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Exploring the psychology of suicidal ideation: A theory driven network analysis

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ABSTRACT

Two leading theories within the field of suicide prevention are the interpersonal psychological theory of suicidal behaviour (IPT) and the integrated motivational-volitional (IMV) model. The IPT posits that suicidal thoughts emerge from high levels of perceived burdensomeness and thwarted belongingness. The IMV model is a multivariate framework that conceptualizes defeat and entrapment as key drivers of suicide ideation. We applied network analysis to cross-sectional data collected as part of the Scottish Wellbeing Study, in which a nationally representative sample of 3508 young adults (18–34 years) completed a battery of psychological measures. Network analysis can help us to understand how the different theoretical components interact and how they relate to suicide ideation. Within a network that included only the core factors from both models, internal entrapment and perceived burdensomeness were most strongly related to suicide ideation. The core constructs defeat, external entrapment and thwarted belonginess were mainly related to other factors than suicide ideation. Within the network of all available psychological factors, 12 of the 20 factors were uniquely related to suicide ideation, with perceived burdensomeness, internal entrapment, depressive symptoms and history of suicide ideation explaining the most variance. None of the factors was isolated, and we identified four larger clusters: mental wellbeing, interpersonal needs, personality, and suicide-related factors. Overall, the results suggest that relationships between suicide ideation and psychological risk factors are complex, with some factors contributing direct risk, and others having indirect impact.

1. Introduction

Suicide is a global health problem, with at least 800, 000 people dying by suicide each year (World Health Organization, 2014). Among 15–29 year olds, it is the second leading cause of death. It is estimated that the number of people who attempt suicide is 20 times higher than those who die by suicide (World Health Organization, 2014).

Traditional attempts at understanding suicide risk have tended to focus on single risk factors for suicidal behaviour (e.g., escape: Baumeister, 1990), or have attended to a specific domain of risk such as cognition (Wenzel, Brown, & Beck, 2009). Although such approaches have resulted in a better understanding of specific risk factors for suicidal behaviour, their narrow focus has not done justice to the complexity of the factors leading to suicidal ideation and behaviour (O'Connor, 2011; O'Connor & Kirtley, 2018; O'Connor & Nock, 2014). Indeed, contemporary theoretical models of suicidal behaviour highlight the complex interaction between biological, environmental, psychological and social factors (Klonsky, May, & Saffer, 2016; O'Connor & Kirtley, 2018; O'Connor & Nock, 2014). This complexity brings challenges not only for patients and clinicians, but also for scientists. Statistical techniques usually applied within the fields of psychology and psychiatry, such as analysis of variance or regression analysis tend to focus on identifying risk factors but they provide limited insight into the relationships between the risk factors themselves. For example, defeat, entrapment, burdensomeness and impulsivity are only a few of the important factors specified within the integrated motivational-volitional model of suicidal behaviour (IMV; O'Connor, 2011; O'Connor & Kirtley, 2018), a predominant model of suicidal behaviour. These

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factors are all highly likely to influence each other as well as the outcome variable (O'Connor, 2011; De Beurs, van Borkulo, & O'Connor, 2017).

Network analysis — a class of methodological techniques that has seen a rapid increase in use in psychology in recent years— offers a novel way to both quantify and visualize the complex interplay between many interacting variables (Borsboom, 2017; Borsboom & Cramer, 2013). As with regression models, one can estimate the predictability of variables in a network. Using network analysis, it is also possible to determine how much variance in each node in a network is explained by all of the other nodes, providing information about how much a node could potentially be influenced by other nodes in the network (Haslbeck & Fried, 2017). Additionally, network analysis provides the opportunity to combine prediction with insight into the relationships among the various risk factors. A network of suicide ideation and its risk factors would provide insight into how risk factors interact among each other, and which factors confer direct risk to suicide ideation after partialling out the effect of the other risk factors.

So far, network analysis has largely been used as an exploratory tool, i.e., to gain insights into the statistical dependencies among a larger number of variables in a dataset (Fried & Cramer, 2017). These variables have usually been selected because they are part of the same rating scale or diagnostic criteria (eg. Bringmann, Lemmens, Huibers, Borsboom, & Tuerlinckx, 2015; De Beurs et al., 2017; Fried et al., 2018) So, rather than selecting symptoms or psychological factors based on theory, they tend to be selected because of their availability.

The present paper is the first paper to understand suicidal ideation from a network perspective by selecting variables based on psychological theory. We applied network analysis to data from the Scottish Wellbeing Study which is comprised of a representative sample of young adults (18–34 years, n = 3508) living in Scotland who completed detailed psychological wellbeing measures (O'Connor et al., 2018a; Wetherall et al., 2018). The dataset includes all major psychological factors for suicide ideation as specified within two dominant theories in suicide prevention: the interpersonal theory of suicidal behaviour (Van Orden et al., 2010) and the integrated motivational volitional model (O'Connor, 2011; O'Connor & Kirtley, 2018).

1.1. Theoretical models of suicidal behaviour

One of the most influential theories in suicidology is the interpersonal theory of suicidal behaviour (IPT: Van Orden et al., 2010; see Fig. 1). The core assumption is that suicidal thoughts emerge when levels of perceived burdensomeness (defined as feeling a burden on others) and thwarted belongingness (defined as feeling that you do not belong) are high. Suicidal thoughts are translated into suicide attempts when the capability for suicide (defined as a reduced fear of death, and increased tolerance for physical pain) is also present. A recent meta-analysis yielded clear support for the perceived burdensomeness–suicidal thoughts relationship whereas the evidence for thwarted belongingness was less strong (Chu et al., 2017).

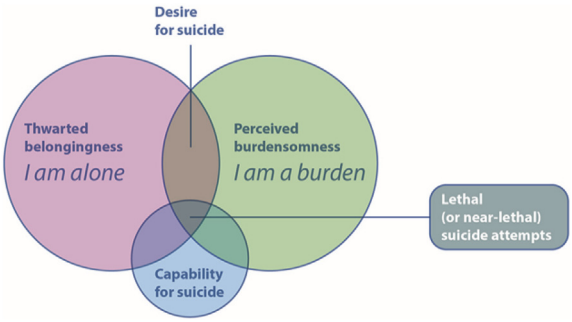

Fig. 1. The interpersonal psychological theory of suicidal behaviour (Van Orden et al., 2010).

The integrated motivational-volitional model of suicidal behaviour (IMV; O'Connor, 2011; O'Connor & Kirtley, 2018) see Fig. 2), another predominant model, proposes that suicidal behaviour results from a complex interplay of motivational and volitional phase factors. Factors within the motivational phase of the model explain how suicidal thoughts emerge in some people but not in others. Factors within the motivational phase include defeat, entrapment, and (lack of) social support. Volitional phase factors, on the other hand, are those factors that govern the transition from suicidal thinking (ideation/intent) to suicidal behaviour; they include exposure to suicide, fearlessness about death and impulsivity. Entrapment is conceptualized as the key driver of suicide ideation within the IMV model with empirical evidence in support of the model continuing to grow (O'Connor & Kirtley, 2018; O'Connor & Portzky, 2018b). Various studies have indicated that a specific type of entrapment, internal entrapment (defined as trapped by pain triggered by internal thoughts and feelings), is more strongly related to suicide ideation than external entrapment (i.e., unable to escape external events/experiences) (Owen, Dempsey, Jones, & Gooding, 2017; Rasmussen et al., 2010). The IMV model also specifies pre-motivational phase factors that assess background factors (e.g., perfectionism), environmental factors and triggering events.

In this paper, we used network analysis to statistically estimate relations among variables based on these two different theories. We selected these theories because they are prominent theories in the literature, and because we had access to data that allowed us to test different hypotheses of the models within one dataset. In sum, the IPT states that the pairwise interaction between perceived burdensomeness and thwarted belongingness directly results in suicide ideation, whereas the IMV model states that entrapment and defeat are the core components, affecting suicide ideation directly. To compare these two competing hypotheses, we estimated a cross-sectional network consisting of the five core components of both models (i.e., burdensomeness, belongingness, defeat and internal and external entrapment) and current suicide ideation. The analysis will provide insight in which of the core components are directly related to suicide ideation, after partialling out all other variables, and how the core components inter-relate. Second, we wanted to explore how all of the major psychological factors, as specified within the IMV model (which includes the core IPT variables), related to each other and to current suicide ideation.

2. Method

2.1. Participants and procedure

The Scottish Wellbeing Study (O'Connor et al., 2018b; Wetherall et al., 2018) is the first nationally representative population-based study of suicidal ideation and behaviour in young adults (18–34 year olds) across Scotland. Participant recruitment was conducted by Ipsos MORI, a social research organisation, from 25th March 2013 and 12th December 2013. A quota sampling methodology was employed, with quotas based on age (three quota groups), sex and working status. Following written consent, participants completed an hour-long interview, carried out face-to-face in their homes, using Computer Assisted Personal Interviewing (CAPI) and including a Computer Assisted Self Interviewing (CASI) module (the questions about suicide were completed confidentially on the computer). Participants completed a battery of psychological and social measures that incorporated key aspects of the IPT and IMV model frameworks of suicide (see measures sections below). All interviewers were trained in the administration of the measures. Ethical approval was obtained from the Psychology Department's ethics committee at the University of Stirling and the US Department of Defence Human Research Protections Office. Participants received £25 in compensation for taking part. All participants were given a list of support organisations at the end of the interview.

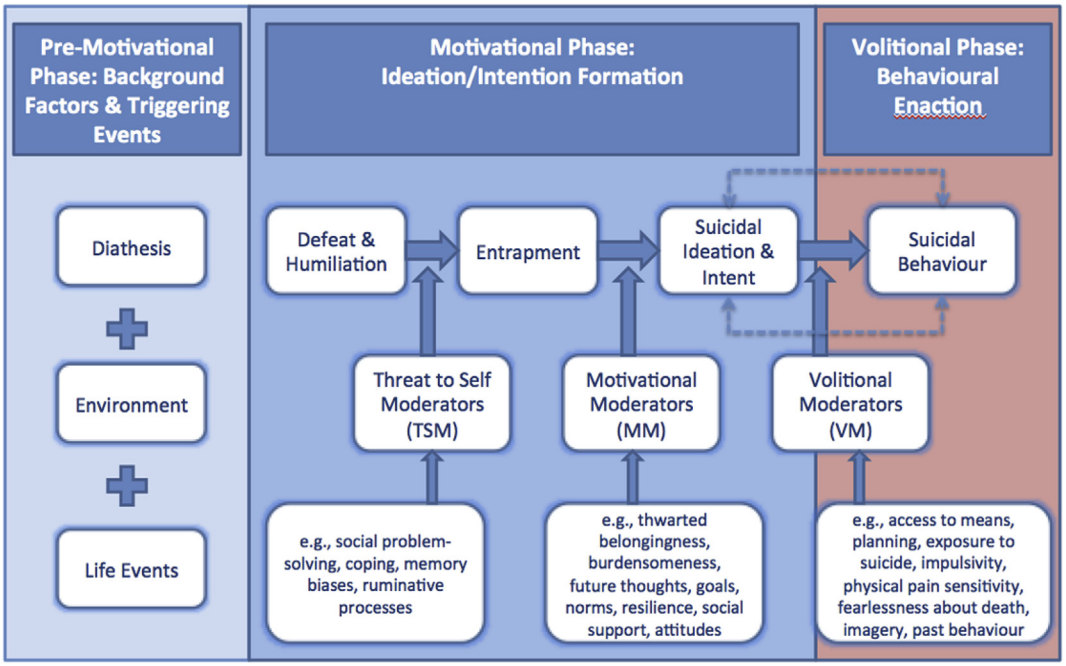

Fig. 2. Integrated motivational-volitional model of suicidal behaviour (O'Connor, 2011; O'Connor & Kirtley, 2018).

2.2. Measures

2.2.1. Suicidal ideation and behaviour

Current suicidal ideation was assessed using the Beck Scale for Suicidal Ideation (BSSI: Beck, Kovacs, & Weissman, 1979) which is a well-established 19-item scale measuring suicidal thinking over the preceding 7-days. The self-report version of this scale has good psychometric properties (De Beurs, de Vries, de Groot, de Keijser, & Kerkhof, 2014; Luxton, Rudd, Reger, & Gahm, 2011). In this study, it displayed high internal reliability (Cronbach's $\alpha = 0.95$). As the BSSI responses are highly skewed, we transformed the variable into a dichotomous variable (0 = no suicide ideation, 1 = any suicide ideation).

History of suicidal ideation and suicide attempts were assessed with two items drawn from the Adult Psychiatric Morbidity Survey (McManus, Meltzer, Brugha, Bebbington, & Jenkins, 2009): "Have you ever seriously thought of taking your life, but not actually attempted to do so?" and "Have you ever made an attempt to take your life, by taking an overdose of tablets or in some other way?". Scores on each item were included as separate nodes in the network.

2.2.2. Mood, stress and wellbeing

Depressive symptoms were measured using the Beck Depression Inventory-II (Beck, A.T., Steer, R.A., & Brown, 1996), a well-established measure of depressive symptoms which contains 21 items. The BDI-II has been shown to yield reliable, internally consistent, and valid scores in many different populations (Dozois, Dobson, & Ahnberg, 1998). In this study, it displayed high internal reliability (Cronbach's $\alpha = 0.95$).

Stress was assessed with the Perceived Stress Scale-Brief (Cohen, S., Kamarck, T. and Mermelstein, 1983), a widely used psychological instrument for measuring the perception of stress and contains 4-items of global self-appraised stress. Concurrent and predictive validities and internal and test-retest reliabilities of the scale have been established. The measure displayed good internal consistency in the present study (Cronbach's $\alpha = 0.80$).

Mental Wellbeing was measured with the 14-item Warwick-Edinburgh Mental Well-being Scale (WEMWBS; Tennant et al., 2007) of positive mental health. The WEMWBS has been shown to have good construct validity and correlates well with other measures of mental health. In this study, the measure displayed high internal reliability (Cronbach's $\alpha = 0.90$).

2.2.3. Pre-motivational and motivational phase risk factors

Defeat was measured using the Defeat Scale (Gilbert & Allan, 1998) a 16-item self-report measure of perceived failed struggle/loss of rank. This scale was found to have good psychometric properties and significantly correlated with depression (Griffiths, Wood, Maltby, Taylor, & Tai, 2014). In the present study, the measure displayed high reliability (Cronbach's $\alpha = 0.96$).

Entrapment is measured by the Entrapment Scale (Gilbert & Allan, 1998), a 16-item measure of the sense of being unable to escape the feelings of defeat and rejection. This measure consists of two subscales: the 10-item *external entrapment* subscale (entrapment by external situations), and the 6-item *internal entrapment* subscale (entrapment by one's own thoughts and feelings) that were utilised in this study. Both have been found to have good psychometric properties (Forkmann, Teismann, Stenzel, Glaesmer, & de Beurs, 2018) and have high internal consistency in the present study (external entrapment Cronbach's $\alpha = 0.94$, internal entrapment Cronbach's $\alpha = 0.95$).

Social support was assessed using the 7-item ENRICHD Social Support Instrument (Mitchell et al., 2003), tapping four defining attributes of social support: emotional, instrumental, informational, and appraisal, and has been found to be a valid and reliable measure of social support. The scale displayed good internal reliability (Cronbach's $\alpha = 0.87$).

Social perfectionism (or socially prescribed perfectionism) was measured with the Socially Prescribed Perfectionism subscale (Hewitt & Flett, 1991) of the Multidimensional Perfectionism Scale, assessing the degree of belief that others hold unrealistically high expectations of one's behaviour. Studies show that this dimension can be assessed in a reliable and valid manner. In the present study the measure displayed good reliability (Cronbach's $\alpha = 0.83$).

Perceived burdensomeness and thwarted belongingness were both assessed using the 12-item Interpersonal Needs Questionnaire (Van Orden, Cukrowicz, Witte, & Joiner, 2012). The INQ includes 7-items to tap burdensomeness (feeling a burden to others) and 5-items to assess belongingness (feeling connected to others), and the scale is internally consistent and has demonstrated construct validity. Both scales showed good internal reliability (Perceived burdensomeness Cronbach's

α = 0.87, thwarted belongingness Cronbach's α = 0.84).

Goal Reengagement and Disengagement were assessed via the 10-item goal adjustment scale (Wrosch, Scheier, Miller, Schulz, & Carver, 2003), consisting of a 4-item goal disengagement (difficulty in reducing effort toward unobtainable goals) subscale and a 6-item goal reengagement (ability to reengage in other new goals) subscale. Both subscales have good validity, and in the present study they have shown adequate to good internal consistency (goal disengagement Cronbach's α = 0.70, goal reengagement Cronbach's α = 0.87).

Optimism was measured using the Life Orientation Test (Scheier, Carver, & Bridges, 1994) which assesses individual differences in optimism/pessimism. The measure consists of 10 items, with four filler items not included in the total score. It has been shown to possess adequate predictive and discriminant validity, and displayed adequate internal consistency in the present study (Cronbach's α = 0.79).

Resilience was measured using the 10-item Brief Resilience Scale (Campbell-Sills & Stein, 2007) adapted from the 25-item Connor-Davidson Resilience Scale (Connor & Davidson, 2003). This 10-item version has good psychometric properties and is highly correlated with the original 25-item version and in the present study it displayed excellent internal consistency (Cronbach's α = 0.90).

2.2.4. Volitional phase risk factors

Acquired capability was measured by the Acquired Capability for Suicide Scale (Van Orden, Witte, Gordon, Bender, & Joiner, 2008), a 5-item measure designed to assess one's fearlessness about lethal self-injury and physical pain sensitivity. The scale has demonstrated convergent and discriminant validity, and in this study the ACSS had an internal consistency of 0.63 (Cronbach's α).

Impulsivity was assessed via the Barratt Impulsiveness Scale Version 11 (Patton, Stanford, & Barratt, 1995), a 30 item self-report questionnaire designed to assess general impulsiveness taking into account the multi-factorial nature of the construct. The BIS is a commonly used scale that has been shown to correlate with behavioural measures of impulsivity and it displayed good internal consistency in the present study (Cronbach's α = 0.83).

Exposure to suicide and self-harm was assessed using 5 items to establish whether participants had friends or family who have self-harmed, attempted suicide or died by suicide (e.g., "Has anyone among your family attempted suicide?"). These items have been used in previous research (O'Connor, Rasmussen, & Hawton, 2012) and have been shown to differentiate those who think about suicide and those who make a suicide attempt (Dhingra, Boduszek, & O'Connor, 2015). Items were dichotomised into no and yes if someone scored positive on any of the 5 items.

Mental imagery was assessed using eight items to establish the frequency with which participants imagine death related imagery, including engaging in self-harm or suicidal behaviour (e.g., "images of yourself planning/preparing to harm yourself or make a suicide attempt"), when they felt down or distressed. Greater presence of suicide-related imagery has been associated with higher levels of suicidal ideation previously (Holmes, Crane, Fennell, & Williams, 2007). The items scale well, with good internal reliability (Cronbach's α = 0.84). As many of the distributions of the continuous scales were non-normal, we applied a nonparanormal transformation to all continuous scales to relax the normality assumption (Zhao, Liu, Roeder, Lafferty, & Wasserman, 2012).

2.3. Conceptual summary of the analysis

2.3.1. Networks of the IPT and the IMV models

First, we estimated a network that consisted only of the core components of the IPT model; perceived burdensomeness and thwarted belongingness, along with current suicide ideation. Next, we estimated a network that included only the core components of the IMV model; internal and external entrapment and defeat. Finally, in network three, we combined the core components of both theories. For each network, we calculated the total amount of variance in suicide ideation explained by all other factors. Additionally, the relative contribution of each separate factor to the explained variance in current suicide ideation was examined.

2.3.2. Network of psychological factors and suicide ideation

A final network, network four, was estimated using all psychological factors assessed within the Scottish Wellbeing Study. As described above, we included several motivational and volitional factors. Note that in the IMV model, all IPT variables (perceived burdensomeness, thwarted belongingness, but also acquired capability) were included. Past suicide ideation and past suicide attempts were added as background risk factors. Although mental wellbeing, stress and depressive symptoms are not components of the IMV, we included them in the network, as they are recognised correlates of suicide ideation (O'Connor & Nock, 2014). Sensitivity analyses without these three factors were also conducted, and the resulting differences in network structure are reported in the online technical appendix. We were specifically interested to learn which factors have a unique relationship with current suicide ideation, after controlling for all other variables and how the different factors interact and clustered among themselves.

2.4. Statistical analysis

2.4.1. Mixed graphical models

In recent years, Gaussian Graphical Models (GGM) have emerged as the state-of-the-art network estimation technique for ordinal or continuous variables in between-subjects data (Epskamp & Fried, 2018), whereas Ising models have been used to estimate networks in binary data (van Borkulo et al., 2014). As our data contained both continuous and binary data, we used mixed graphical models that deal with mixed data (Haslbeck & Waldorp, 2015), implemented in the R package MGM to estimate pair wise interaction. The nodes of the network represented the sum scores of the separate scales. To avoid estimating spurious relations among variables, we needed some form of control that accounts for these false associations; to this end, we used an L1-penalized regression (Epskamp & Fried, 2018). The penalty parameter was selected using cross validation. This indicates that weak, non-informative edges are shrunken to zero, resulting in a matrix with regularized coefficients that represent conditional dependence relations. The matrix can be used to inspect which risk factors have a direct association with our outcome of interest, current suicide ideation, after partialling out all other factors (Costantini et al., 2015; De Beurs et al., 2017). The matrix was visualized using the qgraph package (Epskamp, Cramer, Waldrop, Schmittmann, & Borsboom, 2012). To visualize potentially high-dimensional data in a two-dimensional graph, we used the Fruchterman-Reingold (FR) algorithm. This algorithm aims to place nodes that are not central (i.e. have little connection to other nodes) at the periphery of the network, whereas central, highly connected nodes are placed towards the centre. FR is the most frequently used placing algorithm within network analysis, although alternatives exist (Jones, Mair, & McNally, 2018).

2.4.2. Estimating predictability

In addition to the structure of the network, we estimated the network's *predictability*; a metric that quantifies how much variance of each node is explained by all of its neighbours. For the continuous variables, the proportion of explained variance is presented graphically. For binary variables, the proportion of explained variance was visualized using the normalized accuracy measure (Haslbeck & Fried, 2017). Different from the explained variance of continuous variables, the normalized accuracy measure quantifies how a node is determined by its neighbouring nodes *beyond* the intercept model. A detailed explanation of both the explained variance and normalized accuracy can be found elsewhere (Haslbeck & Waldorp, 2018). Both metrics range

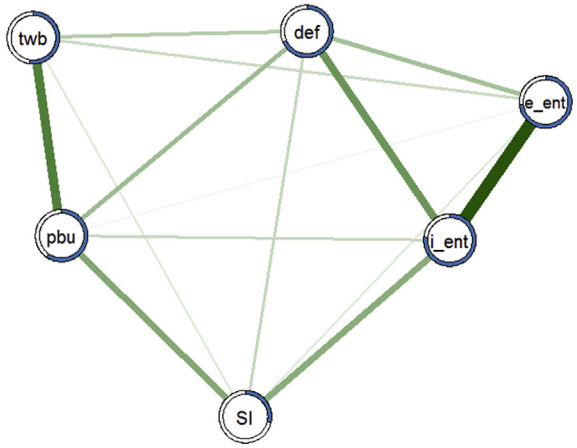

Fig. 3. Network of core components of both the IPT and the IMV and their association with current suicide ideation. SI: current suicide ideation, i_ent: internal entrapment, e_ent: external entrapment, pbu: perceived burdensomeness, twb; thwarted belongingess, def; defeat. Green connections represent positive associations, thicker edges represent stronger associations. The blue colouring of the white circle around each node represents the amount of variance explained in that node by its neighbours. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

from zero to one, a zero indicates that no variance in the risk factor is explained by any of the other factors, whereas a one means that all variance is explained.

2.4.3. Relative importance of risk factors

To determine the relative importance of each risk factor in a given network on current suicide ideation, we used the package relaimpo (Grömping, 2006). The relative importance of a factor refers to the quantification of a single factor's contribution within a multiple regression mode. By taking a hierarchical approach in which all orders of variables are used, the average independent contribution of a variable is obtained (i.e., the unique variance each of the predictors shares with the outcome). Bootstrapped confidence intervals for the difference between independent variables can be calculated to test whether one predictor explains significantly more variance in the outcome than the other predictors (Grömping, 2006). Relative importance was estimated for each of the models described above. Since our model violated distributional assumptions, we performed a sensitivity analysis by re-estimating the outcomes using the continuous score on the Beck Scale for Suicide ideation.

2.4.4. Clustering

To estimate the number of clusters within networks, several techniques have been developed. We use a commonly used technique that is implemented within the Igraph package: the spinglass algorithm (Csardi, 2010). The spinglass algorithm comes from statistical physics. Each node can be in one of c spin states. Edges among nodes determine which pairs of nodes are more likely to be in the same state, and which are more likely to be in different states. As the spinglass algorithm is not deterministic (i.e. repeating the procedure can lead to a different solution), we repeated the algorithm 1000 times and used the median outcome.

3. Results

3.1. Sample and participant characteristics

The demographics of the young people (n = 3508) interviewed reflect the Scottish census data collected in 2011 (see O'Connor et al., 2018b; Wetherall et al., 2018). Just over 50% of the respondents were female. Around 39% were aged 18–23, 36% aged 24–29, and 25% were 30–34 years. The majority of the sample was White (94%) and 81% of participants were not married. Nearly half were in full-time employment, 17% were in full-time education and 11.5% were unemployed. Half of the participants (49.8%) lived in rental accommodation, with the majority of the remainder either owning their own home (23.2%) or living with parents/relatives (23.1%). Variance inflation factors for all variables were acceptable (between 1.02 and 1.78), indicating no problems of (multi-)collinearity.

3.2. Network one: the association between core components of the IPT and suicide ideation

The first network consisted of the variables perceived burdensomeness, thwarted belongingness and suicide ideation; both risk factors were directly related to suicide ideation, and to each other. The predictability metric indicated that 16% of the variance of suicide ideation was explained by the two factors.

3.3. Network two: the association between core components of the IMV model and suicide ideation

Within a network of the core components of the IMV model, defeat, internal and external entrapment were directly related to suicide ideation. According to predictability metric, the core components explained 23% of the variance in suicide ideation.

3.4. Network three: combining core components of the IPT and the IMV model

Fig. 3 shows the network of core IPT and core IMV model components. Internal entrapment and perceived burdensomeness were most strongly related to suicide ideation. Defeat, external entrapment and thwarted belonginess had the strongest relation with other factors but only a weak relation with suicide ideation (identifying them as potentially important *indirect* risk factors). The predictability metric indicated that the explained variance of suicide ideation was 26%.

3.5. Relative importance of risk factors in network three

Fig. 4 shows the order of relative importance of the variables included in network three (Fig. 3). Internal entrapment stood out with the largest significant relative contribution (relative contribution: 7.6%, 95% CI 6.4–8.8). Thwarted belongingness explained significantly the least variance in the suicidal ideation variance (relative contribution: 3.3% 95% CI 2.7–4.1), while perceived burdensomeness (relative contribution: 5.7%, 95% CI 4.8–6.78), external entrapment (relative contribution: 5.3%, 95% CI 4.5–6.4) and defeat (relative contribution: 4.9, 95% CI 4.1–5.9) had statistically equal contributions.

3.6. Network four: association between psychological risk factors contained within the IMV model and suicide ideation

Fig. 5 shows the network of 17 factors contained within the IMV model (including IPT factors), in addition to depressive symptoms, stress, mental wellbeing and current suicide ideation.

Of the 20 psychological factors, 12 were directly related to current suicide ideation; whereas mental wellbeing, (lack of) social support, goal disengagement, stress, perfectionism, defeat, external entrapment and history of a suicide attempt were not directly related. There was considerable inter-relationship between the factors, none of the factors was isolated.

As in network 3, defeat and thwarted belonginess were not (strongly) directly related to suicide ideation. The spinglass algorithm resulted in four clusters. The first contained the core risk factors of the

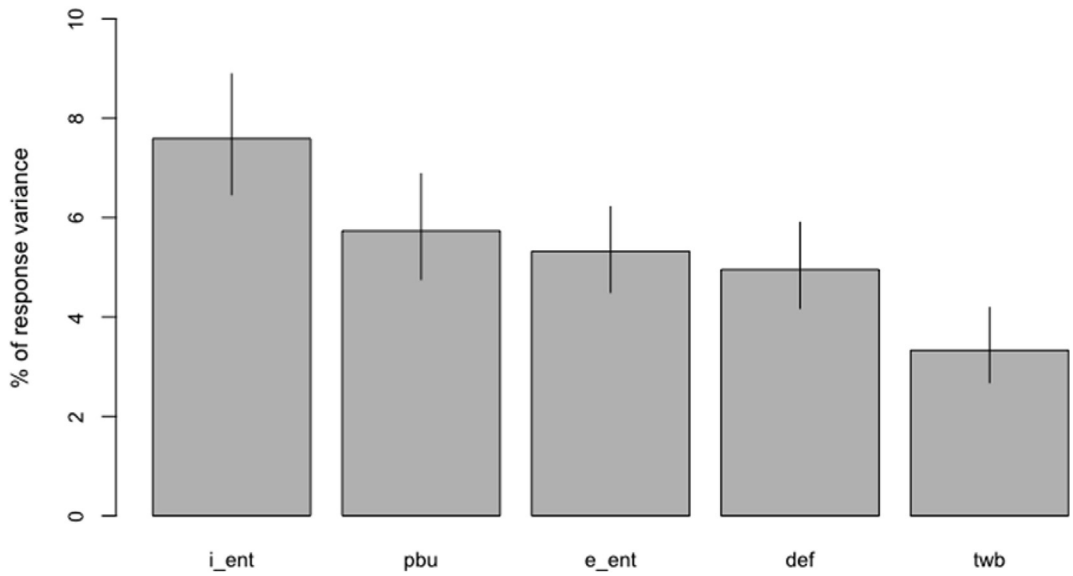

Fig. 4. Relative importance of the core components of the IPT and the IMV model for current suicide ideation. i_ent: internal entrapment, pbu; perceived burdensomeness, e_ent; external entrapment, def;defeat, twb; thwarted belongingness.

IMV model, entrapment and defeat, next to depressive symptoms, mental wellbeing and stress. We labeled this cluster the 'emotional wellbeing cluster'. A second cluster contained all of the IPT items, together with social support and perfectionism, which we labeled the 'interpersonal cluster'. Cluster three involved relatively stable personality-type constructs including items related to future perspective, impulsivity and resilience (the 'personality cluster'). Finally, cluster four consisted of the target variable of interest (i.e., current suicide ideation), and the four suicide-related factors: history of suicide attempt, history of suicide ideation, mental imagery about death and exposure to suicidal behaviour, labeled the 'suicidal cluster'. Since depressive symptoms, stress and mental wellbeing are not explicitly part of the IMV model, we re-ran the models excluding them. Results were similar, except that acquired capability was now part of the personality cluster.

Also, as the BDI has an item on suicide ideation we did a sensitivity analysis including the BDI sum score without the suicide item, and found no noteworthy differences in network structure or metrics. We report on this analysis in a supplementary file added to the submission.

3.7. Relative importance of risk factors in network four

A history of suicide ideation accounted for 17% of the variance in current suicide ideation in a univariate analysis. Core theoretical factors such as internal entrapment accounted for 20% of the variance in suicide ideation in a univariate analysis. Including all 20 theoretical factors in a multivariate model explained 34% of the variance in suicide ideation. Relative importance analysis found that history of suicide ideation, internal entrapment and perceived burdensomeness all had statistically equal contributions (Fig. 6).

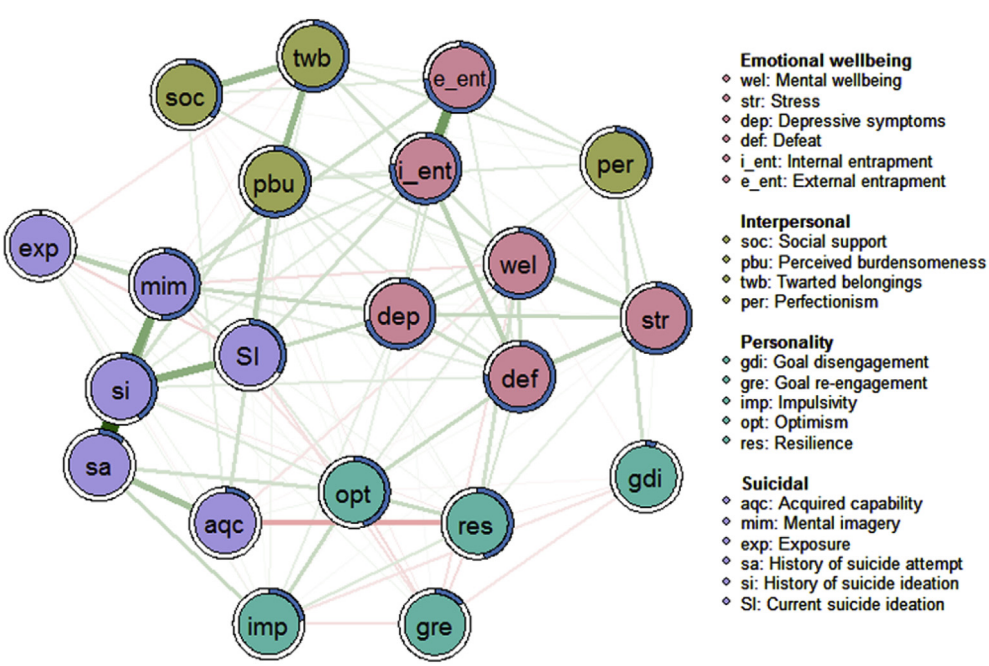

Fig. 5. Network of different psychological factors and current suicide ideation. The variables are re-coded so that green lines represent the expected relationship (positive for risk factors, negative for protective factors), and red indicates unexpected relationships. Thicker edges represent stronger associations. The colouring of the white circle around each node represents the amount of variance explained in that node by its neighbours. The colors of the nodes represent the clusters identified via the spinglass algorithm. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

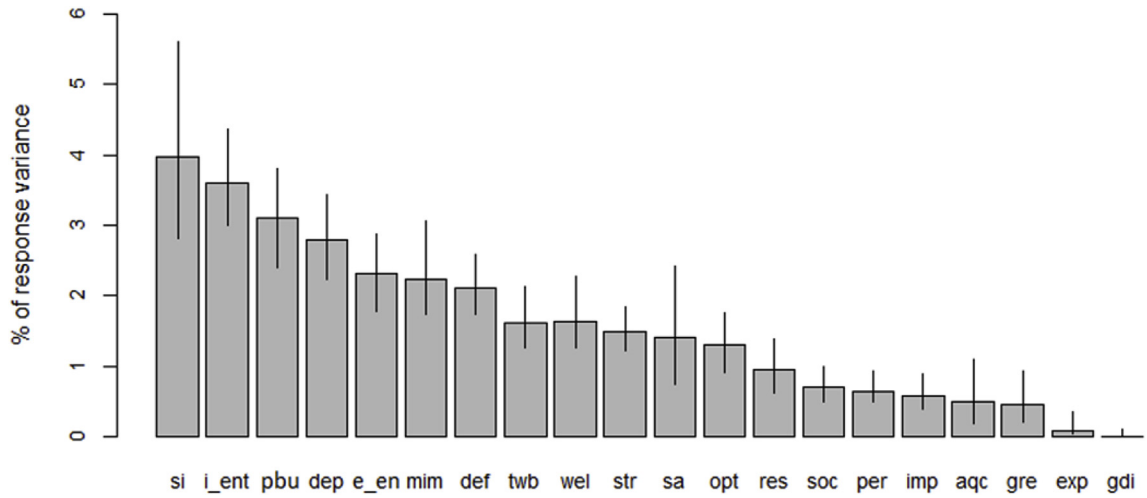

Fig. 6. Relative importance of psychological factors for current suicide ideation. si; history of suicide ideation, i_ent; internal entrapment, pbu; perceived burdensomeness, dep; depressive symptoms, e_ent; external entrapment, mim; mental imagery, def: defeat, twb; thwarted belongingness, wel; mental wellbeing, str; stress, sa; history of suicide attempt, opt; optimism, res; resilience, soc; social support, per; perfectionism, imp; impulsivity, aqc; acquired capability; gre; goal reengagement, exp; exposure, gdi; goal disengagement.

4. Discussion

4.1. Network of core components

In this study, we set out to better understand how key psychological factors as determined by two leading theories in suicidology, the interpersonal psychological theory (IPT), and the integrated motivational-volitional (IMV) model, interact among each other, and how they relate to suicide ideation. Within the IPT, suicide ideation is hypothesized to be related to high levels of perceived burdensomeness and thwarted belongingness (Van Orden et al., 2010), whereas the IMV model proposes that entrapment is central in the development of suicide ideation (O'Connor, 2011; O'Connor & Kirtley, 2018).

Network analysis of the core compoments of the two models indicate that both perceived burdensomeness and internal entrapment are important factors that are directly related to suicide ideation. Thwarted belonginess and defeat were less strongly related to suicide ideation, and more to perceived burdensomness and internal entrapment.

4.2. Wide range of psychological factors

When estimating a network of 20 different psychological factors and suicide ideation (network four), most factors seem to be directly related to suicide ideation, even after controlling for all other factors. The core components defeat and thwarted belonginess had mainly an indirect effect on suicide ideation. Furthermore, all psychological factors were related to other pychological factors, even when controlling for all other nodes in the network, none of the factors was isolated. This supports the presumption that suicide ideation is the result of the interplay of many different factors, of which some have a direct relationship with suicide ideation and others an indirect relationship (Klonsky et al., 2016; O'Connor & Kirtley, 2018; O'Connor & Nock, 2014). Internal entrapment, perceived burdensomeness, history of suicide ideation and depressive symptoms were the most important statistical predictors of current suicide ideation. The recursive character of suicide ideation has been shown in other studies (Hallensleben et al., 2018; Kleiman et al., 2017). The effect of mood on suicide ideation is in line with the differential activation hypothesis and has also been demonstrated in numerous previous studies (Cha et al., 2018; Lau, Segal, & Williams, 2004; Williams, Barnhofer, Crane, & Beck, 2005). Within the network, four clusters were identified. Entrapment, defeat, depressive symptoms, mental wellbeing and stress formed one cluster that was labeled as the 'emotional wellbeing cluster'. The factors that tapped into social interaction with others (perceived burdensomeness, thwarted belongingness, social support, social perfectionism) also seem to cluster, labeled the 'interpersonal cluster'. The 'personality cluster' was related to more stable personality traits, such as optimism, impulsivity and resilience. Finally, the 'suicidal cluster' included suicide ideation, as well as a history of or exposure to suicidal behaviour, and many of the key volitional factors such as mental imagery about death and acquired capability. Although exploratory, these four clusters provide an innovative framework for the understanding of the risk factors for suicide ideation and how they group together.

All of the more action-related, volitional phase risk factors except for history of an attempt were directly related to current suicide ideation, indicating that volitional phase factors play an important role not only in the emergence of actual suicidal behaviour but also in the presence of suicide ideation. However, this is unsurprising and is likely to be driven by the fact that some of those who reported suicidal ideation have also attempted suicide, that suicide ideation usually precedes a suicide attempt and that some people cycle between suicidal thoughts and suicidal behaviour. This is consistent with epidemiological research that found similar predictors for suicide ideation and suicide attempts, suggesting that, despite the fact that specific factors govern the transition between suicidal thoughts to attempts, suicidality (thoughts and behaviours) may be ordered on a continuum with shared risk factors (Ten Have, Van Dorsselaer, & De Graaf, 2013). Currently, ecological momentary data using mobile phones are being collected which will allow us to determine the temporal order of motivational and volitional phase risk factors (Nuij et al., 2017). Mental imagery was one of the volitional phase risk factors directly related to suicide ideation. Research attention has only recently focused on mental imagery as a potential risk factor for suicide ideation (Crane, Shah, Barnhofer, & Holmes, 2012; Ng, Di Simplicio, McManus, Kennerley, & Holmes, 2016; Van Bentum et al., 2017). Optimism, resilience and goal re-engagement were also directly but inversely related to suicide ideation. Protective factors are poorly researched in suicide prevention and have not received sufficient theoretical attention, but they may point to exciting new possibilities for suicide prevention (Franklin et al., 2016; O'Connor & Nock, 2014; O'Connor & Portzky, 2018a).

4.3. Implications for the IPT and IMV model

What do our findings mean for the IPT or the IMV model? In sum,

we found that a core component of each theory (IPT: perceived burdensomeness; IMV: internal entrapment) was indeed strongly related to suicide ideation. The association between the other core component of each theory (IPT: thwarted belonginess; IMV: defeat, external entrapment) and suicide ideation requires further investigation; strong *direct* relations between these second core components and suicide ideation were not supported by this study.

We aimed to use the network model as a tool to show how the different factors relate to each other. We included factors that reflect previous thought or behaviour (such as history of suicide ideation) because we wanted to control for these factors, and because we were interested in the relations between these factors and other factors. In a GGM, an edge between two nodes can occur for several reasons. The most common scenarios are a true causal relation (entrapment ↔ suicide ideation) or an unmeasured third node (entrapment ← cognitive reactivity → suicide ideation). Likewise, the absence of an edge has several interpretations, the two most common being the absence of a true causal effect, or insufficient power to pick up a small causal effect. This means that the fact that some core elements of both theories (IPT: thwarted belonginess; IMV: defeat, external entrapment) are strongly related to other variables—but not to suicide ideation—tells us that these nodes are potentially moderators or mediators of suicide ideation.

Ten risk factors beyond the core components such as depressive symptoms and mental imagery were found to have a direct effect on suicide ideation. What role do these factors play in the development of suicide ideation, and how should they be added to the current models to better understand suicide ideation? Or how should we take into account that a risk factors such as lack of social support that is theorized to be a motivational moderator with a link to suicide ideation via entrapment was mainly related to other motivational moderators such as twarted belonginess? Before making any suggestions to adjust the theories, it is important to recognise, that we have only presented one analysis from a single dataset from a specific target group: a large population-based sample of young Scottish adults (n = 3457). Relations between risk factors and suicide ideation might look different in other samples, such as chronically depressed inpatients. It is also important to note that this is a heterogeneous sample comprising individuals with a wide range of suicidal histories, including those who had made repeated suicide attempts. It also captures respondents who were suicidal once many years ago, therefore adding considerable statistical noise. Second, and more fundamentally, like other domains of human behaviour, given its complexity, it is unlikely that one single parsimonious theory would describe all variance in suicide ideation. Even eminent theorists within suicidology, such as Shneidman or Baumeister, who proposed influential theories for suicidal behaviour, stated that it would be naive to think a single theory would explain all suicides (Gunn & Lester, 2014). Theories advance our knowledge about the factors that lead to suicidal ideation and behaviour, and therefore are the foundation of our current understanding of suicidal behaviour. Psychological theories are needed to understand the processes that underpin the emergence of suicide ideation and the transition from thoughts to suicide attempts (Gunn & Lester, 2014; O'Connor & Nock, 2014). They will inform the development of psychosocial interventions to address suicide ideation when it first emerges, as well as mitigating the risk of a suicide attempt. The IPT stresses the importance of interpersonal needs, which has resulted in a much better understanding of the role of the relationship with others and suicidal behaviour (Van Orden et al., 2010). The IMV model has added other psychological processes to the equation, fueling research into the effect of feelings of humiliation, defeat and entrapment on suicidal ideation and behaviour (O'Connor, 2011; O'Connor & Kirtley, 2018). Our analysis suggests that even more risk factors may be directly related to suicide ideation which, if replicated, may lead to a refinement of both theories, provide more nuance in our understanding or to the emergence of a novel theory. For example, from the clustering of risk factors in this study one might argue for a model focusing on four larger latent constructs: emotional wellbeing, interpersonal needs, personality and specific suicide related risk factors.

For this study, we examined two important theories for which we had the appropriate data. There are, however, other theories in suicidogy (Gunn & Lester, 2014; O'Connor & Nock, 2014). As we will provide the code for our analysis online, our network analysis can easily be applied to other datasets that contain information needed to test competing models.

4.4. Limitations

We used cross-sectional data to estimate undirected networks. Therefore, we do not know the direction of the identified relationships between any two nodes. Based on the IMV model, we posit that entrapment directly influences suicide ideation, however, it is possible that the reverse relationship may also be true; indeed this is likely given the cyclical nature of suicidal thinking and behaviour (O'Connor & Kirtley, 2018). Future work should explore whether it is feasible to estimate directed networks within cross-sectional data (Maathuis, Colombo, Kalisch, & Bühlmann, 2010; Pearl, 2000), allowing us to better understand actual causal relations between psychological factors and suicidal behaviour.

Networks offer insights in the pairwise association between variables. Due to computational challenges, adding interaction terms between three variables in which at least one is continuous is not yet possible within the available software packages. This limitation is noteworthy as interactions play an important role in both theories. However, in many studies, moderation effects are often much smaller then pairwise effects (Chu et al., 2017; Haslbeck, Borsboom, & Waldorp, 2018). Another limitation is the use of the spinglass algorithm. Although it is well established within network science, it can be regarded as somewhat simplistic as nodes can only be part of one community, whereas it might be better to allow nodes to be part of multiple communities (e.g. Gaiteri et al., 2015). It is beyond the scope of this article to describe and compare different clustering techniques so we refer the interested reader to the online chapter of Barabási (http://barabasi.com/networksciencebook/chapter/9).

Furthermore, the risk factors are measured on different time scales. For example, the suicide items refer to how one was feeling in the past week but the depression questions relate to the past two weeks. The personality statements on the other hand do not have any time frame, as they refer to traits, and not states. Personality tends to be more stable over time, whereas we know from mobile phone studies that suicide ideation fluctuates heavily over time (Hallensleben et al., 2018; Kleiman et al., 2017). This is likely to impact upon the role of a node in the network. For example, nodes that represent a trait are less easy to target via an intervention, as they tend to be stable over time. Future studies should investigate the impact on network structure of the difference in time scales of items or questionnaires.

Another important issue relates to topological overlap. Do the different scales really represent different constructs? For example, we found that the components of the IPT alone explained 16% of the variance, and the components of the IMV accounted for 23%, but adding the IPT components to the IMV network only resulted in an increase of variance of 3%. When adding the 15 sum scores outside both theories, variance increases only by 9%. This indicates that at least some scales overlap, as was also indicated by the results of the clustering. Entrapment, defeat, stress and depressive feelings all seem to tap into an underlying construct as do the other risk factors. One might argue that risk factors within a cluster are interchangeable at least to some degree. Relatedly, it is also possible that important nodes are missing, resulting in spurious correlations between the included nodes. Importantly, when including all available variables, the explained variance was still only 34%. Although this is quite high given the complexity and individual differences in suicidal patients, it also means that 66% of the variance must be explained by other, non-assessed variables. This is consistent with the earlier statement that suicidal

behaviour is the end result of the complex interplay of biology, psychology, environment and culture (Klonsky et al., 2016; O'Connor & Kirtley, 2018; O'Connor & Nock, 2014). In this study, we only included psychological variables. Indeed, a recent article argues for the use of multilayer networks to understand psychopathology, including environmental, genetic, metabolic and psychological information (Guloksuz, Pries, & Van Os, 2017). Also, as highlighted elsewhere, given that suicidal ideation and other core constructs of the existing models (e.g., entrapment) wax and wane, repeated assessment of the core variables over time is important to enhance prediction as is the specificity of the timeframes.

In this study, we were interested in relationships among broader psychological constructs, not relationships among individual items. We therefore modeled scale sum scores as nodes, even though it has been argued that the summing of items into scales (e.g. summing different depression symptoms into one overall depression score) can obfuscate more fine-grained details (Fried & Nesse, 2015). Both approaches have been used widely (Briganti, Fried, & Linkowski, 2019; De Beurs et al., 2017; Fonseca-Pedrero et al., 2018; Forkmann et al., 2018), however we do not think that one approach is superior to the other in principle, it would depend on the research question. The main challenges of a more fine-grained approach are the estimation of too many parameters, which is a threat to both power and interpretability of the network structure, as well as including the same node several times (e.g. sad mood may be assessed multiple times in a depression scale, and several more times in other scales in a study; Fried & Cramer, 2017). The main challenge for the broader approach is that the researchers might miss differential relationships of items between constructs (if construct X relates to construct Y, this does not mean all items of construct X relate to all items of construct Y, which might provide highly important information in some contexts).

Currently, follow-up data within the Scottish wellbeing study are being collected. This will allow us to test whether the baseline network structure of psychological factors is related to future suicidal behaviour. Similar to van Borkulo and colleagues' study of depression (van Borkulo et al., 2015), one could hypothesize that a denser network at baseline is predictive of future suicidal behaviour. In other words, the more strongly that different psychological factors are related, the more likely a (small) change in one symptom (say increase in stress) will affect other symptoms (e.g. entrapment, perceived burdensomeness and suicide ideation). This domino effect might increase the likelihood of future suicidal behaviour at follow-up (see also Cramer et al., 2016).

To conclude, this study demonstrated the application of network analysis to better understand the wide range of psychological processes associated with suicide ideation in a large representative sample of young adults. We hope that this study inspires other researchers to use modern statistical algorithms to better account for the complexity of suicidality and to test theoretically-guided hypotheses.

4.5. Contributors

The idea for the article was conceived by DdB. KW, SC, DoC, EF, RO, and RoC collected the data and prepared the data for the current analysis. DdB and EF did the analysis. DdB, RoC and EF interpreted the analysis and wrote the initial draft. All authors contributed to the writing of the manuscript and all authors agree with the final version.

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Competing interests

The authors have no competing interests to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2019.103419.

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