress-related growth had a positive

association with positive reframing and for four out of five timepoints, stress-related growth was positively associated with optimism.

Temporal stability. When including all variables, temporal network stability was high ($r≥.98$). However, limited to time-varying stress-related growth, temporal stability was lower ($r≥.39$) than for psychopathological symptoms and rumination, indicating higher variability of associations over time.

Moderation. We investigated whether levels of stress-related growth moderated edge weights. After regularization, there was no moderator effect except for the association between positive reframing and coping using emotional support in January 2021, where higher levels of growth were related to a stronger partial correlation between positive reframing and coping using emotional support (interaction weight=.03).

LASSO regressions. For April 2020, we predicted stress-related growth based on pre-pandemic RFs, while controlling for baseline levels of stress-related growth at all other timepoints (see Table 2). In April 2020, higher levels of coping using emotional support, internal locus of control, optimism and hardiness, more positive reframing, and, interestingly, lower sense of mastery were related to more stress-related growth. For the assessments between August 2020 and January 2021, only baseline stress-related growth was identified as predictor of later stress-related growth, while in March 2021, also higher levels of optimism were associated with more stress-related growth. When controlling for sociodemographic variables, higher levels of hardiness and social support were associated with more stress-related growth in August 2020 (see SM8).
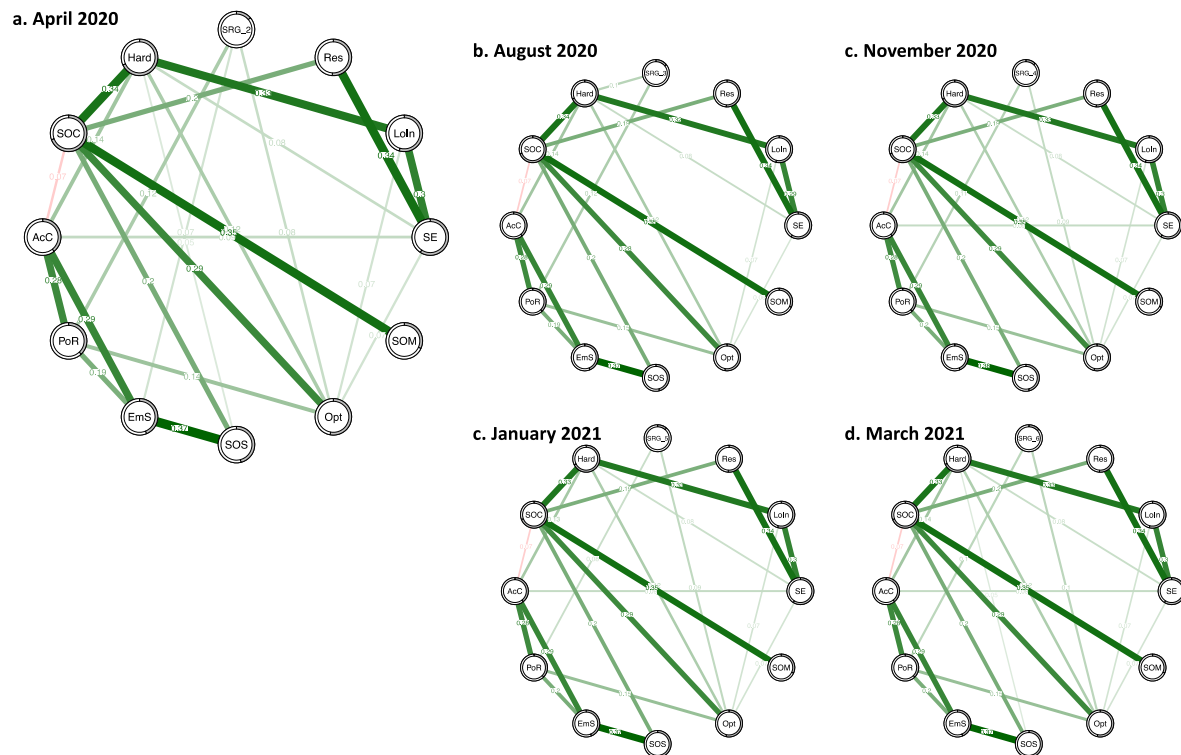
Figure 4. Network model of pre-pandemic resilience factors and stress-related growth during the pandemic

Note. Absolute values of partial correlations. Green lines indicate positive relationships, red lines negative relationships. Wider lines represent stronger associations. Predictability of nodes is indicated by the grey parts of the circles surrounding each node. AcC=Active Coping; EmS=Emotional Support (Coping); Hard=Hardiness; LoIn=Internal Locus of Control; Opt=Optimism; PoR=Positive Reframing (Coping); Res=Dispositional Resilience; Rum=COVID-19-related Rumination; SE=Self-Efficacy; SOC=Sense of Coherence; SOM=Sense of Mastery; SOS=Social Support; SRG=Stress-Related Growth.

Discussion

This 1-year prospective study examined pre-stressor resilience factors (RFs) and their association with mental health during one year of stressor exposure. Like other studies on RF networks[13,14], we found pre-stressor resilience factors (RFs) to be strongly interrelated. Sense of coherence (SOC) played the most prominent role in the RF network and as a correlate and predictor of psychopathological symptoms and COVID-19-related rumination. In line with our hypotheses and previous research[67-70], the importance of SOC was further supported by LASSO regressions showing that higher SOC was associated with lower symptoms and rumination at all timepoints. Interestingly, when simultaneously accounting for other RFs, SOC showed no partial correlation with stress-related growth, which was uniquely associated with positive reframing and optimism in the network models and had inconsistent predictors in the LASSO regressions.

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To our knowledge, this study was the first to examine a broad range of RFs in an adult general population sample using a prospective design. In the pre-pandemic network of RFs, SOC was the most central node with unique positive partial correlations with hardiness, sense of mastery, dispositional resilience, and optimism, and one small negative association with active coping. On a conceptual level, the SOC components *manageability* and *meaningfulness* may overlap with the *control* and *commitment* components of hardiness[71], with *manageability* and *control* referring to the feeling of being able to handle life challenges and *meaningfulness* and *commitment* representing the belief that these challenges are a potential source of purpose and growth[72]. Parts of the *manageability* component may also overlap with sense of mastery as the belief to be in control in different life domains[73], the *competence* dimension of dispositional resilience[74] (e.g., self-reliance, independence), and the positive outcome expectancy of optimism[75]. Interestingly, there was also a link between SOC and social support, while none of the items of the SOC measure[47] referred to social relationships. The negative, yet small, unique association with active coping in the network model may point to differences between the concept of active coping as a set of intentional, goal-directed efforts to minimize physical, psychological and social harm of stressor exposure[76], and the SOC component *manageability*. While active coping stresses the use of own resources to handle stress, the *manageability* component of SOC explicitly includes the reliance on external resources[72]. However, to date, evidence on overlaps between different SOC dimensions and other RFs is missing, and conclusions are limited to qualitative analyses[77]. Due to the large number of questionnaires assessed in this study, we were not able to use a longer version of the SOC scales[48] allowing for the analysis of SOC components. Moreover, many scales for the assessment of RFs - including those for SOC assessment - lack robust factorial validity[78]. Thus, future research needs to improve the psychometric assessment of SOC and other RFs.

Our study was also the first to examine a network of RFs and their association with mental health during the first year of the pandemic as a major global stressor. Interestingly, the networks of pre-pandemic RFs and mental health outcomes remained highly stable for psychopathological symptoms and COVID-19-related rumination and still considerably robust for stress-related growth,

also when edges were limited to those including time-varying outcomes. Thereby, our findings support the notion that RFs found to be strongly associated with mental health outcomes cross-sectionally, remain relevant over time. This challenges previous criticism on RFs stating that cross-sectionally relevant associations diminish over time with some RFs becoming irrelevant after a few months[79]. Also in our study, we found decreasing associations over time, but relevant associations remained robust in the first year of the pandemic and were neither modified by sociodemographic characteristics nor mental health outcomes. Thus, our findings suggest that it matters which RF is examined as predictor, with SOC being a particular important predictor in our study.

In line with previous research[67–70], our findings point to SOC's incremental validity beyond other RFs for psychopathological symptoms and rumination and thereby challenge the notion that the association of SOC and mental health only arises from the overlap between SOC and mental health measures[80,81]. Furthermore, when examining SOC's predictive value using a LASSO regression approach and controlling for baseline symptoms, SOC remained a significant predictor of psychopathological symptoms and rumination, thereby raising the question of what accounts for the unique value of SOC. Our network of pre-pandemic RFs suggests that SOC combines relevant aspects of other RFs (i.e., control beliefs and meaning), which may explain its strong associations with psychopathological symptoms and rumination. At the same time, our findings do not answer the question of what SOC adds beyond other RFs as we did not examine SOC components and focused on SOC's overlap with other RFs. Previous studies suggested that the SOC component *meaningfulness* may account for its incremental validity[82], however, future research using network models and a dimensional assessment of SOC is needed[69].

While correlational patterns for psychopathological symptoms and COVID-19-related rumination were similar, stress-related growth as the only positive mental health outcome yielded different results. At four out of five timepoints, stress-related growth showed a positive partial correlation with positive reframing and optimism. These associations are in line with a previous meta-analysis finding posttraumatic growth to be associated with higher levels of optimism and reappraisal[83], and may reflect that optimistic reframing forms a base for stress-related growth. This

notion is further supported by research into *perceived benefits*[84], which were found to be positively associated with positive reframing after stressful life events[85]. Using a LASSO regression approach we observed mixed findings, with stress-related growth showing a positive association with coping via emotional support, hardiness, internal locus of control, and positive reframing, and a negative association with sense of mastery in April 2020. However, at later assessments, only previous stress-related growth predicted growth levels, except for the last assessment in March 2020, when self-efficacy was also associated with higher levels of growth. Surprisingly, stress-related growth neither showed a partial correlation with SOC nor was SOC selected as a predictor in the LASSO regression although the *meaningfulness* component explicitly comprises growth from life challenges. Future studies need to examine correlates of stress-related growth in the context of multifaceted stressors.

The results of the current study also point to a sizable problem of resilience research by showing that a set of 11 RFs accounts for only 39% of the variance in psychopathological symptoms cross-sectionally, and RFs explained 3% of the variance in rumination and 10% of the differences in stress-related growth. These findings are in line with the so-called 'resilience paradox'[86], describing the fact that neither single RFs nor their sum can account for the complex phenomenon of resilience. Especially for stress-related growth and rumination, associations were weak, which might reflect that many RF assessments have been optimized for high correlations with psychopathological symptoms (i.e., items have been selected to maximize the correlation with symptom measures[46,50]). However, it is crucial to focus on transdiagnostic outcomes like rumination that go beyond symptom measures and are involved in the onset and persistence of mental disorders[87]. Thus, future resilience research needs to broaden the scope of resilient outcomes[15]. Furthermore, these studies need to combine research into RF networks and recent theories on underlying resilience mechanisms[1]. Moreover, such studies may compare networks comprising RFs and resilience mechanisms between different trajectories of mental health after stressor exposure[15].

It is important to consider the limitations of the current study. First, the study is based on a diverse but nonrepresentative sample recruited via an online panel[36] and was observational in nature. Thus, mental health as assessed in this study does not exclusively reflect responses to

stressor exposure but also spontaneous[88] and/or seasonal fluctuations[89], as we do not have a long-term assessment of pre-pandemic mental health in this sample to trace fluctuations independent of the pandemic. Models used in this study are based on (partial) correlations, hence preventing causal conclusions from being drawn. Moreover, a substantial number of respondents dropped out during the study period. We performed dropout analyses showing that study completers were equally educated but older and more likely to be women as compared to those who dropped out, which limits the generalizability of our findings. Furthermore, RFs were not assessed repeatedly during the pandemic, and our results build on a single pre-pandemic assessment in February 2020. We decided against a repeated assessment as a comprehensive assessment would have been too time-consuming, thus heightening the risk of larger dropout rates. Nevertheless, future studies need to examine a fully longitudinal RF network in face of significant stress. These studies may also make use of elaborated assessments of stressor exposure that allow for the investigation of stressor reactivity[90]. Due to the dynamic course of the pandemic with varying stressors over time, we were not able to include such a measure in the present study. However, with our study taking place during the pandemic, we ensured that a major stressor was present at that time[15], allowing conclusions about resilience in line with the outcome-based resilience definition.

The current study enhances our understanding of RFs in the face of a major global stressor. We found that SOC was the strongest component of a network of pre-pandemic RFs and showed the strongest unique association with psychopathological symptoms and COVID-19-related rumination in the first year of the pandemic. Consistent with previous studies, SOC demonstrated incremental validity beyond other RFs and remained a significant predictor over time. Patterns of associations for stress-related growth were different, pointing to the need of multidimensional outcomes in resilience research. Future studies need to shed light on the incremental validity of SOC and should combine research into RF networks with recent theories on mediating resilience mechanisms.

Author contributions

SKS: conceptualization (lead), formal analysis (lead), methodology (lead), writing – original draft preparation; JF: methodology, writing – review and editing (equal); MRS: conceptualization (supporting), methodology, writing – review and editing (equal); AMK: methodology, writing – review and editing (equal); LvB: methodology, writing – review and editing (equal); OT: resources (supporting), supervision (supporting), writing – review and editing (equal); ASG: data curation, project administration, resources (lead), supervision (supporting), writing – review and editing (equal); KL: resources (supporting), supervision (supporting), writing – review and editing (equal); TM: conceptualization (supporting), resources (supporting), supervision (lead), writing – review and editing (equal).

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Conflict of interest

The authors declare to have no conflict of interest.

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