A longitudinal network analysis of suicide risk factors among service members and veterans sampled for suicidal ideation or attempt

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Abstract

Background. Suicidal thoughts and behaviors are elevated among active-duty service members (ADSM) and veterans compared to the general population. Hence, it is a priority to examine maintenance factors underlying suicidal ideation among ADSM and veterans to develop effective, targeted interventions. In particular, interpersonal risk factors, hopelessness, and overarousal have been robustly connected to suicidal ideation and intent.
Methods. To identify the suicidal ideation risk factors that are most relevant, we employed network analysis to examine between-subjects (cross-sectional), contemporaneous (within seconds), and temporal (across four hours) group-level networks of suicidal ideation and related risk factors in a sample of ADSM and veterans (*participant* $n = 92$, observations $n = 10\,650$). Participants completed ecological momentary assessment (EMA) surveys four times a day for 30 days, where they answered questions related to suicidal ideation, interpersonal risk factors, hopelessness, and overarousal.
Results. The between-subjects and contemporaneous networks identified agitation, not feeling close to others, and ineffectiveness as the most central symptoms. The temporal network revealed that feeling ineffective was most likely to influence other symptoms in the network over time.
Conclusion. Our findings suggest that ineffectiveness, low belongingness, and agitation are important drivers of moment-to-moment and longitudinal relations between risk factors for suicidal ideation in ADSM and veterans. Targeting these symptoms may disrupt suicidal ideation.

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Despite calls to action to better prevent suicide (e.g. The 2021 Brandon Act; Department of Veterans Affairs, 2019), suicide rates have gradually increased since 2011 among active duty service members (ADSM) and veterans. In particular, active duty army suicide rates (36.3/100 000) were higher than other active duty military services (Marine Corp 23.9/100 000; Navy 16.7/10 000; Air Force 15.3/100 000; Department of Defense, 2022), and higher than age and sex adjusted rates in the general population (14.0/100 000; Garnett, Curtin, & Stone, 2022). Suicide rates are elevated in veterans as well (31.7/100 000; Department of Veterans Affairs, 2022) as compared to ADSM and civilians. Thus, identification of what maintains suicidal ideation among ADSM and veterans is imperative, as this understanding can help build more targeted interventions for suicidal ideation.

Several statistical, theoretical, and methodological advances are helping clinical scientists rethink the way suicidal ideation is studied, within and outside the military. First, meta-analytic findings highlight that suicidal ideation prediction is improved when risk processes are measured over short time windows (i.e. hours, days, or weeks; Franklin et al., 2017), suggesting the need for intensive longitudinal data collection. A second advance relates to a shift in how psychopathology overall is conceptualized. Psychiatric disorders have long been conceptualized through the medical model framework, where a latent disease entity is thought to cause all mental disorder symptoms. However, the network theory of psychopathology (Borsboom & Cramer, 2013) proposes that there is no underlying disease entity that causes all mental disorder symptoms. Instead, it proposes that psychiatric symptoms interact with one another, and it is these symptom interactions that cause and constitute psychopathology. Informed by these advances, the current study used intensively collected longitudinal data and network analysis to identify suicide risk factor symptoms that are most central within an at-risk military sample (i.e. ADSM and veterans with current suicidal ideation or a previous suicide attempt).

Given the need to study multiple risk factors for suicidal ideation simultaneously, while also realizing the impracticality of studying all possible risk factors, this study focused on interpersonal risk factors, hopelessness, and overarousal for several reasons. First, according to the interpersonal psychological theory of suicide, suicidal ideation occurs in the context of two interpersonal factors: perceived burdensomeness and low belongingness, as well as hopelessness about these states changing (Joiner, 2005; Van Orden et al., 2010). In support of this, burdensomeness, low belonging (e.g. Chu et al., 2017; Van Orden et al., 2010), and hopelessness (Qiu, Klonsky, & Klein, 2017; Riera-Serra et al., 2023) are robust precursors of suicidal ideation. Second, overarousal not only precipitates suicidal ideation (e.g. Busch, Fawcett, & Jacobs, 2003; Ribeiro, Silva, & Joiner, 2014; Robins, 1981) but it also facilitates engagement in suicidal behavior (Ribeiro et al., 2015). Taken together, evidence suggests that suicidal ideation emerges from combinations of interpersonal risk factors, hopelessness, and overarousal, yet to date, no research has investigated these constructs in a dynamic fashion.

To identify the symptoms that most strongly maintain suicidal ideation we employed network theory and analysis. Network theory proposes that within a symptom network, central symptoms cause the emergence or maintenance of other symptoms in the network. Network theory's associated methodology, network analysis, identifies central symptoms, which have the greatest impact on the other symptoms (referred to as the 'symptom network'). Because symptoms are interconnected, reductions in the most central symptom(s) can influence treatment outcomes (e.g. Elliott, Jones, & Schmidt, 2020; Olatunji, Levinson, & Calebs, 2018). Empirically identifying the most central symptoms and tailoring treatments accordingly is the epitome of evidence-based practice and personalized medicine (e.g. Fernandez, Fisher, & Chi, 2017; Levinson, Cusack, Brown, & Smith, 2022). Additionally, identification of central symptoms can aid clinicians in identifying the most effective treatments for suicidal ideation in general.

In most suicide network research to date, central symptoms have been identified using cross-sectional data. For instance, in the first suicide-specific network analysis, De Beurs, van Borkulo, and O'Connor (2017) modeled the cross-sectional, between-subjects symptom structure of suicidal ideation, as assessed by the Beck Scale for Suicide Ideation (BSS; Beck, Kovacs, and Weissman, 1979), among 367 patients who were admitted to a hospital after a suicide attempt. Desiring to make a suicide attempt had the greatest centrality, meaning that it had the highest importance in the network. In a follow-up study, De Beurs et al. (2019) found that perceived burdensomeness and internal entrapment contributed most strongly to suicidal ideation within a large sample of Scottish young adults ($N > 3500$). Thoughts of killing oneself and feeling inadequate were central nodes for suicide networks among clinical outpatients and individuals with an eating disorder (Smith et al., 2020). Perceived burdensomeness was identified again as most central in a network analysis of a veteran sample with a history of suicide attempts (Saulnier et al., 2023). Among a sample of 50 individuals who met criteria for muscle dysmorphia, Ortiz, Grunewald, Forrest, and Smith (2023) conducted a comorbidity analysis of muscle dysmorphia and suicidal ideation symptoms and found that the most central suicide-related factor was feelings of burdensomeness. Oakey-Frost et al. (2023) identified protective factors among undergraduates ($N > 550$) and found that meaning in life and hope had the highest centrality estimates.

Between-subjects, cross-sectional networks are helpful for generating hypotheses about central network symptoms and to identify the overall structure of a network at a group level but have been criticized because they cannot identify temporal processes. However, recent developments have allowed for the estimation of group-level contemporaneous and temporal symptom networks using data collected from ecological momentary assessment (EMA). These networks are able to determine whether one symptom influences another at the next time point (e.g. whether desiring a suicide attempt leads to hopelessness or vice versa) and model how symptoms interact with one another over time. The group-level temporal network indicates, on average, how symptoms at time t predict one another at time $t + 1$. To the best of our knowledge, only two studies have used EMA data to develop longitudinal networks of suicide symptoms that incorporate time into the model. In the first study of its kind, Rath et al. (2019) constructed temporal networks from EMA data collected from 74 in patients with major depression and suicidal ideation. They found that the only symptoms that predicted later suicidal ideation were suicidal ideation (autoregressive effect) and perceived burdensomeness. Ortiz et al. (2023) collected EMA data from 50 individuals with muscle dysmorphia over three weeks (average of 71 prompts completed/participant). In their models they included 10 symptoms of muscle dysmorphia and five items assessing suicidal ideation; they found that feeling disgusted predicted the most other symptoms in the network, including weighing oneself and dwelling on the past.

In addition to temporal symptom networks, EMA data allow for the modeling of contemporaneous networks. Contemporaneous networks describe how symptoms interact with one another within seconds when adjusting for (1) all other variables within that time period and (2) all variables at the previous time point (e.g. time $t - 1$). While contemporaneous networks do not identify the directionality of associations, they are meaningful because they identify symptom interactions that occur more quickly than the sampling interval. For example, if a sampling interval is four hours but feelings of anger lead to feelings of irritability within minutes, the relation between anger and irritability will not be captured with the four-hour lag and therefore will not be reflected in the temporal network. However, this relation would appear in the contemporaneous network. Estimating both temporal and contemporaneous networks will provide rich detail for how symptoms predict one another over time and interact with one another over a span of seconds.

The current study harnesses recent advances to shore several gaps that remain in our understanding of suicidal ideation within the military. First, the majority of network analytic studies to date have been cross-sectional, which does not allow for an understanding of how symptoms relate to one another over time. Second, the symptoms that have been included have varied, and have not included interpersonal risk factors, hopelessness, overarousal, and suicidal ideation in one model. Third, there are, to our knowledge, no studies employing longitudinal network analysis to understand suicidal ideation in ADSM and veterans, despite their elevated risk. Thus, the current study determined the central suicide risk symptoms in an at-risk ADSM and veteran sample and how these symptoms relate cross-sectionally, contemporaneously, and temporally. We predicted that symptoms related to active ideation and perceived burdensomeness would be the most central symptoms in the between-subjects network, as found in past work (e.g. De Beurs et al., 2017, 2019; Ortiz et al., 2023). Given that few studies have employed EMA data to construct longitudinal networks, we did not have specific predictions for these networks.

Method

Participants

Participant recruitment occurred between January 2020 and October 2022. Although the study initially intended to focus exclusively on ADSM receiving behavioral health services at Wright Patterson Medical Center (WPMC), the onset of the COVID-19 pandemic disrupted in-person data collection. This necessitated transitioning the study to be completed fully online, which then allowed us to recruit from the continental United States; we also allowed for the inclusion of Veterans meeting all other study inclusion criteria (see below). Study procedures were approved by WPMC's IRB, with the Human Research Protection Office (HRPO) at the US Army Medical Research and Development Command approving all procedures.

Inclusion criteria were as follows: (1) between the ages of 18 and 65, (2) English language fluency, (3) current or past month suicidal ideation and/or a suicide attempt within the past year, and (4) having served or serving in the military (including reservists and national guard). In total, 99 participants consented to participate and provided baseline data (mean age = 32.16 [S.D. = 8.60], 75.8% male, 81.8% white). The sample primarily consisted of participants who were in an active duty status (68.7%). The sample further identified as primarily active duty army (58.6%); the next most represented branch was air force (19.2%). Exclusion criteria included active psychosis or mania and/or serious suicidal intent requiring hospitalization or immediate treatment (i.e. reporting a current suicide plan or attempt within the past week). Sociodemographic information for the sample is presented in Table 1.

Procedure

Potential participants at WPMC were recruited by a study coordinator who advertised the study to behavioral health patients using flyers and announcement of the study in relevant behavioral health groups. Potential participants were also recruited online by a research participant recruitment firm (Trialfacts), as well as through social media advertisements. Potential participants first completed a screening questionnaire, which confirmed military history by asking questions likely to only be answered correctly by those with a military history (e.g. meaning of certain military acronyms) and inclusion/exclusion criteria. Participants who were eligible were then scheduled to complete an online study overview and consenting session which was conducted on HIPAA compliant Zoom. Military history and inclusion/exclusion criteria were confirmed at this online session (Military service was confirmed by first reminding participants it was illegal to impersonate a military member and then asking participants if they were in fact serving or had ever served).

Once participants were enrolled in the study, they were emailed a link to complete a battery of baseline questionnaires. They were then guided through downloading an app (Lifedata) used to collect the EMA data. Over the 30-day EMA period, participants received four semi-random pings each day to complete the EMA survey between the hours of 0700–2100. Assessments were set to occur on average once every 3–4 h. (On the day of enrolling in the study (Day 0), pings were prorated, based on the time of day participants enrolled. Thus, Day 0 of the EMA protocol includes varying numbers of pings across participants, whereas for Days 1–31 of the EMA protocol, all participants received four pings. This means that the maximum total number

Table 1. Sociodemographic characteristics of the current sample

Variable	Mean	s.d.
Age	32.16	8.60
Variable	Frequency	Percentage
Gender		
Male	75	75.8
Female	24	24.2
Race (select all that apply)		
Caucasian/White	81	81.8
Black/African American	12	12.1
Native American/Alaska Native	5	5.1
Asian	8	8.1
Pacific Islander	3	3.0
Other	6	6.1
Ethnicity		
Hispanic/Latino	11	11.2
Not Hispanic/Latino	88	88.8
Military Branch (select all that apply)		
Army – active duty	58	58.6
Army – reserve	6	6.1
National Guard	14	14.1
Air Force – active duty	19	19.2
Air Force – reserve	2	2.0
Air National Guard	4	4.0
Navy – active duty	13	13.1
Navy – reserve	2	2.0
Marine Corps – active duty	1	1.1
Marine Corps – reserve	0	0
Coast Guard – active duty	1	1.1
Coast Guard – reserve	1	1.1
Public health service	2	2.0
Service status		
Active duty	68	68.7
Veteran	31	31.3
Lifetime suicidal ideation		
Present	99	100
Absent	0	0
Lifetime suicide attempt		
Present	50	50.5
Absent	47	47.5
Missing	2	2.0

Note: Analytic sample of 99 participants.

of pings per participant could range from 121 (received one ping on Day 0) to 124 (received four pings on Day 0)). After completing the 30-day EMA protocol, participants were emailed a link to complete a battery of questionnaires at one- and three-month

follow-up. However, only EMA data were analyzed in the current study. Please see online Supplement for additional details regarding participant safety procedures over the course of the study.

Selected measures

Baseline measures

Demographics. We collected data on participant age, gender, race, ethnicity, suicidal ideation and behavior history, and military service history, see Table 1.

EMA assessment

The EMA protocol entailed completing short (i.e. two minutes or less) assessments on participants' mobile phones or internet-enabled devices, consisting of 40–43 items. EMA survey items assessed participants' experience over the preceding hours on a visual analog slider (VAS) ranging from 0 (*not at all*) to 100 (*very much,*) for the following items, which were adapted from established measures. A 0–100 VAS is preferential for inclusion in contemporaneous and temporal models. Only items assessing interpersonal risk factors, hopelessness, and overarousal were analyzed in the current study. EMA completion was high, with an average of 90.73 (74.43%) of pings completed per participant. See Table 2 for EMA items (Table 3).

Preliminary analyses

Two sets of preliminary analyses were performed. These sets of preliminary analyses refer to item reduction and sample reduction.

Item reduction

Group-level networks can reliably be estimated when networks include roughly eight items (i.e. symptoms; Epskamp, Waldorp, Mõttus, & Borsboom, 2018). However, as described above, the EMA protocol included 40–43 items. Therefore, we reduced the item set using five steps outlined in the Supplement (see also online Supplemental Tables S1 and S2). Ultimately, we had two items represent suicidal ideation (passive suicide ideation and active suicide ideation). Three items represented interpersonal risk factors (not feeling close to other people, feeling ashamed and disgusted with oneself and others, and feeling ineffective).

Table 2. Descriptive statistics for all network nodes

Variable	*M*	S.D.	% non-zero	% ⩾10/100
Active ideation	16.74	25.12	91.98	70.56
Passive ideation	27.70	19.40	83.45	51.26
Not close to others	64.02	22.04	99.79	99.19
Ineffective	59.21	21.84	99.91	99.35
Shame + disgust self others	39.87	23.45	96.6	89.01
Hopeless	34.66	25.16	95.76	84.14
Agitation	34.96	21.95	97.64	87.67
Sleep problems	46.32	25.24	98.42	90.61

Note. Agit, agitation; disgust_shame, shame + disgust with others; not_close, not close to others; ineffect, ineffective; sleep_prob, sleep problems; passive_si, passive suicidal ideation; active_si, active suicidal ideation; hopeless, hopeless.

One item represented hopelessness (hopeless). Two items assessed overarousal (agitation and sleep problems).

Sample reduction

$N = 97$ participants had any EMA data. However, $n = 3$ of these participants had fewer than 30 observations, which is the minimum recommended number of observations per participant and were removed. Once we arrived at the final 8 items to be included in our suicidality network, we inspected each item for each of the $n = 94$ participants to ensure sufficient variability in all items. Two participants were missing all observations on the item assessing sleep quality and distress. We took the conservative approach of excluding these individuals from analyses, due to concerns about imputing all observations for a given item. This brought the total sample size to $n = 92$ participants, $n = 10\,650$ observations (min observations per participant = 32, max observations per participant = 119).

Data analytic plan

Missing EMA data were imputed with a Kalman filter, which is an imputation method that accounts for time dependencies among observations.

Group-level networks

Multilevel vector autoregression models were estimated using the mlVAR R package (Epskamp et al., 2018; Epskamp, Deserno, & Bringmann, 2019). mlVAR has a two-step model estimation process. In the first step, a multilevel model is estimated for each variable in the network at time T. Level 1 predictors are participant-mean-centered lagged versions of all other network variables (time $T – 1$). Level 2 predictors are participant means (i.e. sample means for each participant) of all variables. This first step of the model estimation process yields group-level temporal and between-subjects networks. The temporal network reflects fixed effects and indicates how nodes at time $T – 1$ predict themselves and all other nodes at the next timepoint (T), after controlling for all other nodes at time $T – 1$, across participants. The between-subjects network is essentially a cross-sectional network of the participant-level means of all variables. The between-subjects network shows how, in general, constructs are associated with one another across people, without taking time into consideration.

In the second step of the model estimation process, multilevel models are again estimated for each variable in the network, but models are estimated using the residuals from the multilevel models in the first step of the estimation process. This second step of the model estimation process yields a group-level contemporaneous network, as well as returns subject-level networks and random effect sizes in addition to the group-level network. Contemporaneous networks also reflect fixed effects and indicate how nodes are co-occurring within the same sampling occasion, across people. mlVARs were estimated using correlated temporal and contemporaneous random effects.

Centrality for the temporal network was indicated by in expected influence and out expected influence. In expected influence indicates how much each symptom is being predicted by other symptoms over time. Out expected influence indicates how much each symptom is predicting other symptoms over time. In both cases, higher values indicate more prediction.

Centrality for the between-subjects and contemporaneous networks were indicated by expected influence. Contemporaneous

Table 3. Initial EMA item pool assessing study variables

Item	Adapted from
Suicidal intent	
I think about wanting to be dead	Self-Injurious Thoughts and Behaviors Inventory (SITBI; Nock, Holmberg, Photos, and Michel, 2007)
I think about not wanting to wake up	SITBI
I am having urges to hurt myself	SITBI
I have a desire to kill myself	Beck Scale for Suicidal Ideation (BSS; Beck et al., 1979)
Interpersonal risk factors	
I am close to other people [reverse-scored]	Interpersonal Needs Questionnaire (INQ; Van Orden, Cukrowicz, Witte, and Joiner, 2012)
I feel lonely	INQ
I feel like I do not belong	INQ
I am disgusted with other people	Disgust with Life Scale (DLS; Ribeiro, Bodell, and Joiner, 2012)
The people in my life would be better off if I were gone	INQ
I feel like a burden to others	INQ
I feel useless	INQ
I feel effective [reverse-scored]	INQ
I am disgusted with myself	DLS
I am feeling ashamed	DLS
Hopelessness	
I might as well give up because there is nothing I can do about making things better for myself	Beck Hopelessness Scale (BHS; Beck, Weissman, Lester, and Trexler, 1974)
My future seems dark to me	BHS
My situation is permanently hopeless	BHS
Overarousal	
I have been feeling irritable	Brief Irritability Test (BITe; Holtzman, O'Connor, Barata, and Stewart, 2015)
I want to crawl out of my skin	Brief Agitation Measure (BAM, Ribeiro, Bender, Selby, Hames, and Joiner, 2011)
I am feeling anxious	Positive and Negative Affect Schedule (PANAS; Watson, Clark, and Tellegen, 1988)
I am feeling afraid	PANAS
Have you been bothered about thoughts of nightmares	Disturbing Dream and Nightmare Severity Index (DDNSI; Krakow et al., 2002)
How worried/distressed are you about your sleep	Insomnia Severity Index (ISI; Bastien, Vallières, and Morin, 2001)
How much is your sleep quality interfering with your daily functioning	ISI

and between-subjects networks are undirected, meaning that whether a symptom is predicting or being predicted by is not considered or modeled. Expected influence therefore indicates, in general, how strongly associated symptoms are.

Results

Group-level networks
All group level networks are shown in Fig. 1 and all group-level centrality metrics are shown in Fig. 2.

Between-subjects network
In the between-subjects network, agitation had the highest expected influence. Not feeling close to others had the second highest expected influence (Fig. 3).

Contemporaneous group-level network
In the contemporaneous group network, feeling ineffective had the highest expected influence. Agitation had the second highest expected influence.

Directed temporal group-level network
In the temporal group network, feeling ineffective had the highest out expected influence. Feeling ineffective positively predicted not feeling close to others, feeling shame and disgusted with self and others, passive suicide ideation, and sleep problems at the next timepoint. Not feeling close to others had the second highest out expected influence. Not feeling close to others positively predicted feeling ineffective and feeling hopeless at the next timepoint. The two symptoms with the lowest out expected influence were passive suicide ideation and sleep problems.
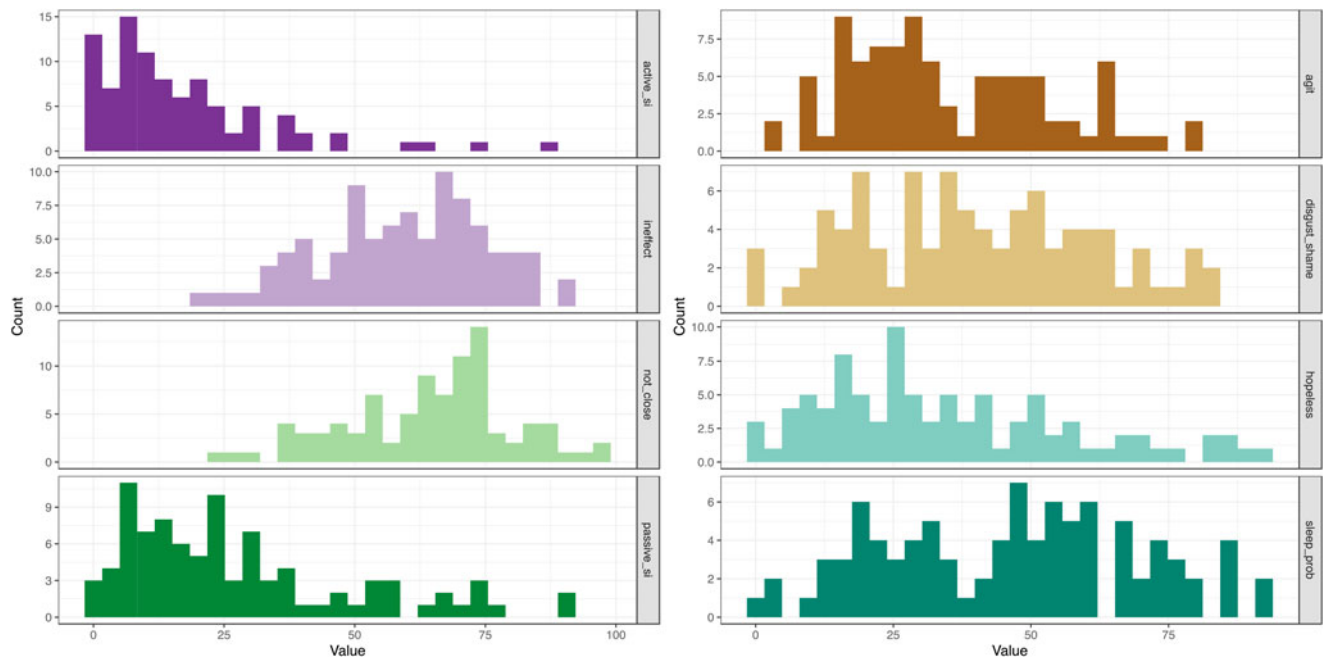
Figure 1. Histograms of all network variables.

Note. Agit, agitation; disgust_shame, shame + disgust with others; not_close, not close to others; ineffect, ineffective; sleep_prob, sleep problems; passive_si, passive suicidal ideation; active_si, active suicidal ideation; hopeless, hopeless.

Agitation had the highest in expected influence. Agitation at the next timepoint was positively predicted by feeling shame and disgusted with self and others, feeling hopeless, and passive suicide ideation. Passive suicide ideation had the second highest in expected influence. Passive suicide ideation at the next time-point was positively predicted by active suicide ideation, hopeless, feeling shame and disgusted with self and others, and feeling ineffective.

Discussion

This study was, to the best of our knowledge, the first longitudinal network analysis of a simplified set of items related to suicide idea-tion, interpersonal risk factors for suicidal thinking, hopelessness, and manifestations of overarousal, and one of only a handful of studies using EMA data to develop longitudinal symptom networks. We estimated central symptoms in at-risk ADSM and vet-erans and how those symptoms related cross-sectionally, contemporaneously, and longitudinally. Different centrality statis-tics were computed, which included expected influence in the between-subjects and contemporaneous networks and out expected influence and in expected influence in the temporal network. We discuss each of these models and interpretations in turn.

Between-subjects networks model on-average, cross-sectional relationships across time. Based on a handful of previous studies (e.g. De Beurs et al., 2017, 2019; Ortiz et al., 2023), we predicted that symptoms related to active ideation and perceived burden-someness would be the most central symptoms in the between-subjects network. However, instead we found that agitation and not feeling close to others (ie., thwarted belongingness) were most central. Although inconsistent with past between-subjects networks, these findings do align with a robust body of research which finds that agitation is associated with suicide outcomes (e.g. Rogers, Ringer, and Joiner, 2016). However, the lack of

directionality in this network allows for fewer conclusions to be drawn relative to the contemporaneous and temporal networks.

Given the relative dearth of longitudinal network analysis studies examining suicidal ideation, we did not have *a priori* hypotheses about the contemporaneous or longitudinal networks. However, each of these models imparts important and dynamic information. In the case of contemporaneous networks, these can be thought of as modeling a dynamic "snapshot" in time. While contemporaneous networks do not identify the directional-ity of associations, they are meaningful because they identify symptom interactions that occur more quickly than the sampling interval. Overall, in the contemporaneous network we found that ineffectiveness and agitation had the highest centrality. These findings partially replicate our findings from the between-subjects network, as well as prior cross-sectional work. Specifically, several past cross-sectional network analysis studies found that perceived burdensomeness (cf., ineffectiveness) was a highly central symp-tom (De Beurs et al., 2019; Ortiz et al., 2023; Saulnier et al., 2023; Smith et al., 2020). Further, agitation emerged as a highly central symptom in our between-subjects model. This suggests that the construct of agitation is important not only on average but also at a moment-to-moment level. In support of this, asses-sing for agitation has been found to greatly improve the assess-ment of suicide risk after discharge from the emergency room (Simpson et al., 2023). Taken together, the symptoms in our model interact dynamically and agitation and ineffectiveness are important drivers.

The directed, temporal networks show how symptoms pro-spectively predict each other from one-time point to the next (i.e. across 3–4 h in our study). Importantly, these models eluci-date predictive relationships between the symptoms. These rela-tionships are critical to understanding directionality and how symptom processes may unfold over time. In the longitudinal net-work, symptoms of ineffectiveness, not feeling close to others (i.e.
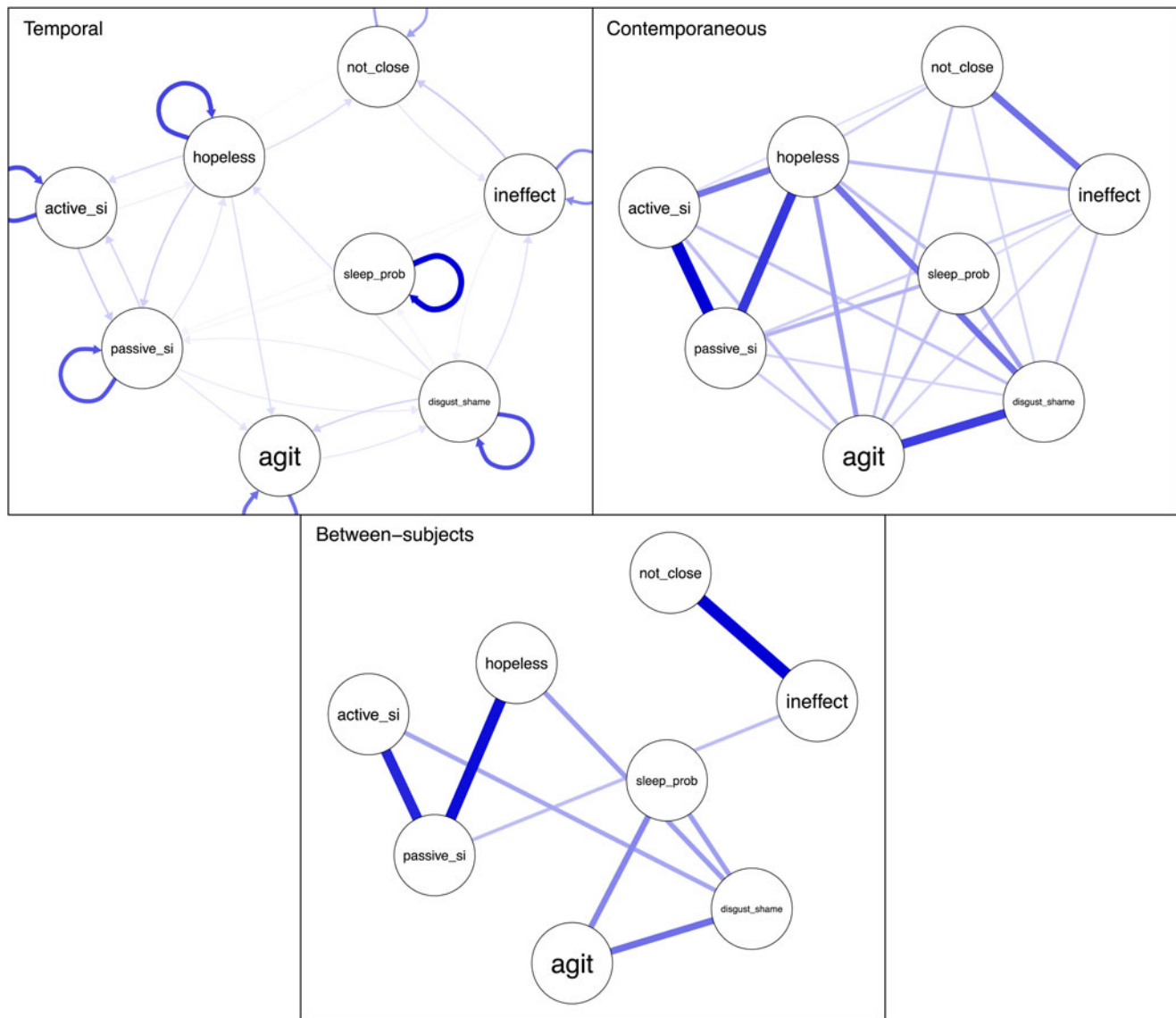
Figure 2. Temporal, contemporaneous, and between-subject networks.
Note. Agit, agitation; disgust_shame, shame + disgust with others; not_close, not close to others; ineffect, ineffective; sleep_prob, sleep problems; passive_si, passive suicidal ideation; active_si, active suicidal ideation; hopeless, hopeless.

thwarted belonging), and agitation predicted the most other symptoms in the network. Specifically, ineffectiveness predicted not feeling close to others, feeling shame and disgusted with self and others, passive suicide ideation, and sleep problems at the next timepoint. This suggests that ineffectiveness is a major contributor to other symptoms of alienation, including low belonging, shame, and disgust. Further, ineffectiveness led to later thoughts of wanting to be dead, as well as difficulties sleeping. This supports and extends prior research noting the centrality of perceived burdensomeness in suicide networks. It also supports one of the only other longitudinal network analysis study of suicidal ideation symptoms which found that perceived burdensomeness predicted suicidal ideation at the next time point (Rath et al., 2019).

Not feeling close to others had the second highest predictive potential and led to more ineffectiveness and hopelessness at the next timepoint. According to the Interpersonal Psychological Theory of Suicide (IPTS; Joiner, 2005), this could be a dangerous

progression as experiencing low belonging in combination with perceived burdensomeness, as well as feeling hopeless about these states improving, is what drives the desire to kill oneself. Although agitation had the third highest predictability, in terms of value, it was nearly identical to the 'out expected influence' of thwarted belongingness. As such, agitation emerged as an important symptom across all three networks.

Additionally, agitation and passive suicidal ideation had the highest 'in expected influence', meaning they were most strongly predicted by other symptoms. That the symptoms of alienation, burdensomeness, and hopelessness predicted suicidal ideation is consistent with leading theories of suicide (e.g. Klonsky & May, 2015; Van Orden et al., 2010). In particular, we found that hopelessness, feelings of disgusted with self and others, and feeling ineffective predicted passive suicidal ideation. Additionally, active suicide ideation also predicted passive suicidal ideation, which suggests a dampening of ideation over time and is consistent with research on fluctuations in the intensity of suicidal ideation, even over
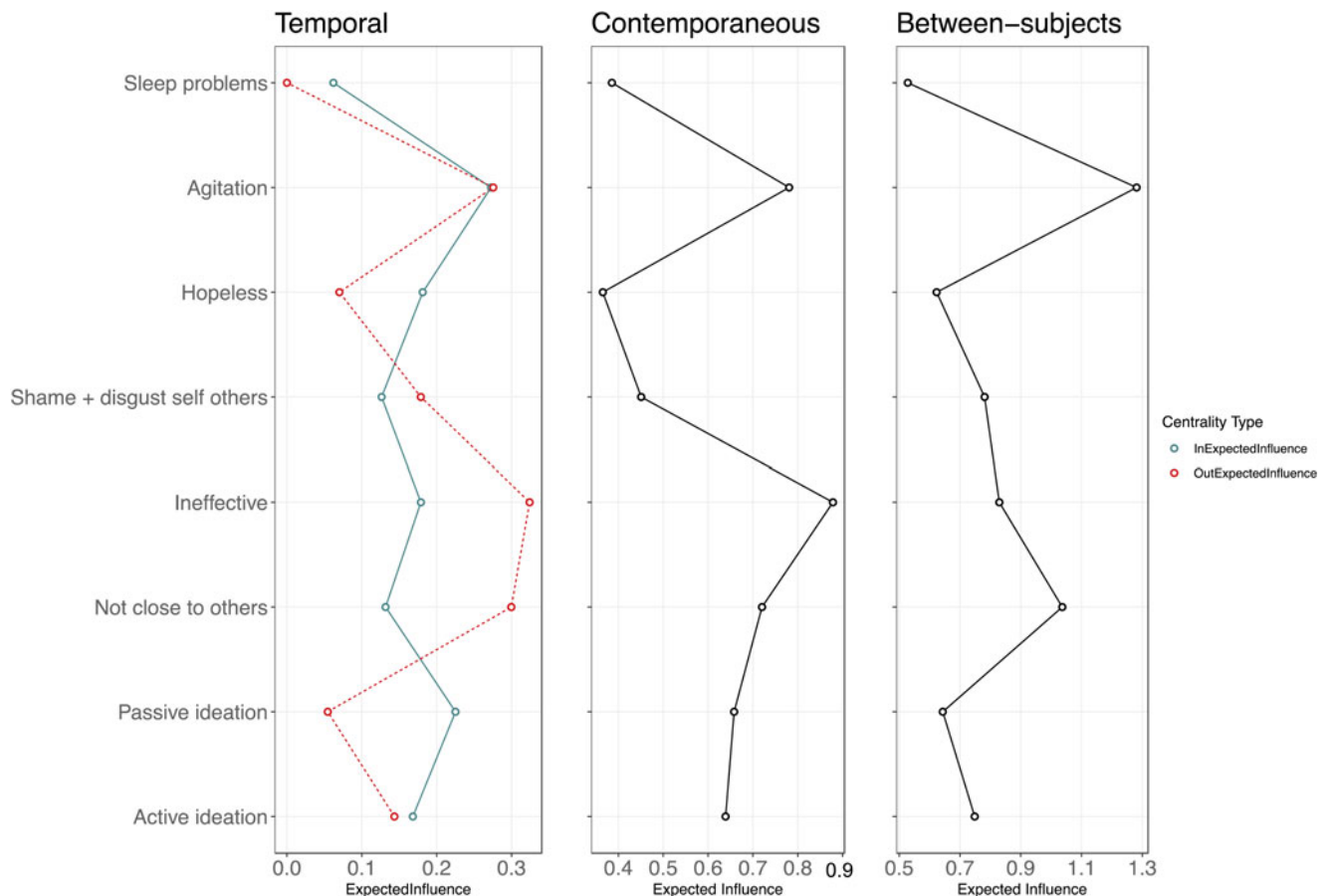
Figure 3. Temporal, contemporaneous, and between-subject expected influence plots.
Note. Agit, agitation; disgust_shame, shame + disgust with others; not_close, not close to others; ineffect, ineffective; sleep_prob, sleep problems; passive_si, passive suicidal ideation; active_si, active suicidal ideation; hopeless, hopeless.

short windows of time (e.g. Hallensleben et al., 2018; Kleiman et al., 2017). Agitation was also highly likely to be predicted by other symptoms, which is interesting to consider given that it also highly predicted other symptoms. This suggests that agitation is capable of both giving and receiving 'inputs' and as such may be an important mechanistic factor for the progression of suicidal ideation.

Considering all three networks allows for a more complete understanding of how risk factors for suicidal ideation interact over different time scales (i.e. on average across time, in the moment, and over the course of several hours; Levinson et al., 2022). Across all three networks, agitation, ineffectiveness, and low belonging were the most influential and/or most predictive symptoms, although the relative ordering varied from network to network. In terms of directionality, it appears that ineffectiveness influences the most other symptoms within seconds and over time. Perceived burdensomeness has emerged as a robust predictor of suicidal ideation, and our results support past meta-analytic findings (Chu et al., 2017). Taken together, these findings suggest that perceived burdensomeness, thwarted belonging, and agitation are highly salient treatment targets that may reduce the likelihood of other symptoms.

Clinical implications

Improved suicide prevention in the military requires uncovering pathways through which suicidal ideation develops (Nock et al.,

2013). Our study begins to do this by understanding how interpersonal risk factors, hopelessness, overarousal, and suicidal ideation relate and progress over time. This delineation provides a description of how individuals at risk for suicidal ideation may present clinically. Importantly, our findings also provide suggestions for which symptoms may be best to target first: specifically, ineffectiveness, low belonging, and agitation. Central symptoms are sensible and possibly highly potent treatment targets, as treatments tailored to central symptoms have strong potential to disrupt the entire symptom network (Lutz et al., 2018). Thus, identifying central symptoms can guide clinicians' selection of empirically supported treatments (Borsboom & Cramer, 2013; Fried & Cramer, 2017) and risk assessments. If clinicians are better able to select appropriate treatments, military suicides may be prevented.

Given the results of our study, it may be beneficial to consider how being in the military can both foster and hinder a sense of belonging and effectiveness. This may be even more needed as technological advances may lead ADSM to be less connected to one another (e.g. drone pilots operating in siloed facilites). Additionally, reconsidering goals and priorities to be more consistent with effectiveness and increased belonging could be lifesaving. For instance, some ADSM report task saturation and working an unbalanced amount of hours that preclude rest and reflection (e.g. MacDermid Wadsworth & Southwell, 2011). Allowing for more time and reflection on one's work and

contribution could allow for renewed effectiveness and a better understanding of one's contributions. Additionally, leadership may wish to find ways to shift cultural values to prioritize and reward group-level achievements over individual accomplishments. Further, interventions targeting ineffectiveness may be a good option for at-risk ADSM and veterans, such as volunteering (Van Orden et al., 2022) and strategies that enhance meaning making (Bryan et al., 2013). Finally, relaxation techniques, including progressive muscle relaxation, massage, and gentle movement, could be beneficial in reducing agitation. However, as noted, in order to engage in these strategies, ADSM will need to be granted the time and wherewithal to do so.

Strengths and limitations

This study possesses a number of strengths. First, to our knowledge, this was the first study to use intensively collected longitudinal data to model symptom interrelations between interpersonal risk factors, hopelessness, overarousal, and suicidal ideation. We also did so in a sample of at-risk ADSM and veterans. Additionally, we constructed three different types of models to help better understand similarities and differences in relations on average, in the moment, and over time.

That said, there are also serval important limitations to note. First, our sample was predominantly white and male, and as such our results may not generalize to other identities. Second, we included eight symptoms in our models and these symptoms were selected through a combination of theory and data-driven decisions. However, there is no consensus on how best to choose items to include as nodes, nor the optimal number of nodes for inclusion. Third, one item in our EMA assessment did not directly tap in the moment experiences (*I have been feeling irritable*). Fourth, in this initial study we only considered how symptoms operate at the group level. However, there is reason to suspect that symptom trajectories are highly variable (e.g. Levinson et al., 2022). As such, the next important step for future research will be to construct intra-individual networks to capture how service members' unique symptoms and experiences increase their *specific* pathways to suicidal thoughts and behaviors (Fisher, Reeves, Lawyer, Medaglia, & Rubel, 2017b). Related, future work would also benefit by testing whether these networks function similarly in ADSM, veterans, and never-serving civilians, as doing so will help target military-specific variables of interest. Fifth, we presented centrality indices and edge weight measurements, however, we acknowledge that there is no consensus on the optimal quantitative effect size measures for networks (Bringmann et al., 2019).

Summary

Interactions among several symptoms have been found to predict increased suicidal ideation severity among military samples, such as insomnia and agitation (Fisher, Houtsma, Assavedo, Green, & Anestis, 2017a), thwarted belongingness and insomnia (Hom et al., 2017), and thwarted belongingness and hopelessness (Anestis, Mohn, Dorminey, & Green, 2017). Our results extend this past research by considering one of the largest sets of interacting suicide risk factors within a military sample to date. Our results offer insights into pathways that may lead to suicidal ideation as well as help improve treatment selection for at-risk ADSM and veterans. Our findings suggest that ineffectiveness, low belonging, and agitation are important drivers of moment-to-moment and longitudinal relations between suicidal ideation risk factors.

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