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Dynamic Network Analysis of Negative Emotions and *DSM-5* Posttraumatic Stress Disorder Symptom Clusters During Conflict

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Investigating dynamic associations between specific negative emotions and PTSD symptom clusters may provide novel insights into the ways in which PTSD symptoms interact with, emerge from, or are reinforced by negative emotions. The present study estimated the associations among negative emotions and the four *DSM-5* PTSD symptom clusters (intrusions, avoidance, negative alterations in cognitions and mood [NACM], and arousal) in a sample of Israeli civilians ($n = 96$) during the Israel–Gaza War of July–August 2014. Data were collected using experience sampling methodology, with participants queried via smartphone about PTSD symptoms and negative emotions twice a day for 30 days. We used a multilevel vector auto-regression model to estimate temporal and contemporaneous temporal networks. Contrary to our hypothesis, in the temporal network, PTSD symptom clusters were more predictive of negative emotions than vice versa, with arousal emerging as the strongest predictor that negative emotions would be reported at the next measurement point; fear and sadness were also strong predictors of PTSD symptom clusters. In the contemporaneous network, negative emotions exhibited the strongest associations with the NACM and arousal PTSD symptom clusters. The negative emotions of sadness, stress, fear, and loneliness had the strongest associations to the PTSD symptom clusters. Our findings suggest that arousal has strong associations to both PTSD symptoms and negative emotions during ongoing trauma and highlights the potentially relevant role of arousal for future investigations in primary or early interventions.

The association between general negative affect and posttraumatic stress disorder (PTSD) has been well established (Brown et al., 2016; Marshall-Berenz, Morrison, Schumacher, & Coffey, 2011; Souza et al., 2008). Moreover, although PTSD was originally conceptualized principally as a disorder of fear (American Psychiatric Association [APA], 1980; Foa & Kozak, 1986), there has been increasing recognition that negative emotions beyond fear are also strongly associated with PTSD (Dalgleish & Power, 2004; Hathaway, Boals, & Banks, 2010; Lancaster, Melka, & Rodriguez, 2011; Ozer, Best, Lipsey, & Weiss, 2003; Resick & Miller, 2009). Of particular relevance to the current study, it is not only peritraumatic fear, helplessness, and horror that are associated with later elevations in PTSD symptoms (Ozer et al., 2003) but also anger, shame, and guilt (Kunst, Winkel, & Bogaerts, 2011; Lancaster & Larsen, 2016; Lee, Scragg, & Turner, 2001; Olatunji, Ciesielski, & Tolin, 2010; Riggs, Dancu, Gershuny, Greenberg, & Foa, 1992). Acknowledging the importance of this broad range of negative emotions, the diagnostic criteria for PTSD in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorers* (*DSM-5*; APA, 2013) incorporated a “negative alterations in cognitions and mood” (NACM) symptom cluster in which fear, guilt, shame, horror, and anger are each specifically identified as persistent negative emotions that may be present in individuals with PTSD.

Although prior literature has established that negative emotions and PTSD are related, there are several important questions about the nature of this association that remain largely unanswered. The first question regards specificity: Are negative emotions uniformly associated with all PTSD symptoms, or

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do different emotions exhibit differential patterns of association with individual PTSD symptoms or PTSD symptom clusters? In one study, retrospectively recalled peritraumatic emotions differentially predicted PTSD symptom clusters (per criteria in the fourth edition of the *DSM* [*DSM-IV*]), with peritraumatic guilt, anger, and fear predicting reexperiencing symptoms but only fear predicting avoidance symptoms and only anger predicting hyperarousal symptoms (Dewey, Schuldberg, & Madathil, 2014). However, like much of the research on peritraumatic emotions, the study by Dewey et al. relied on retrospective recollection. Because emotions are often transient phenomena (Ekman & Davidson, 1994) and are vulnerable to potentially severe recall bias (Ebner-Priemer & Trull, 2009; Levine & Safer, 2002; Wilhelm & Grossman, 2010), the reliance on retrospective reports represents a significant limitation.

The second question regards the temporal association between negative emotions and PTSD symptoms: Are negative emotions causes for or consequences of PTSD symptoms, or both? Studies investigating the relation between emotions and PTSD symptoms generally conceptualize emotions as drivers or predictors of PTSD symptomatology rather than consequences of symptomatology (Badour, Bown, Adams, Bunaciu, & Feldner, 2012; Dewey et al., 2014; Kunst et al., 2011; Lancaster et al., 2011; Olatunji et al., 2010). However, the cross-sectional nature of many of these studies precludes any determination of the temporal direction of these relations. Among longitudinal studies that have explored the associations between negative emotions and PTSD, most have focused on associations over periods of weeks or months. Yet, we would argue that much of the interesting dynamics of this relationship are likely to occur over much briefer time intervals given the lability of emotions in daily life (Wichers, Wigman, & Myin-Germeys, 2015). For example, intrusive memories may elicit emotions such as shame or guilt not on a timescale of months but of minutes or hours. Thus, although the literature has established that negative emotions and PTSD are related, a richer understanding of their temporal associations may be found by examining these associations at smaller intervals of time.

As reviewed earlier, the prior literature on this topic has established the importance of a range of negative emotions in the PTSD syndrome, but there has been little exploration of the relations between specific negative emotions and individual PTSD symptoms or symptom clusters (Dewey et al., 2014). Moreover, to our knowledge, no studies have explored dynamic associations between PTSD and negative emotions over the relatively brief timescales likely to be of particular importance to understanding this relation. As a result, we know little about the ways in which PTSD symptoms interact with, emerge from, or are reinforced by negative emotions over the course of day-to-day life. The present empirical investigation addressed these limitations by collecting data via the experiencing sampling methodology (ESM) and estimating dynamic network models of negative emotions and PTSD symptom clusters in a sample of Israeli civilians during a period of armed conflict.

Advances in mobile technology have improved intensive longitudinal assessment methods. One of these methods, ESM, has increasingly been used by researchers to collect data on symptoms, emotions, and experiences as they occur in or near real time in individuals' daily lives (Cohn, Hagman, Moore, Mitchell, & Ehlke, 2014). Typically, ESM requires participants to complete self-report questionnaires several times a day over a number of days. This collection of real-time (or near real-time) data in real-world environments increases ecological validity relative to traditional methods that use retroactive assessment (Bolger & Laurenceau, 2013). Moreover, ESM is better able to capture context and its complexity, and it enables the examination of within-person processes (i.e., processes as they unfold within an individual over time; Hamaker, 2012; Molenaar & Campbell, 2009) while at the same time capturing between-person processes. Thus, ESM methodology allows researchers to address questions regarding the specificity of the relations between negative emotions and the PTSD clusters while investigating the dynamic interactions between these different components.

A number of studies have previously utilized ESM for exploring PTSD symptoms in daily life (Chun, 2016), whereas other studies have investigated general emotional reactivity to daily stressors (Bylsma, Taylor-Clift, & Rottenberg, 2011; Wichers et al., 2007), negative affect as a mediator between PTSD and drinking behavior (Cohn et al., 2014), and emotional reactivity to stress as a predictor of future psychopathology (Vaessen et al., 2017). To our knowledge, however, no studies have yet used ESM to examine the association between PTSD symptom clusters and specific negative emotions.

In recent years, the network theory of psychopathology has offered a new conceptualization of mental health, in which syndromes, such as PTSD, are posited to arise, at least in part, due to causal interactions among the symptoms comprising the syndrome (Borsboom, 2017; McNally, 2016). To explore this theory of mental disorders, psychometric network models, which can estimate the complex dependencies among items and for which metrics of network inference can be used to identify items especially important to the network (e.g., those with strong or numerous associations to other items in the network; Epskamp & Fried, 2018), have been developed. Network analysis has been used to investigate PTSD symptom–level associations with cross-sectional data (e.g., Armour, Fried, Deserno, Tsai, & Pietrzak, 2017; Bryant et al., 2016; McNally et al., 2015; Mitchell et al., 2017; Spiller et al., 2017). In a recent paper, researchers showed that these PTSD network structures replicated well across four different samples of traumatized patients receiving treatment (Fried et al., 2017). Studies have also investigated the comorbidity of PTSD with other diagnostic constructs, such as depression and substance abuse (Afzali et al., 2016; Choi, Batchelder, Ehlinger, Safren, & O'Cleirigh, 2017). However, to our knowledge, no network study has modeled PTSD symptoms together with specific individual negative emotions.

In the last few years, network analysis has been extended to a multilevel framework, using intensive longitudinal data gathered through ESM to estimate dynamic networks (Bodner, Kuppens, Allen, Sheeber, & Ceulemans, 2017; Bos et al., 2017; Bringmann et al., 2013; Epskamp, Waldorp, Mõttus, & Borsboom, 2018; Greene, Gelkopf, Epskamp, & Fried, 2018; Lydon-Staley, Xia, Mak, & Fosco, 2018; Pe et al., 2015). Dynamic networks could provide useful insights into potentially predictive associations between components by the estimation of directed temporal networks, in which the direction of the association between network components from moment to moment can be depicted (Bringmann et al., 2013). Temporal networks enable a calculation of the extent to which an item is predicted by items at the previous measurement ("in-strength") and the extent to which an item predicts other items at the following measurement ("out-strength"). Contemporaneous network, which depict the within-measurement associations between symptoms, can also be estimated. Elucidating these two processes—contemporaneous and temporal—could indicate potential mechanisms through which psychopathology builds up and bring us closer to identifying symptoms or emotions that might be novel prevention or intervention targets (Fisher, Reeves, Lawyer, Medaglia, & Rubel, 2017).

In the current study, we investigated the dynamic network associations of 10 negative emotions with the four *DSM-5* PTSD symptom clusters using ESM data obtained during a period of ongoing stress exposure in Israeli civilians exposed to rocket fire during a period of conflict. We aimed to identify negative emotions that may play important roles in the development of traumatic stress reactions, to assess which of the PTSD clusters had the strongest associations with negative emotions, and to investigate the direction of temporal connections between PTSD clusters and negative emotions. This analysis was exploratory, meaning that we could not directly test hypotheses. Nonetheless, we did have some predictions. First, given the emphasis of negative emotions in the *DSM-5* NACM cluster, we anticipated that negative emotions would be most strongly connected to the NACM cluster. Further, based on prior findings that negative emotions predict later PTSD symptoms, we anticipated that negative emotions would predict the PTSD symptom clusters to a greater extent than the PTSD symptom clusters would predict negative emotions.

Method

Participants and Procedure

The present paper utilized data collected within a large prospective ESM study conducted during and after the Israel–Gaza conflict that took place in July and August 2014 (Gelkopf et al., 2017; Greene, 2018b; Greene et al., 2017; Lapid Pickman, Greene, & Gelkopf, 2017). During the 50-day conflict, rockets and mortar shells were fired at Israeli communities from Gaza, and the Israel Defence Forces conducted ground and air attacks on Gaza. A general population sample of Israeli adult civilians ($n = 114$) exposed to rocket fire were recruited through social networks, snowballing methods, and via advertisements placed at local organizations, communities, and universities and colleges. Participants contacted the research team directly. Participants entered the study gradually and began providing ESM reports on Days 8 to 24 of the conflict. The participants used Qualtrics (Provo, UT) online survey software to complete ESM assessments via smartphones twice a day at predetermined times for 30 days and could respond within 2 hr. Participants gave informed consent, were remunerated ($150 USD), and the design and procedure were approved by University of Haifa Ethics Committee.

In line with Myin-Germeys, van Os, and Schwartz (2001), we excluded data from participants who provided fewer than 20 assessments, all of whom dropped out of the study (mostly in the first week). Participants retained in the final sample ($n =$ 96, 84.2%) answered a mean of 49.2 ($SD = 7.282$) of 60 potential assessments. Missing data within completed assessments was very low (13 of 4,273 assessments). For the analyses, we removed all pairs of lagged and current variables that contained missing responses (Epskamp et al., 2018). Of the final sample, 70.8% participants ($n = 68$) were female, and the average participant age was 30.1 years ($SD = 9.0$). Most participants were Jewish (97.9%), secular (60.4%), and were born in Israel (83.3%). Detailed sample characteristics are presented in Supplementary Table S1. There were no statistically significant associations ($\alpha = .05$) between the degree of missing assessments and demographic characteristics (i.e., age, gender, education, income, relationship status, employment) nor in mean levels of negative affect or traumatic stress symptoms. Additionally, in terms of the aforementioned variables, there were no differences between included participants and those who dropped out.

Measures

Traumatic stress symptoms. Symptoms of traumatic stress were measured using a self-report questionnaire (Gelkopf et al., 2017) adapted from a Hebrew version of the PTSD Checklist for *DSM-5* (PCL-5; Weathers et al., 2013). This 20-item self-report tool was adapted in two ways. First, the time frame for experiencing each symptom was adjusted from "in the past month" to "since the last questionnaire" (a minimum gap of 8 hr). Second, the Likert scale was changed from 5 to 4 points for consistency with the number of response options included in the other (85-item) ESM assessment, with the aim of reducing participant burden. The 4-point response options ranged from 0 (*not at all*) to 3 (*to a very high degree*). A multilevel composite reliability analysis, as described by Geldhof, Preacher, and Zyphur (2014), found high composite reliability coefficient estimates; within-person reliability was 0.87, $p < .001$; and between-person reliability was 0.93, $p < .001$. Mean scores were calculated for the four subscales, which correspond to the four *DSM-5* PTSD symptom clusters: Intrusions, Avoidance, NACM, and Arousal. Due to concerns that the item regarding negative emotions in the PCL-5 overlapped with the assessment of individual negative emotions, we removed this item from the NACM subscale in the current study.

Negative emotions. Ten negative emotions were assessed using five items, related to sadness, guilt, fear, anger, and loneliness, from a Hebrew version of the Manual for the Positive and Negative Affect Schedule–Expanded Form (PANAS-X; Watson & Clark, 1999), which is used extensively in ESM studies (South & Miller, 2014); four items, related to shame, stress, helplessness, and feeling overwhelmed, used in an ESM study of motor vehicle accident survivors (Carlson et al., 2016); and one item related to despair that was added by the research team. Participants were asked to rate the extent to which they had experienced each emotion since they answered the last questionnaire on a 4-point Likert scale ranging from 0 (*not at all)* to 3 (*very much*). This measure showed composite reliability scores of .87, $p < .001$, within-person and .96, $p < .001$, between-person (Gelkopf et al., 2017).

Data Analysis

Network diagrams depict variables ("nodes") and the associations among them, represented by links ("edges") connecting the nodes. In the current study, the 14 nodes represented the four *DSM-5* PTSD clusters and 10 negative emotions. We focused on the intercommunity edges between PTSD clusters and negative emotions (i.e., the "bridge connections"; Heeren, Jones, & McNally, 2018) rather than the intracommunity edges among PTSD symptom nodes or among negative emotion nodes. Note that we use "community" here conceptually and not as statistically derived groups of variables.

Dynamic network analysis uses a multilevel vector autoregression (multilevel VAR) model, in which each variable is regressed on all the variables in the network from the previous assessment while using a multilevel structure to account for clustering within individuals (Bringmann et al., 2013; Epskamp et al., 2018). This model produces three networks: temporal, contemporaneous, and between-persons. In the current study, the temporal network is a directed network of regression coefficients depicting the lagged associations between PTSD clusters and negative emotions from one time point to the next time point (Epskamp et al., 2017, 2018). This shows whether a deviation from a person's mean in one variable predicts a deviation from a person's mean in another variable at the next measurement occasion, for which Granger-causal connections (Granger, 1969) between symptoms can be inferred (Bringmann et al., 2013; Schuurman, Ferrer, de Boer-Sonnenschein, & Hamaker, 2016). In other words, the temporal network shows how well each variable predicts other variables at the next measurement (Borsboom & Cramer, 2013). This approach allowed us to identify which negative emotions and which PTSD clusters were most predictive of other variables at the next assessment (i.e., high "out-strength") and which negative emotions and PTSD clusters were most predicted by other nodes at the previous assessment (i.e., high "in-strength").

The contemporaneous network is a Gaussian graphical model (GGM) based on the covariance of the residuals from the VAR model, which estimates the within-time window associations of variables, somewhat akin to a multilevel partial correlation network, after controlling for temporal effects (Epskamp et al., 2017). In the current study, this showed the within-measurement associations between negative emotions and PTSD clusters. Lastly, the between-persons network depicts the covariance between stationary means of different individuals (Epskamp et al., 2018). In this paper, we focus on the temporal and contemporaneous networks; the between-persons network is shown in Supplementary Figure S1.

Temporal, contemporaneous, and between-persons networks were estimated by a two-step multilevel VAR using the *mlVAR* package in R (see Supplementary Materials for codes) and the *networktools* R package to calculate bridge strength for these networks. We estimated forced random effects of incoming edges to a single node (temporal) or edges connected to the same node (contemporaneous) to be orthogonal, as has been recommended to do in networks with more than eight nodes (Epskamp et al., 2018). In the contemporaneous and between-persons networks, we used the "AND rule"; in other words, an edge was included in the final model only if both regressions on which the edge was based were significant at an alpha value of .05 (Epskamp et al., 2018). For these networks, we first estimated the full networks with all possible associations, then removed all intracommunity connections from the graphs to display only the intercommunity bridge connections. The layout of the networks is the average layout of the full contemporaneous and temporal graphs, each of which were based on the Fruchterman-Reingold algorithm.

Because our two communities of interest (i.e., negative emotions and PTSD symptom clusters) differ in their number of constituent nodes (10 and 4, respectively), the range of potential bridge strength values for nodes differs between communities (0–4 vs. 0–10). For negative emotions, there are only four potential bridge connections and, thus, a maximum possible bridge strength of 4. In contrast, each PTSD symptom cluster can have up to 10 bridge connections and a maximum possible bridge strength of 10. To facilitate the comparison between the findings for PTSD symptoms and emotions, we adjusted the bridge strength values for the PTSD cluster nodes by multiplying them by 0.4, leading to the same 0–4 range as negative emotions. These adjustments were made for contemporaneous bridge strength as well as for temporal bridge in-strength and out-strength.

Results

The average per-person mean, standard deviation, and range of PTSD cluster and negative emotion scores are shown in Supplementary Table S2. The full temporal network and the bridge connections temporal network are shown in Figure 1.

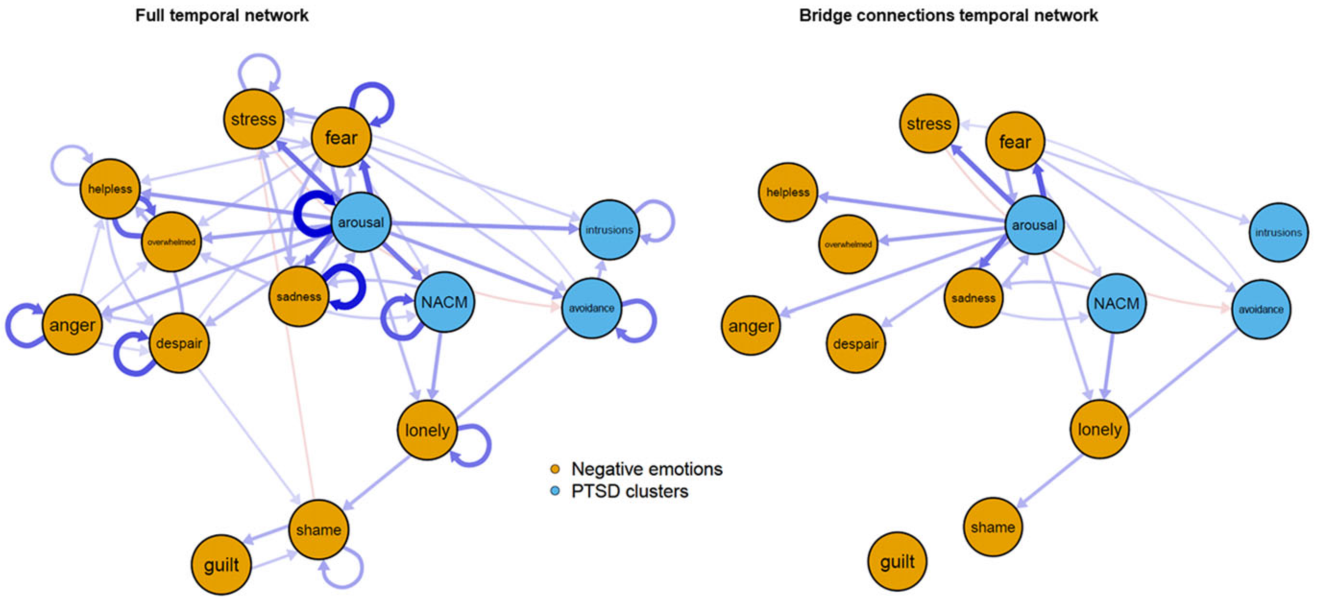

Figure 1. Temporal networks of negative emotions and posttraumatic stress disorder (PTSD) symptom clusters. Arrows indicate the direction of the temporal (lagged) association. Blue edges denote positive associations, red edges negative associations between nodes. Edge thickness represents edge weight (i.e., thicker edges indicate stronger associations). Curved arrows that exit and enter the same node indicate autoregressive associations (a node predicts itself). NACM = negative alterations in cognitions and mood.

Bridge temporal in-strength (the extent to which nodes from one community are predicted by nodes from the other community at the previous assessment) and bridge temporal out-strength (the extent to which nodes from one community predicted nodes in the other community at the following assessment) are depicted in Figure 2.

Negative emotions were predicted by the PTSD symptom clusters more than vice versa, with bridge in-strength for sadness (0.22), stress (0.19), fear (0.17), and loneliness (0.17) all higher than bridge in-strength for PTSD symptom clusters (0.02, 0.04, 0.04, and 0.07 for intrusions, avoidance, NACM, and arousal, respectively). The bridge out-strength values clarify this general trend: Arousal had the highest out-strength of all nodes (0.37), with the other PTSD symptom clusters far lower (0.07, 0.05, and 0 for NACM, avoidance, and intrusions, respectively). Specifically, arousal predicted all the negative emotions except for guilt and shame. Among negative emotions, fear (0.26) and sadness (0.13) both predicted PTSD symptom clusters at the next measurement occasion, as did stress, albeit to a lower extent (0.04). Fear predicted all four PTSD symptom clusters whereas sadness predicted arousal and NACM. It should be noted that the only negative association identified in the temporal bridge network was from stress to avoidance (−0.04), and the association was weak.

Figure 3 shows the full contemporaneous network and the contemporaneous network depicting only the bridge connections, and Figure 4 shows the adjusted bridge strength contemporaneous associations between the PTSD symptom clusters and the negative emotions. As shown in Figure 4, NACM had the most connections to negative emotions, with a bridge strength of 0.20; this was followed by arousal (0.17) and intrusions (0.04). Avoidance was not significantly associated with negative emotions. The negative emotions with the strongest contemporaneous bridge connections to the PTSD symptom clusters were sadness (0.21), stress (0.17), loneliness (0.14), anger (0.13), and fear (0.10).

The specific negative emotions with contemporaneous connections to the NACM cluster were sadness (0.16), loneliness (0.14), despair (0.08), anger (0.07), and helplessness (0.05). The negative emotions related to arousal were stress (0.12), fear (0.10), overwhelmed (0.08), anger (0.07), and sadness (0.05). The intrusions cluster was specifically associated with shame (0.05) and stress (0.04). Notably, all negative emotions except for guilt were directly associated with at least one PTSD symptom cluster.

Discussion

In the current study, we investigated the dynamic network associations between negative emotions and PTSD symptom clusters during a period of conflict exposure. We found that PTSD symptom clusters exhibited direct temporal and contemporaneous associations with a wide range of negative emotions, including anger, despair, fear, helplessness, loneliness, a feeling of being overwhelmed, sadness, shame, and stress. These findings are broadly consistent with recent theory and research emphasizing the importance of negative emotions beyond fear alone in the PTSD syndrome. Across networks, negative emotions were primarily related to the NACM and arousal clusters, whereas negative emotions showed only weak or no direct connections to the intrusions and avoidance clusters.

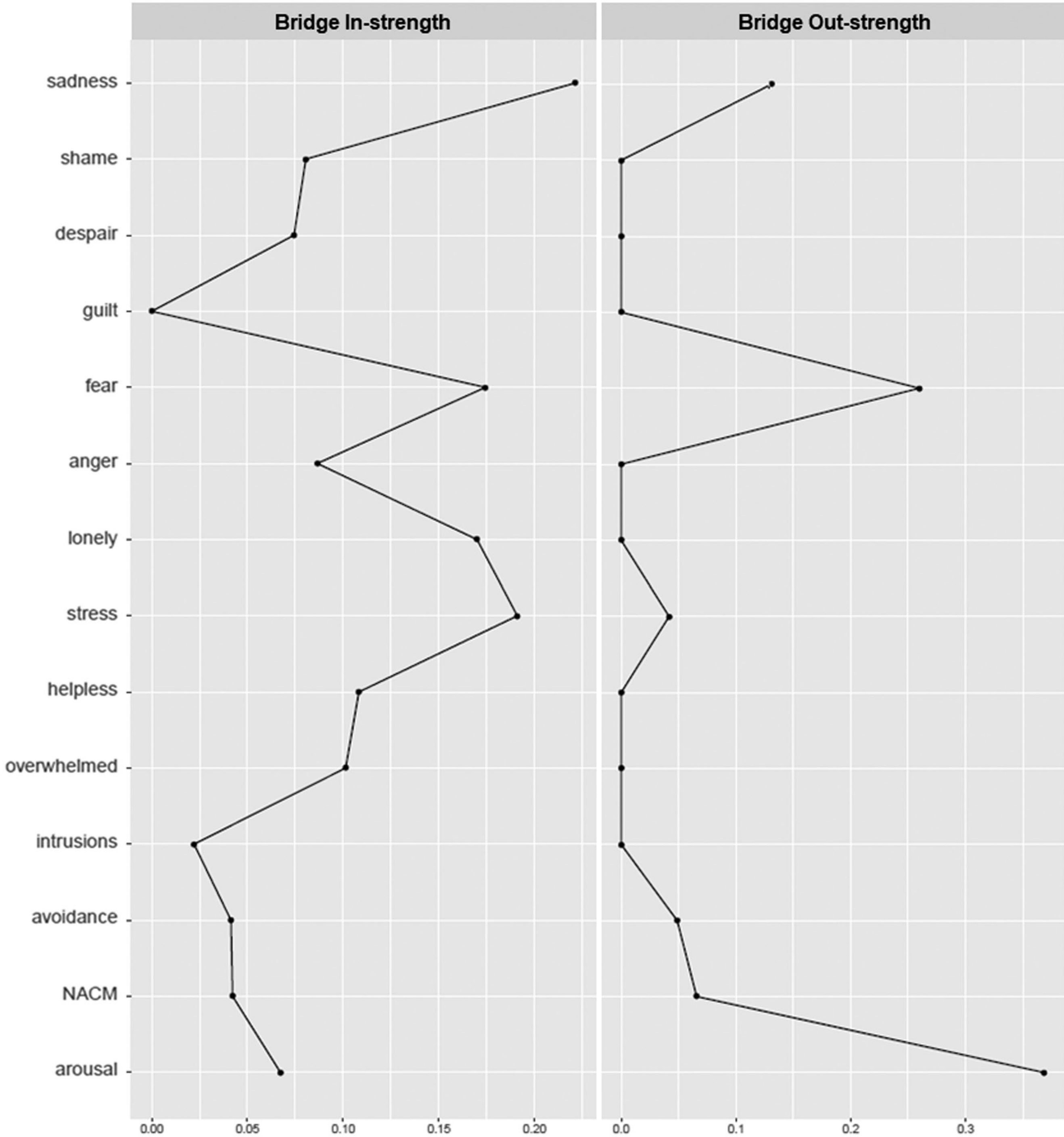

Figure 2. Temporal bridge in-strength and out-strength. NACM = negative alterations in cognitions and mood.

Although this study was largely exploratory, we had two broad hypotheses. First, we anticipated that negative emotions would be more strongly connected to the NACM cluster than to the other PTSD symptom clusters, both within and across time. Our results were not fully consistent with this hypothesis. In the contemporaneous network, the NACM cluster had connections to sadness, helplessness, anger, despair, and loneliness; however, arousal exhibited comparable connections. Furthermore, in the temporal network, negative emotions were more strongly connected to the arousal cluster than to the NACM cluster. Although the NACM cluster predicted only sadness and loneliness and was predicted only by fear and sadness, the arousal cluster predicted all the negative emotions except guilt and shame, and it was predicted by fear and sadness.

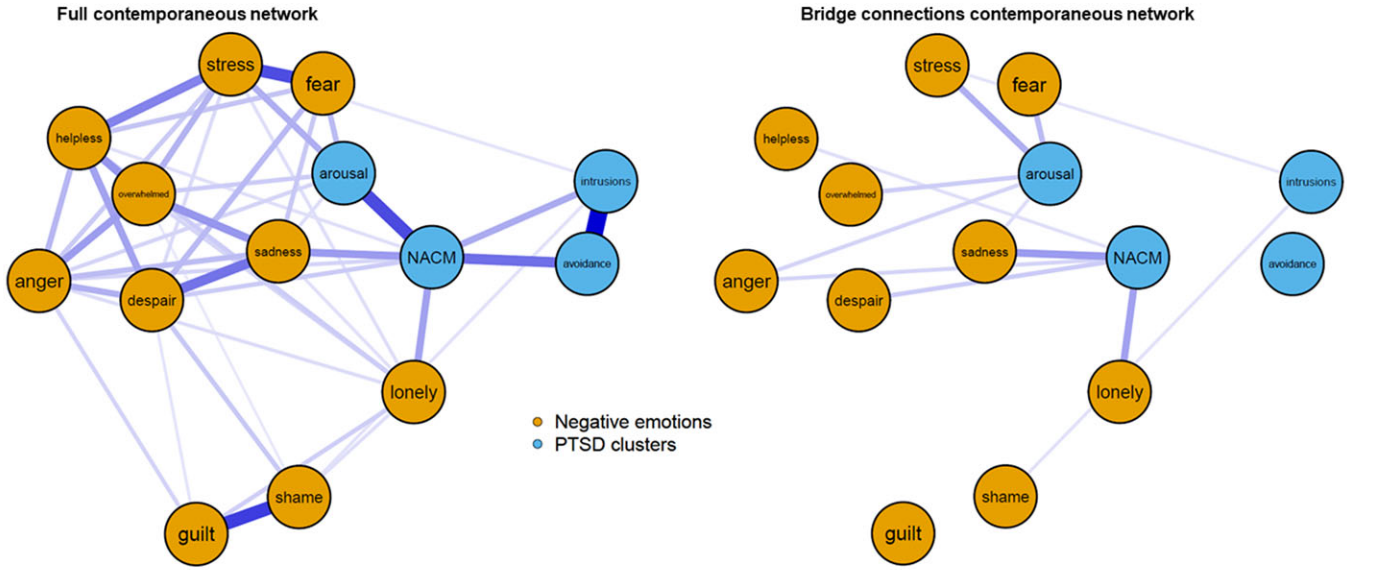

Figure 3. Contemporaneous networks of negative emotions and posttraumatic stress disorder (PTSD) symptom clusters. Blue edges denote positive associations between nodes; there are no negative edges. Edge thickness represents the degree of association (i.e., thicker edges represent a stronger association). NACM = negative cognitions in cognitions and mood.

Our second hypothesis was that negative emotions would be more predictive of PTSD clusters than vice versa. Interestingly, the opposite pattern of results emerged, largely due to the observation that arousal strongly predicted all negative emotions except shame and guilt. Perhaps the conceptualization of arousal should be expanded to represent a general state of hypersensitivity to stress exposure; this could manifest as externalizing behaviors, such as irritability or risk taking, but also in feeling overwhelmed, helpless, or in despair in the face of traumatic stimuli. Previous longitudinal studies have found that arousal is a strong predictor of other PTSD symptoms (Schell, Marshall, & Jaycox, 2004; Pietrzak et al., 2014; Solomon, Horesh, & Ein-Dor, 2009). Additionally, previous studies have identified peritraumatic physiological arousal, such as increased heart and respiration rates, as predictors of later PTSD (Bryant, Creamer, O'Donnell, Silove, & McFarlane, 2008; Morris, Hellman, Abelson, & Rao, 2016; Shalev et al., 1998). The current findings suggest that one mechanism by which arousal may confer later risk is by heightening the experience of negative peritraumatic emotions, which themselves have been linked to a higher risk for PTSD. Alternatively, it may be that a higher level of peritraumatic emotion is epiphenomenal, associated with later PTSD only by virtue of its association with elevated peritraumatic arousal, which may confer risk through other mechanisms, such as heightened consolidation of fear memories (Bryant et al., 2008).

In that context, it is important to emphasize that this study took place during an extended period of trauma exposure; thus, the current findings, particularly regarding arousal, may be more representative of peritraumatic rather than posttraumatic phenomena. It should also be noted that the PTSD arousal cluster includes a range of symptoms and is not a direct assessment of elevated physiological arousal nor the type of arousal emphasized in the "core affect" of constructionist theories of emotion (Russell, 2003). In future research, it may be informative to incorporate ambulatory assessment of psychophysiology to further investigate the associations between peritraumatic arousal and negative emotions.

Several other noteworthy findings help generate hypotheses for future work. First, among the negative emotions in the temporal network, fear was most predictive of PTSD clusters in general and it predicted all four *DSM-5* symptom clusters. This finding is consistent with prior studies that have identified peritraumatic fear as a predictor of subsequent PTSD (Badour et al., 2012; Lancaster et al., 2011). Future studies could investigate whether individuals who exhibit strong associations between fear and concurrent acute stress symptoms are more likely to go on to develop PTSD.

Second, sadness was the emotion with the highest bridge strength in the contemporaneous network, and it had high bridge in-strength in the temporal network. This indicates that sadness had strong within–time period associations with the PTSD symptom clusters and was well predicted by PTSD symptom clusters at the previous assessment. Studies have previously suggested that peritraumatic sadness is a predictor of subsequent PTSD (Hathaway et al., 2010) and depression (Creamer, McFarlane, & Burgess, 2005; Dalgleish & Power, 2004; Rizvi, Kaysen, Gutner, Griffin, & Resick, 2008). Peritraumatic sadness may be a bridge symptom between PTSD and depression (Afzali et al., 2017) whereby traumatic stress reactions could trigger sadness, which in turn develops into depression. In addition, some other negative emotions, such as fear, despair, stress, helplessness, and loneliness, could indicate the presence of mental disorders often comorbid with PTSD, such as

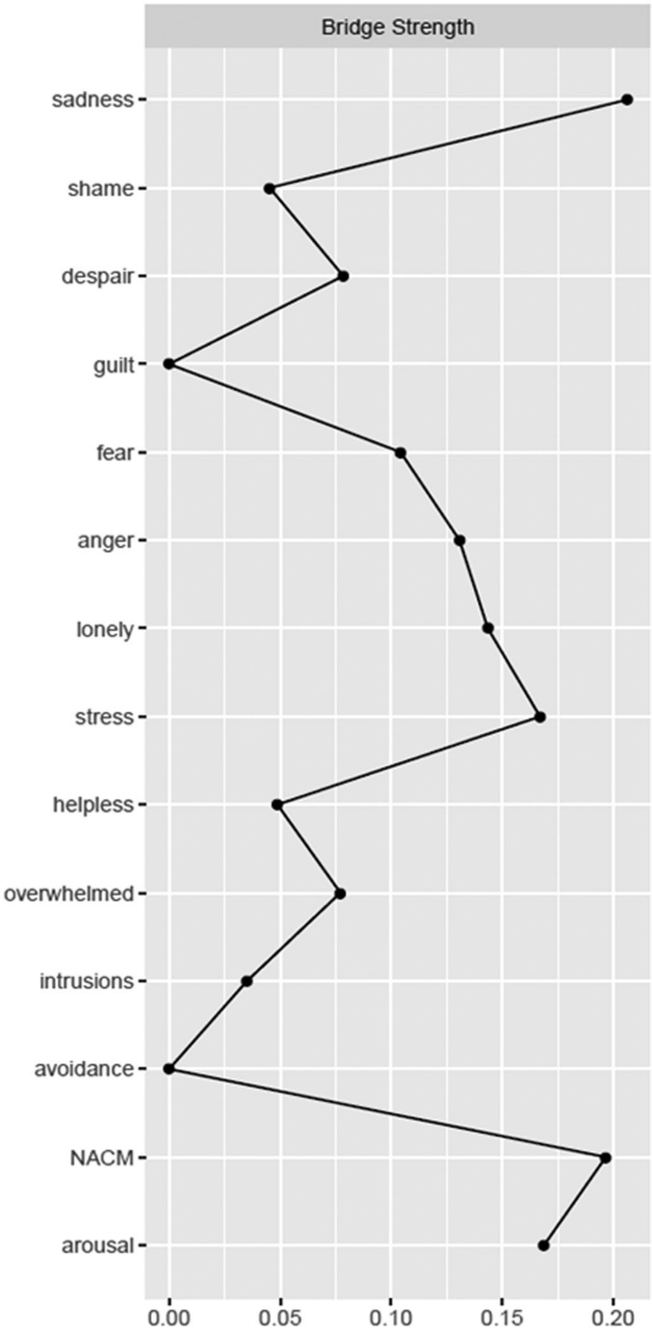

Figure 4. Contemporaneous bridge strength between negative emotions and posttraumatic stress disorder (PTSD) symptom clusters. NACM = negative alterations in cognitions and mood.

depression. Accordingly, edges between these negative emotions and PTSD symptom clusters could indicate paths by which PTSD is associated with these commonly comorbid conditions.

Third, comparisons of negative emotion bridge in-strength versus out-strength in the temporal networks revealed some interesting differences. For example, both feeling stressed and feeling lonely had high bridge in-strength but low bridge out-strength. In other words, they were predicted by PTSD symptom clusters rather than being predictive of the clusters. Specifically, stress was predicted by arousal and avoidance, and loneliness was predicted by arousal and NACM. This suggests that over short time frames, such as the 12-hr lag implemented in the current study, feelings of stress and a fleeting sense of loneliness could be outcomes of trauma reactions more so than risk factors. Whether this is the case in other samples and over shorter or longer time frames requires future follow-up work.

Finally, guilt had no bridge connections to the PTSD clusters in either the contemporaneous or temporal network. Although some previous studies have found peritraumatic guilt to be associated with subsequent PTSD (Dewey et al., 2014; Lancaster & Larsen, 2016), this finding is consistent with prior studies that have found that guilt is often not associated with PTSD symptoms or psychopathology more broadly, after controlling for the effects of shame (Robinaugh & McNally, 2010; Tangney, Wagner, & Gramzow, 1992). Indeed, we found that shame was contemporaneously associated with intrusions and was prospectively predicted by avoidance. The lack of association between guilt and PTSD symptoms might also be explained by the specific context of the current study, which took place among civilians during a period of conflict exposure. In this situation, individuals may be less likely to make a guilt appraisal and more likely to blame others for the event (Greene, 2018a), whereas guilt may play a more important role following other types of trauma exposure, such as sexual assault (Amstadter & Vernon, 2008) or combat exposure (Litz et al., 2009). Finally, it should be noted that guilt, along with shame, had the lowest per-person variances of the network variables, which could have contributed to relatively lower connection strength (Terluin, de Boer, & de Vet, 2016).

There were some study limitations. Ideally, we would have modeled each of the 20 PTSD symptoms separately along with the 10 negative emotions. Unfortunately, this model cannot, at present, handle a large number of nodes, unless data for many hundreds of participants are available (Fried & Cramer, 2016). Further, it is not clear what sample size is needed to sufficiently power these kinds of studies, as power calculation is not yet available for mlVAR and related time-series models. Moreover, although we consider modeling the *DSM-5* PTSD clusters a conceptually appropriate way for reducing PTSD items into clusters, recent research suggests many different statistical groupings, and findings may differ across different symptom groupings (Armour et al., 2015).

It should also be noted that we assessed symptoms and emotions peritraumatically during the first and second month of a conflict, and findings may not generalize to the associations between emotions and PTSD symptom clusters following the exposure period or to other types of trauma exposure, especially given that both peri- and posttraumatic emotions differ by trauma type (Creamer et al., 2005; Kaysen, Morris, Rizvi, & Resick, 2005). We recommend that future studies conduct ESM during or following various kinds of trauma exposure to investigate whether the current network structure replicates.

Additionally, although ESM reduces recall bias for peritraumatic reactions, the 12-hr gap between measurements in the current study meant that participants still had to make a retrospective assessment. Future studies could reduce the gap between measurements or alter the question to ask "how do you feel right now?" to capture potentially fleeting emotions and states in an even more time-sensitive and accurate manner. Finally, the multilevel VAR network analysis only models linear processes and assumes stationarity, treating the properties of the network as constant over time (Epskamp et al., 2018). Models that allow for dynamic processes to change over time are in development, but they require more assessment points than were available in the present study (Haslbeck, Bringmann, & Waldorp, 2017).

This study provides novel insights into the dynamic relations between specific negative emotions and PTSD symptom clusters during a period of ongoing trauma exposure. Our hypotheses, which were based on prior cross-sectional and longitudinal research, were not well supported, which emphasizes the need for intensive longitudinal assessment studies. Our findings highlight the potentially important role of arousal for negative emotions and suggest that during ongoing trauma, the emotions of fear, sadness, stress, and loneliness may be especially associated with PTSD clusters. More broadly, our findings suggest that a wide range of negative emotions may play a role in the early stages of the PTSD syndrome. Further research is needed to investigate whether these findings replicate in other samples and contexts. The current findings are not, by themselves, sufficient to guide treatment decisions, and researchers have increasingly recognized that the treatment implications of findings from network analysis are unlikely to be simple or straightforward (Fried et al., 2017). Nonetheless, it may be valuable to investigate targeting arousal along with fear in phase-orientated interventions in situations of ongoing trauma. Initially focusing on helping individuals build regulation capacity and thus reduce their levels of arousal may have implications for ameliorating subsequent PTSD symptoms and a wide range of negative emotions.

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